IMPACT OF LEAN MANUFACTURING ON ORGANISATIONAL PERFORMANCE OF INDIAN INDUSTRIES

THESIS

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by

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FEBRUARY, 2017

DEDICATED

To

My Parents

DECLARATION

I hereby declare that this thesis entitled "**Impact of Lean Manufacturing on Organisational Performance of Indian Industries**" by **Rakesh Kumar**, being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in **Mechanical Engineering** under Faculty of YMCA University of Science & Technology Faridabad, during the academic year 2016-17, is a bona fide record of my original work carried out under guidance and supervision of **Dr. Vikas Kumar**, Professor, Mechanical Engineering and has not been presented elsewhere.

I further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

Rakesh Kumar

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CERTIFICATE

This is to certify that this thesis entitled **Impact of Lean Manufacturing on Organisational Performance of Indian Industries** by **Rakesh Kumar** submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Department of Mechanical Engineering under Faculty of Engineering and Technology of YMCA University of Science & Technology Faridabad, during the academic year 2016-17, is a bonafide record of work carried out under my guidance and supervision.

I further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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ABSTRACT

Manufacturing industries have always faced challenges mainly due to increasing customer's expectation, fluctuating demand, and competition in markets. There is no doubt that manufacturing industry sector has always embraced changes and improved their key activities and processes to deal with the challenges. The key of staying competitive in the global market is to become more efficient. For any industry; it is essential to have an effective connection between manufacturing strategy and the organisational goal and hence lean is adopted by many companies as an approach to achieve manufacturing excellence based upon the continued elimination of waste. Lean manufacturing has been recognized by many researchers as a continuous improvement process designed for long term benefits of the business. Lean manufacturing is being increasingly implemented around the world and so is the case in India. The effects of lean implementation in manufacturing are enormous, mainly in reduction of the consumption of costlier resources like the human effort, manufacturing space, investment and the time to develop a new product.

Though researchers and practitioners both agree upon potential benefits of lean manufacturing, but to establish the fact, an empirical research is required to be carried out in order to know the status of lean manufacturing and its effect on the overall performance in the context of Indian industries. In this study, the correlation between lean manufacturing practices and organisational performance is observed through a survey research conducted in diversified geographical locations of India covering small, medium and large sized manufacturing companies. The impact of lean manufacturing is analyzed in the form of operational and financial performance enhancement. In addition to this the status of implementation of lean manufacturing, benefits gained, obstacles faced by Indian industries are also discussed.

This study aims to identify the key areas of focus for effective implementation so that Indian industry takes care of them during practicing lean manufacturing and remains competitive in the global market. This research investigates all the key aspects and interprets the results to serve as a useful guide for the Indian organizations looking for adopting the approach of lean manufacturing. Better understanding about the subject and effective implementation can enhance the ability of the organisations to face the challenges such as increasing customer expectations, fluctuating demand and increasing competition in the market. Prospects for future study are also discussed. In essence, this research may be a mile stone in setting the direction of lean manufacturing in the Indian industry.

Keywords: Lean manufacturing, elements of lean manufacturing, lean manufacturing enablers, operational performance, financial performance, organisational performance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES/GRAPHS

LIST OF ABBREVIATIONS

AGFI	Adjusted the Goodness of Fit Index
AM	Autonomous Maintenance
ASV	Average Shared Variance
AVE	Average Variance Extracted
BPR	Business Process Re-engineering
CFI	Comparative Fit Index
CR	Composite Reliability
CNC	Computerized Numerical Control
CFA	Confirmatory Factor Analysis
COPQ	Cost of Poor Quality
DF	Degrees of Freedom
EFA	Exploratory Factor Analysis
FMCG	Fast Moving Consumer Goods
FIFO	First In First Out
GFI	Goodness of Fit Index
ISO	International Organization for standardization
ISM	Interpretive Structural Modeling
JIT	Just-in-Time
KMO	Kaiser-Meyer-Olkin
LAM	Lean Award Model
LM	Lean Manufacturing
LTA	Lost Time Analysis
NCR	National Capital Region
NFI	Normed Fit Index

NVA	Non value adding
OD	Outer diameter
OEE	Overall equipment effectiveness
OEM	Original Equipment Manufacturer
PNFI	parsimonious Normed fit Index
PDCA	Plan, Do, Check and Adopt
PCA	Principal Component Analysis
ROWA	Return on working asset
RMSEA	Root Mean Square Error of Approximation
SMED	Single Minute Exchange of Die
SWCT	Standard work combination table
SEM	Structural Equation Model
SSIM	Structural Self-Interaction Matrix
TPM	Total Productive Maintenance
TQM	Total Quality Management
TPS	Toyota Production System
TLI	Tucker-Lewis Index
US	United States
USA	United States of America
VSM	Value Stream Mapping
VA	Value-Added
VM	Visual Management
WIP	Work in Process

CHAPTER I

INTRODUCTION

Manufacturing organizations are paying more attention to the ever-increasing dynamics of business based on frequently changing customer requirements. The customers, who are serious buyers, expect a quick response from the organizations towards their changing needs for high value and innovative products. As a consequence, the product life cycle has reduced considerably (Bordoloi et al., 1999).This development triggered the evolution of a highly competitive environment in every segment of the manufacturing industries. Therefore, the manufacturing organizations require to adopt proactive and innovative approach for improving their manufacturing capabilities. Lean manufacturing is a widely accepted approach for making significant improvement in product quality, cost and delivery to customer by identifying and eliminating all forms of waste from the manufacturing system(Womack and Jones, 1996). Waste is any kind of activity or input for which customer is not ready to pay. Presence of waste, in any form, is a critical factor which adversely affects the organisational performance (Womack and Jones, 2010, 1996). The lean manufacturing principles in industry gained importance because the Japanese companies who adopted lean manufacturing were able to develop, manufacture and supply the products to the customers with lesser input resources like material, machines, tools, human effort, capital investment, floor space, time and total expenses (Womack et al., 1990). Successful implementation of the lean manufacturing leads to enhanced competitiveness through reduction of the input cost. Therefore, for sustenance in a globally competitive environment, it is important for an organization to reduce the input cost to maximize the profit, improve product quality and offer the best price to the customer. Researchers (Belekoukias et al., 2014; Belokar et al., 2012; Taj and Morosan, 2011) argued that lean manufacturing have significantly contributed towards organizational performance improvement.

The dynamically changing customer's needs for a better product and the availability of significant competitors collectively put immense pressure on the organizations to deliver the best product with best price. To achieve this objective; many manufacturing organizations have adopted the lean manufacturing. The basic thought behind the implementation of lean manufacturing is to involve the employees in cost reduction via elimination of waste. Customer is a key stakeholder in business and therefore companies must work for more value additions in the product rather than merely focusing on profits. The customer is always ready to pay more for enhanced value in the product. The difference between cost of the product and the value of the product decides the profit. Therefore, it is imperative to consider every aspect of a value stream in order to eliminate the waste and improve productivity of each resource. To achieve this, manufacturing companies are practicing the lean manufacturing as a renowned manufacturing management practice which enables a system to sustain and excel in a highly competitive environment. As explained by researchers (MacDuffie, 1995; McLachlin, 1997) lean manufacturing corresponds to a versatile model that makes use of a bunch of best manufacturing practices to win the confidence of the customer by attaining manufacturing excellence(MacDuffie, 1995).

In 1950s, Ford Motor Company engineered mass production strategy to counter the encouraging forecasts of customer demand which supported making of large numbers of products with bigger batch sizes. Meanwhile, customer's expectations increased and they became more demanding. Thus the approach of making product in large numbers with bigger lot sizes became highly complex and required high level of inventories to make product available to customer with new expectations. Subsequently the manufacturing company started realizing the importance of delivering the high quality product in optimal quantities and at the right time (Hines et al., 2004; Hounshell, 1985). Adopting few characteristic of mass production and incorporating new concepts of reliable equipment and flexible manufacturing; Toyota Motor Company invented a new manufacturing approach in second half of 1950s which was named as Toyota Production System. Later, this system was known as lean manufacturing (Liker, 2004; New, 2007). From more than four decades lean manufacturing is being adopted by many organisations as a system for performance improvement (Baines et al., 2006; Esain et al., 2008; Paez et al., 2005; Ziskovsky and Ziskovsky, 2007).

Since the commencement of the concept of manufacturing and product assembly lines 'efficiency' is considered as a vital objective of manufacturing (Holweg, 2007). The organisations realized that one prominent factor that can negate the impact of market competition is performance improvement by enhancing their manufacturing efficiency. Toyota Motors Company recognized this fact and used Toyota Production System to monitor and improve efficiency with the methodical way of waste elimination from the manufacturing processes with adopting best manufacturing practices to manufacture the products synchronized with the customer demand (Fullerton et al., 2003; Shah and Ward, 2007; Simpson and Power, 2005; Womack et al., 1990). Manufacturing organizations adopt lean manufacturing as a prominent manufacturing management practice to survive in highly competitive environment. This is achieved by implementing the various best manufacturing practices by making synergies of all such practices through employee involvement at all levels. Many organizations have acknowledged that market competition and many other adverse external environmental forces may be countered by improving its own competitiveness. Hence organizations have taken this situation as an opportunity to improve their performance. Noteworthy, these circumstances have changed the manufacturing strategy of organizations and have motivated them to adopt latest techniques to improve overall business performance.

Some studies from existing literature on operation management reveal that manufacturing results can be improved by implementing the lean manufacturing system. However, previous studies are not enough to establish the direct and positive relationship between lean manufacturing practices and the organizational performance. Thus, it will be appropriate to assess the effectiveness of lean manufacturing system in Indian context. Since researchers have argued that the lean manufacturing contributes significantly towards organization's performance worldwide hence, it is imperative to conduct a research study to assess the impact of lean manufacturing on organizational performance of Indian industries.

1.1. RESEARCH OBJECTIVES

Toyota Motors Company, a major Japanese car manufacturing company, is an excellent example which has successfully implemented lean manufacturing practices. Since last five decades, Toyota is continuously inventing and implementing lean with its unique standard called Toyota Production System (TPS). Under the banner of TPS, Toyota has consistently enhanced its manufacturing competitiveness over its three US based giant competitors; General Motors, Ford and Chrysler. With lean manufacturing in the core of manufacturing, Toyota has dominated the world's passenger vehicle market. Toyota has practiced lean manufacturing ever since it has been discovered and in return it has achieved highest level of manufacturing excellence and has produced better organizational and financial results. The primary objective of this research is to evaluate precisely the relationship between the lean manufacturing practice and its impact on organizational performance by assessing the real time data of lean manufacturing implementation in Indian industries.

The objective is further categorized into the following:

- To identify key elements of lean manufacturing and their applicability in the context of Indian industries.
- To measure the level of lean manufacturing implementation in the Indian Industries.
- To measure the obstacles faced and benefits gained by Indian industries through implementation of lean manufacturing.
- To establish the relationship between lean manufacturing practices and performance factors within Indian industries.
- To measure the impact of lean manufacturing on organizational performance of Indian industries.
- To identify future research directions related to lean manufacturing.

1.2. RESEARCH MOTIVATION

Although in many research studies, conclusion has been presented by researchers in favor of improvements gained after implementation of lean manufacturing. Practitioners have also posted the benefits gained after the implementation of lean manufacturing. A plethora of research studies available in the literature show positive contribution of lean manufacturing with one or more organizational performance parameters. A majority of studies in the literature are restricted in evaluating a few aspects of lean manufacturing which relate to the organizational performance parameters. Inventory reduction has been consistent in most of the cases (Billesbach and Hayen, 1994; Kumar, 2010; Mishra et al., 2013) however many other parameters have been inconsistent. But still firm evidence on consistent, significant and a positive relationship of lean manufacturing Implementation with the organizational performance is yet to be established.

In many studies(Belekoukias et al., 2014; Biggart and Gargeya, 2002; Chen and Hua Tan, 2011; Kattman et al., 2012; Taj and Morosan, 2011) a positive correlation between lean manufacturing implementation and apparent performance parameters has been reported. These empirical research studies have not clearly gauged the actual level on lean manufacturing implementation and consequent improvement in organizational performance parameters. This may be because of the fact that different manufacturing companies can have different ways of lean manufacturing implementation. For example, a mobile phone manufacturing company may have completely different perspective on lean manufacturing than a company engaged in manufacturing automobile parts. Thus, this research study aims to create a wider spectrum for assessing the level of lean manufacturing implementation and the level of organizational performance in Indian context. To further elaborate on this, lean manufacturing implementation level has been considered as an important input domain whereas the organizational performance have been considered as the output (results) domain in the proposed study.

1.3. RELEVANCE OF THIS STUDY

In recent times, India is becoming a major hub of manufacturing for the world. Many national and multinational companies have established manufacturing facilities in India, primarily because of favorable government policies, low land acquisition cost, cheap raw material and low labor cost. The presence of multinational companies in India has intensified the level of competitive environment in India and this competition has encouraged Indian companies to transform from conventional manufacturing style to lean manufacturing for improved performance.

Many research studies report about the improvements gained after implementation of the lean manufacturing. Practitioners have also reported about the benefits gained by lean manufacturing implementation. The managers accountable for implementation of lean manufacturing might be inclined to perceive just a few performance parameters that confirm their conviction. Hence comparable scale for determining the lean practice and performance improvement is required to develop the strength of the research investigation. Hence, a criteria must be established for measuring lean manufacturing implementation and organizational performance. In a plethora of research studies, positive contribution of lean manufacturing towards one or more organizational performance parameters has been reported. Most of the studies are confined to investigating only a few aspects of lean manufacturing related to organizational performance parameters (Belekoukias et al., 2014; Belokar et al., 2012; Chen and Hua Tan, 2011; Demeter and Matyusz, 2011; Wan and Frank Chen, 2008; Yang et al., 2011). This study makes an effort to establish parameters of lean manufacturing implementation and organizational performance. Additionally, it aims at finding whether there is a significant correlation between lean manufacturing implementation and organizational performance in the Indian Industries.

1.4. SIGNIFICANCE OF RESEARCH

This research presents a fair understanding about lean manufacturing presence inside the manufacturing environment of Indian industry. Information collected through questionnaire from middle and higher level employees presents their view point on lean manufacturing practices and their importance as enablers for achieving business excellence. Apart from determining definitive correlation between lean manufacturing implementation and organizational performance parameters, this study is prominent for practicing professional and researchers.

In the previous studies (Biggart and Gargeya, 2002; Demeter and Matyusz, 2011; Kattman et al., 2012; Rahman et al., 2010; Wan and Frank Chen, 2008, 2008; Yang et al., 2011), each and every element of lean manufacturing has not been measured rather a few lean practices have been evaluated and their impact on organizational performance have been measured. In this study, a novel mechanism has been proposed to measure the lean manufacturing implementation level encompassing all lean elements through seven lean manufacturing enablers.

The studies reported in the literature (Belekoukias et al., 2014; Berry and Cooper, 1999; Fullerton and McWatters, 2001; Rahman et al., 2010) have not comprehensively covered all the vital financial performance parameters such as sales growth, stock turn ratio and return on equity. This study attempts to identify the correlation between the lean manufacturing practices and operational and financial parameters. The main contribution of this study is the establishment of the normalized scale of relationship between lean manufacturing and organizational performance.

This study is able to relate and assess the level of lean manufacturing to all the organizations involved in manufacturing. Consequently, benefits of lean manufacturing can be traced back to the company's financial documents. This study makes use of an appealing method to improve response rate of the survey. The respondents were motivated in order to support the examiner that the researcher wants to know how they have improved their operational and organizational performance with implementation of lean manufacturing. This type of inspiration might motivate several practitioners to derive more value from scholarly researches to the real world of manufacturing hence improving the affiliation between researchers and industry.

The verification of the fact that lean manufacturing implementation is helpful in improving organization performance still needs firm evidence. The practitioners and researchers confirm the evidence of positive relationship between lean practices and business results but have been inconsistent in ascertaining an affirmative correlation between lean manufacturing and organizational performance. In general, organisations hire consultants for lean manufacturing implementation and hence the way of execution may vary from organisation to organisation and hence an ambiguity may arise about the measurement of level of lean manufacturing implementation. Research may have ambiguity in identifying the real level of implementation of lean manufacturing within the domain of research study. The level of implementation of lean practices still need to be clearly measured through gauging the level of implementation of each dimension of lean manufacturing based on some data and facts. The second ambiguity is regarding the discernment of performance parameters considered in research studies reported in the literature. In general, practitioner evaluates the performance in relation with the peer group or by observing the change in outcome of certain parameters by making efforts to achieve certain objectives and this may encourage some biases in responses. The validity of the research may need to have an independent source for providing the data regarding achieved performance parameters. The third issue pertains to the actual measurement of impact of lean manufacturing on organisational performance parameters. Hence, it is obvious that the existing research studies investigating the impact of lean manufacturing practices may fall short of considering the overall impact on various dimensions of organizational performance.

This research takes care of all the issues by obtaining the feedback from shop or office level practitioners to the top executives to create the data base. In the sub-categorization of organizational performance this study has covered both operational and financial performance parameters. Thus, this research develops the most appropriate method of measuring the implementation level of lean manufacturing and determining its impact on the organizational performance in the context of Indian industries.

CHAPTER II

LITERATURE REVIEW

2.1. INTRODUCTION

Numerous research papers dealing with the theory, practice and performance of lean manufacturing have been published in the last four decades but the subject is still under discussion. The literature published in books, conferences, national and international referred journals were reviewed. The research work reported in the area of lean manufacturing in the referred journals till November 2015 has been reviewed. A total of 217 research papers have been examined.

It is observed that majority of reviewed papers have been published in International Journal of Quality and Reliability Management (IJQRM), Journal of Operation Management (JOM), International Journal of Productivity and Quality Management (IJPQM), Production and Operation Management (POM), International Journal of Production Research (IJPR). International Journal of Production Economics(IJPE), Journal of Manufacturing Technology Management(JMTM), European Journal of Operational Research(EJOR), International Journal of Operations & Production Management(IJOPM), International Journal of Business and Management(IJBM), International Journal of Engineering Research & Technology (IJERT), International Journal of Innovative Research in Science, Engineering and Technology(IJIRSET), International Journal of Engineering Science and Technology(IJEST), Production and Inventory Management Journal(PIMJ), Management Science Letters(MSL), Operation and Supply Chain Management(OSCM), International Journal of Lean Thinking (IJLT) etc. The distribution of articles reported in the present study is given in Table below:

Table 2.1: Year wise distribution of reviewed research articles

Years	1971-1990	1991-2000	2001-2010	2011-2015
Numbers of articles	17	61	71	68

From the literature review, it was observed that lean manufacturing implementation techniques and measurement of their impact have been analyzed most by the research scholars. Their studies report that there is positive relationship between lean manufacturing and performance improvement. It has also been revealed from the literature review that researchers adopted different practice factors, performance factors in their research studies. Hence there is no common understanding on how to measure the implementation of lean manufacturing and how to measure the impact of lean on organisational performance. It may be challenging to establish the factors responsible for implementation of lean manufacturing and measuring the organizational performance but at the same time it may be a subject of interest to both practitioners and researchers. The following objectives have been addressed in this chapter:

- To understand the major elements of lean manufacturing
- To recognize the factors responsible for implementation of lean manufacturing
- To recognize the factors responsible for measuring the organisational performance

In this chapter, the lean manufacturing has been discussed. Its invention, development over the period of time, definitions given by researchers, various elements and the enablers of lean manufacturing based on the literature review have been thoroughly discussed. Further, the factors of organisational performance measurement are discussed. Finally, chapter attempts to identify the measurement factors of lean manufacturing, which have significant impact on the organizational performance.

2.2. HISTORY OF LEAN MANUFACTURING

Post World War II, Japanese companies were facing acute shortages of raw material, human resources and financial crisis. The troubles faced by Japanese companies were different from their competitors in Europe and USA. The Toyota Motor Company realized that their competitors in auto market were performing better in comparison with Japanese companies. With the intention to counteract the prevailing condition and to move ahead of the competitors; Taiichi Ohno, Shigeo Shingo and Toyoda Kiichiro worked out a plan which was highly disciplined and improvement oriented (Womack and

Jones, 1996). This system was initially practiced and developed at Toyota Motors and thus was named as Toyota Production System and the same system was called later as "Lean Manufacturing". Toyota Production System was evolved in 1950s and till 1970 it remained under invention stage within Toyota Motor Company Nagoya, Japan but now it is practiced by manufacturing companies globally (Bremner et al., 2003). The fundamental design of this system was to improve the utilization of resources by identifying and reducing wastage from the manufacturing system. A book written by Womack, Jones and Ross "The Machine That Changed the World" (1990) revolutionized the idea of lean manufacturing. The book emphasized the great success gained by Toyota and identified the vast gap in manufacturing management that existed between the Toyota motors company and auto sector of rest of the world. The findings of this study reveal that not only Toyota Motors, but other Japanese manufacturers following this system are using comparatively lesser resources for the same output(Krafcik, 1988; Liker, 2004; New, 2007; James P. Womack et al., 1990).

In the mid of 20th century when countries were focused to improve their economy; industrial revolution came out as the main driver of economy booster under the flagship of automobile industry. Japanese companies were able to produce more with the limited resources by adopting TPS. Based on performance outcomes of Japanese industries, the researchers started investigating the "Japanese management" techniques (Drucker, 1971). The name lean manufacturing evolved from the introduction of the term "Lean" by Krafcik (1988) and "Lean production" by Womack et al., (1990). Later lean manufacturing got popularity in the published literature on industrial engineering and operations management (Shah, 2002).

2.2.1. Development Phase of Lean Manufacturing

Discovery of lean manufacturing started with the study of Japanese management practices (Drucker, 1971). The uniqueness of these practices was the adoption of the continuous process improvement with problem solving techniques and involvement of workforce. Sugimori et al. (1977) identified Toyota Production System as the prominent process improvement approach developed and practiced at Toyota Motors, Japan. Researchers (Shingo, 1988; Shingo and Dillon, 1989) discussed subcomponents of Toyota Production System such as 5S, Kanban, quality circle, first in first out (FIFO), line balancing, work standardization and other similar techniques under Just-in-time production. ‘Lean Manufacturing’ was initially used in a book ‘The Machine that Changed the World (1990)’ explaining the manufacturing practices under Toyota Production System at Toyota Motor Company(Baines et al., 2006). This book did not only describe the gap but also measured the magnitude of the gap between the Japan manufacturing techniques and western world (Baines et al., 2006; Emiliani, 2006; Holweg, 2007).

Table 2.2: Scholarly literature on Lean Manufacturing in past four decades

Years	1971-1990	1991-2000	2001-2015
Phases of lean manufacturing	Development phase	Practice /implementation phase	Performance phase
Number of lean publications	17	61	139
Growth of Lean manufacturing	Japanese manufacturing methods started getting noticed based on their ability to produce superior product with lesser inputs. As a result evolution of research papers on new manufacturing techniques like TPM, TQM, JIT, Six sigma etc	Lean Manufacturing elevated to strategic implementation. Value Stream methods expand use beyond manufacturing to service sectors.	Measuring the impact of lean manufacturing on organisation performance started getting measured in addition to the articulates on human resource and culture development aspects
Examples of scholarly lean literature	(Drucker, 1971; Krafcik, 1988; Schonberger, 1986; Shingo, 1988; Shingo and Dillon, 1989; Sugimori et al., 1977; J. P. Womack et al., 1990)	(Balakrishnan et al., 1996; Berkley, 1992; Billesbach and Hayen, 1994; CHANG and LEE∗, 1995; Flynn et al., 1995; Huson and Nanda, 1995; Inman and Mehra, 1993; Koufteros et al., 1998; MacDuffie, 1995; Sakakibara et al., 1997; Samson and Terziovski, 1999)	(Agarwal et al., 2006; Ahuja and Khamba, 2008; Anand and Kodali, 2008; Antony et al., 2012; Belekoukias et al., 2014; Biggart and Gargeya, 2002; Bozarth et al., 2009; Chen and Meng, 2010; Demeter and Matyusz, 2011; Dombrowski and Mielke, 2014; Fullerton et al., 2003; Fullerton and McWatters, 2001; Kinney and Wempe, 2002; Kumar and Kumar, 2015; Kumar, 2010; Li et al., 2005; Mishra et al., 2013; Nordin et al., 2010; Rahman et al., 2010; Shah, 2002; Taj and Morosan, 2011; Wong and Wong, 2011, 2011; Yang et al., 2011)

2.2.2. Implementation Phase of Lean Manufacturing

After knowing the benefits of lean production gained by Toyota Motors many organisations started implementing the concept of lean manufacturing. When organisations were facing difficulties in implementing various lean tools and techniques under a single coherent system, a book "Lean Thinking" (Womack and Jones, 1996) supported the managers to understand the strategy of implementing the intended changes across the organization. Many researchers contributed through numerous research articles in exploring the much needed knowledge on the way of lean manufacturing implementation and resistive forces in lean manufacturing implementation (Detty and Yingling, 2000; Hines and Taylor, 2000; Kippenberger, 1997; Storch and Lim, 1999). Initially lean manufacturing techniques were practiced exclusively in the manufacturing segment only (Carnes and Hedin, 2005; Paez et al., 2005). Later these tools were practiced in the other areas of the organisations such as new product development, sales, marketing and offices areas (Seitz, 2003).

2.2.3. Performance Phase of Lean Manufacturing

Notably, increase in the performance of the organisations in the form of productivity, cost, quality, delivery, safety and morale after implementation of lean manufacturing encouraged the researchers to study and publish the literature on reliability of lean manufacturing (Bayou and De Korvin, 2008; Doolen and Hacker, 2005; Kennedy and Widener, 2008; Meade et al., 2006; Shah and Ward, 2007; Wan and Frank Chen, 2008). Many researchers offered various perspectives of lean manufacturing in developing the knowledge supporting the lean archetype (Baines et al., 2006; Emiliani, 2006; Holweg, 2007). Utah State University initiated an assessment system to measure improvement in organisational performance through achieving excellence in manufacturing. This prestigious system is known as the 'Shingo Prize' and it provides a platform for researchers and practitioners to present the benefits gained through implementation of lean manufacturing(Stone, 2012).

2.3. DEFINITIONS OF LEAN MANUFACTURING

Today's customer driven competitive market has put a tough challenge to manufacturing organisations to develop some new tools to survive and become more profitable in global market. To come out of this situation and to grow in the market segment many manufacturing organisations have adopted implementation of lean manufacturing. Though lean manufacturing is a subject of interest for researchers and practitioners and a lot of literature is available on the subject but a universally accepted definition of lean manufacturing is not available. Researchers describe lean manufacturing as they observe it. Some definitions given by researchers are depicted in table 2.3.

Table: 2.3: Definition of Lean manufacturing as described by various researchers

S. No.	Researcher	Definition of Lean manufacturing as described by various researchers
1	(Womack et al., 1990)	Lean manufacturing is a set of practices focused on reduction of wastes and non-value added activities from a firm's manufacturing operation.
2	(Womack and Jones, 1996)	Lean manufacturing is the strategy used for elimination of everything that does not add value to the product or service
3	(McLachlin, 1997)	Lean manufacturing represents a multifaceted concept that may be grouped together as distinct bundles of organizational best practices
4	(Russell and Taylor, 1999)	Leanmanufacturing philosophy uses several concepts such as one-piece flow, kaizen, cellular manufacturing, synchronous manufacturing, inventory management, poka yoke, standardized work, work place organization, and scrap reduction to reduce manufacturing waste.
5	(Green, 2000)	Lean manufacturing is a complex cocktail of ideas including continuous improvements, flattened organization structures, team work, elimination of waste, efficient use of resources and cooperative supply chain management
6	(Fullerton et al., 2003)	Lean manufacturing is the systematic elimination of wastes from an organization's operations through a set of synergistic work practices to produce products and services at the rate of demand.
7	(Liker and Wu, 2006)	Lean manufacturing may be defined as a manufacturing philosophy, which focuses on delivering the highest quality product to customer on-time and at the lowest cost.
8	(Shah and Ward, 2007)	Lean manufacturing is bundles of practices includes JIT, total quality management, total preventative maintenance, and human resource management, pull, flow, low setup, controlled processes, productive maintenance and involved employees.
9	(Ferdousi, 2009)	Lean manufacturing is a management practices to improve customer satisfaction as well as organizational effectiveness and efficiency
10	(Singh et al., 2009)	Lean manufacturing is a dynamic process of change driven by a systematic set of principles and best practices aimed at continuous improvement this refers to the total enterprise, from the shop floor to the executive suite, and from the supplier to end customer
11	(Womack and Jones, 2010)	Lean is about tools that create goods and services that offer precise customer value, but with less…"
12	(Taj and Morosan, 2011)	Lean manufacturing means manufacturing without waste
13	(Chen and Hua Tan, 2011)	Lean manufacturing is an approach to resolve manufacturing problems which helps industries in identifying and eliminating all forms of waste resulting in improved productivity, quality, cost and delivery
14	(Dal et al., 2000)	Lean manufacturing is the elimination of wastes from manufacturing system to get better results in supplies, process time reduction and quality improvement
15	(Saraswat et al., 2014)	Lean manufacturing is a strategy adopted to achieve manufacturing excellence with continuous process improvement
16	(Kumar and Kumar, 2015)	Lean manufacturing as a prominent manufacturing approach to survive in extremely competitive environment.
17	(Kumar and Kumar, 2016)	Lean manufacturing approach is a set of tools and techniques used to make manufacturing more effective to deliver highest value to customer by utilizing the resources in a efficient manner with the focus on employees involvement.

The basic thought behind the lean manufacturing is involving employees in elimination of waste. Customer is believed to be the originator of the selling price of the product so companies must work for more value addition to product rather than working for making profits only. More the value is added to the product or service; customer will agree to pay for more. The difference between cost of the product and the value of the product decides the profits (Monden, 2002). So, to stay competitive, the global organisations must look for every aspect of value stream to eliminate waste. This will lead to reduction in cost and add value to the product.

2.4. THE PRINCIPLES OF LEAN MANUFACTURING

The five principles of lean manufacturing are value, value stream, flow, pull, and perfection as described by Womack & Jones (1996).

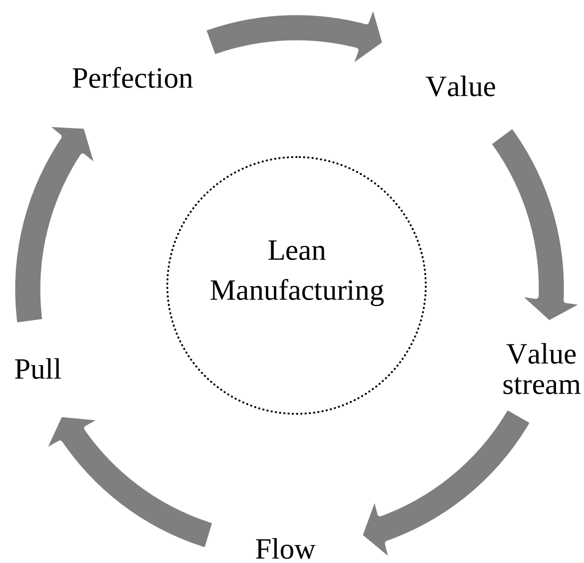


Figure 2.1: The five principles of the lean manufacturing

The first principle of lean manufacturing is ‘Value’ and it may be defined as “a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer” (Womack and Jones, 1996). Value is something that the customer is ready to pay for and waste is anything that does not add value to the product from customer’s perspective. The ‘Value Stream’ may be defined as the production flow from raw material to delivery of product to the customer including all the actions; value added and non-value added through the main flows (Rother and Shook, 1999). ‘Flow’ is defined as “the progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials into the hands of the customer with no stoppages, scrap, or backflows” (Womack and Jones, 1996). ‘Pull’ is a “system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need” (Womack and Jones, 1996). ‘Perfection’ is “the complete eliminations of waste from all the activities of manufacturing”.

2.5. SEVEN WASTES OF MANUFACTURING

Taiichi Ohno argued that up to 95% of all costs are accounted for non value adding activities in non lean manufacturing environments. The waste can be categorized into seven types which are commonly referred to as the “seven wastes of manufacturing”. These wastes are over-production, waiting, transportation, over-processing, inventory, excess motion and defects (Silva, 2012).

Overproduction – Overproduction is a form of waste which occurs because of producing more than the demands of customer (Shingo and Dillon, 1989).Overproduction is expensive waste in manufacturing since it impedes the even flow of materials and adversely affects productivity and quality of the product. “Just in Time” approach is used to take care of overproduction loss of manufacturing (McBride, 2003). The related lean element is pull system which states that the production order must be equal to the customer demand. Everything manufactured in excess of customer order may be held up till next customer demand is received, hence resulting in holding up of valuable resources consumed in manufacturing the product.

Waiting – Waiting category of waste is referred to waiting of goods for processing, equipment waiting for material, labor, man waiting for material, information and equipment etc. Typically product remains in-waiting for 99% of manufacturing time in traditional mass production system (Silva, 2012). Lean manufacturing necessitates the resources are available at the time of manufacturing on a just-in-time basis – neither early nor too late by connecting processes mutually so that waiting time is reduced .

Transportation–Transportation of material or goods do not add value to the product hence it is a type of waste. Unnecessary handlings and movements may cause damage to the product and may adversely affect the product quality. Lean manufacturing necessitates the delivery of the material at the point of use (Kumar and Kumar, 2015).

Over processing– Over processing is the type of waste referred to doing unnecessary steps in processing the parts. Some of the more common examples of this are re-working, inspecting, re-checking etc. This may be avoided by improving product layout, tools and improving product design (Mishra et al., 2013).

Inventory– Any kind of excess inventory that does not add value to the product must be reduced(De Haan and Yamamoto, 1999). The inventory between manufacturing processes refers to the inventory from raw material stage to the finished goods stage. Surplus inventory occupies floor space and makes manufacturing incapability and quality issues out of sight. This leads to increased handling cost, obsolescence, damaged goods and longer lead times (Silva, 2012).

Excess Motion – The unnecessary motion that does not add value the product is termed as excess motion waste. Extra motion is generally a result of poor layout, lack of consistency in work methods and poor housekeeping.

Defects – Defects refers to the rejection of product and results in significant cost to company. In many companies the total cost of poor quality or defect is a considerable percentage of whole manufacturing cost. Defect waste includes repairing, salvaging and replacement of product (Kumar, 2010).

All the above mentioned sources of waste are interrelated with each other so removing or reducing the one waste may lead to reduction of other one and so on. Inventory is considered to be the most significant form of waste (Mishra et al., 2013). Researches have revealed that value addition time has not been more than 15% of total time which signifies that remaining 85% time is waiting time (Kumar and Kumar, 2015). During this time material is either in raw form or work in progress or in finished parts stage. This waiting time does not add any value to the product or services therefore efforts must be made to eliminate/reduce this non-value adding time. Once reduction in inventory takes place, value stream becomes leaner and hidden problems may surface out. Then, immediate action is required to fix the issues to main un-interrupted flow in the manufacturing line. Lean manufacturing is preferred approach for reducing manufacturing costs by eliminating all kinds of waste from manufacturing processes (Anand and Kodali, 2008).

In leaner inventory levels lot sizes are reduced so frequent changeovers becomes essential part of a manufacturing process. More changeovers result in more loss of time in setups so it becomes imperative to reduce the setup or change over time to keep the setup change time cost constant per unit of produced part (Karlsson and Ahlström, 1996). This issue was noticed by Shingo at Toyota and developed a concept of reducing change over time where change over time got reduced from hours to minutes. This this concept is widely known as 'Single Minute Exchange of Die' (SMED) (Shingo, 1988). Success of SMED concept resulted in bringing inventory level down drastically. The reduction in breakdown time of equipment is another way of reducing inventories and this can be achieved through keeping machine in healthy state with the another concept called preventive maintenance. The main aim of preventive maintenance is to reduce losses in account of unplanned break down of machines. Working with lower inventory with longer and frequent breakdown of equipment may result in loss of productivity.

Lower inventory level reduces waste in the form of waiting time but at the same time space requirement for handling the inventory is also reduced to great extent. The saved space can be used for other resources like new equipments and results in increased space productivity per unit floor space. Equipment can be brought closer and lesser space between machines results in lesser transportation of man and materials and thus another form of waste is reduced as moving parts do not add any value to the final product (Kumar and Kumar, 2012). In addition to other benefits; lesser transportation reduces wastage of time also. Cellular manufacturing is closer solution to reduce the movement of man and material. Cell manufacturing may also reduce energy utilization as many nonproductive operation are reduced as dedicated group of manpower is used to run the cell in synchronized way (Kumar and Kumar, 2012).

Another way of reducing waste is by reducing rework and scrap. Loss of resources in reworking and producing scrap is total wasteful activity and finally affects the product quality and cost. Lower inventories also support the reduction of rework and scrap as parts move to the next process where they are inspected and can be traced back followed by fixation of the root cause before they are manufactured in abundance. Lower reworking and scrap levels positively impacts productivity(Hayes and Clark, 1986). Moreover; level of scrap is essential performance parameter to measure operational performance of any organisation. Importance of product quality is undeniable aspect in today's competitive market. Many tools are available to measure and improve upon the waste such as just-in-time manufacturing, load leveling, total productive maintenance and continuous improvement (Nordin et al., 2010). Toyota was the first company to develop and utilized tools to reduce or eliminate the waste. Initially, lean manufacturing was developed with the intention to work with lower inventories and removing all kind of wastes from manufacturing system by adopting more creative manufacturing methods and improving product quality (Boppana V. Chowdary and Damian George, 2011). In fact, industries are always looking for innovative ways to get competitive edge over their competitors. Nowadays, increasing global competition has further increased the intensity of the search for innovative ways of cost reduction by eliminating non value adding activities (Kumar, 2010). Lean manufacturing is one such way through which industries are looking for reducing product cost and increasing quality (Dombrowski et al., 2012).

Indian industries are also looking for such innovative manufacturing methods to keep themselves competitive in their market segment (Ahuja and Khamba, 2008). However, Indian industries have started adopting lean manufacturing, derived from extensive benefits gained by companies who have implemented lean manufacturing and enhanced their manufacturing performance (Upadhye et al., 2010). Lean manufacturing focuses for achieving operational perfection by continually removing wastes with a high level of worker involvement in the process improvement (Silva, 2012). Segregation of value adding and non value adding activities is the first step in lean manufacturing approach followed by elimination of non value adding activaties to reduce the input cost (Clegg et al., 2010). Manufacturing companies are required to adopt lean manufacturing into their daily work practices for getting maximum benefits (Kumar and Kumar, 2015). Indian industries have recognized lean manufacturing as an important manufacturing strategy (Kumar and Kumar, 2015) however, Indian industry still has not gained full advantage from lean manufacturing due to its limited implementation (Khadse et al., 2013).

2.6. OTHER MANUFACTURING EXCELLENCE INITIATIVES

Similar others manufacturing excellence initiatives are adopted in parallel with lean manufacturing like flexible manufacturing system, just-in-time-manufacturing, cellular manufacturing, total quality management (TQM), lean six sigma, zero defect and total productive maintenance (TPM). All similar initiatives are intended for reducing cost and adding more value to product or service consequently growing the business.

2.6.1. Flexible Manufacturing System (FMS)

Plenty of research studies have been carried out on manufacturing flexibility since 1980's. However, the significance of the role of manufacturing flexibility in the history of industrial development is still not clear (Scranton, 1991). Researchers observed that it is the urgency to respond to market dynamics to stay alive in the competitive market. But for many industries, it is a strategic selection out of many available options for achieving manufacturing excellence (Scranton, 2000).

Flexible Manufacturing System is discussed in many published studies with a main objective as the ability of the manufacturing system to switch efficiently to another product as per the changes in the customer requirements (Schonberger, 1982). The term manufacturing flexibility is frequently discussed in the operations management literature but many issues are still unanswered. Major problem is contradictory terminology; some elements have overlapping of definitions with common characteristics, imperfect component list, dissimilarity in measures for elements in addition to lack of empirical evidence to support the improvements gained through improved flexibility (Beach et al., 2000). Researchers have presented studies on the impact of flexible manufacturing on performance parameters of organisation (Sethi and Sethi, 1990) and have revealed that there is correlation between change in manufacturing flexibility and organisational performance parameters (Vokurka and O'Leary-Kelly, 2000). Researchers have identified that organisations with stable manufacturing environments may be able to gain benefit in manufacturing performance with adopting the FMS but this is not much likely for most of the industry (Vokurka and O'Leary-Kelly, 2000).

2.6.2. Just-in-Time (JIT) Manufacturing

Just-In-Time manufacturing is very much related with lean manufacturing. JIT manufacturing like lean manufacturing attempts to produce right part at the right time by eliminating waste from manufacturing(Amasaka, 2002). JIT manufacturing targets wastes like defects, work-in-process inventory, losses due to poor scheduling with continuous focus on work culture, flexible workforce, cross training, long-term employment, job enlargement, workforce involvement and improving visibility (Kumar, 2010). Customer is driving the demand for the manufacturing system. Manufacturing may be either 'push type' or 'pull type'. Push system is termed as traditional manufacturing and pull system is termed as JIT manufacturing. Nevertheless, the major differentiation is in how customer demand is handled. JIT is a system that facilitates the manufacturing system to accept the unexpected changes in the customer demand by manufacturing the right quantity and right quality of product (Monden, 2002). Just-in-time also manages the activities other than in-house manufacturing such as purchasing and distribution. It consists of mainly three elements: JIT purchasing, JIT production and JIT distribution.

Just-In-Time Purchasing: Just-In-Time Purchasing is well defined by Gunasekaran (1999) as purchasing should take place at the same time when product is required for use. Here purchasing follows the demand and only strategic inventory is kept instead conventional purchasing practice of buying and holding the stock for use till it is required by manufacturing lines. In JIT purchasing; supplier-buyer relations and communication plays important role. Suppliers must be reliable and certified for quality supplies in terms of product quantity, quality and timings (Mishra et al., 2013). The purpose of JIT Purchasing is to save holding cost of inventory by making purchasing system efficient and reliable by keeping purchasing very close to manufacturing (Gunasekaran, 1999). Even if the transportation cost of materials is greater than before due to repeated deliveries into smaller lots but this cost is counterbalanced by reduced cost of creating a purchase order and reduced inventory holding cost.

Just-In-Time Production: Like lean manufacturing JIT Production is in relation with waste eliminating from manufacturing processes. JIT Production plays an important role in the lean manufacturing implementation. (Monden, 2002) and (Levy, 1997) have the same opinion that JIT Production is the spine of the lean manufacturing. Just-in-time production is about having lesser inventories in the form of raw materials, work in process and finished goods. In JIT production environment customer demand is triggered for production scheduling. Customer demand is converted into signals for production in terms of model mix, quantity, time and time of delivery (Mishra et al., 2013). In general, final process receives the demand and delivers the parts to customer against demand(Chan et al., 2010). Simultaneously it sends order to preceding process and hence pull takes place throughout the value stream. Once customer demand is satisfied and there is no further requirement, then manufacturing of parts is discontinued and hence production is stopped to avoid over production. The entire value manufacturing lines are synchronized with the kanban system. Parts are delivered in smaller lot size and deliveries are frequent. A kanban is used to manage the delivery consignments. Kanban system is basically an information method to control the quantity of parts to be manufactured at each station.

Just-In-Time Distribution: JIT distribution success lies in coordination between customer and suppliers. Since it is an external activity and needs special expertise skill hence many times, a third-party logistics is utilized by manufacturing organisations so that they can focus on their core capability. Third-party logistics distributor is an external party which works for materials management and product distribution job for the manufacturing organisations (Chen et al., 2000). JIT Distribution supports the exchange of smaller lots of produced parts between supplier and customer. This becomes critical when inventory levels are kept on lower side instead of having buffer stock in traditional manufacturing systems. Whole supply chain is driven by frequent and effective communication channel. Some of the benefits from JIT are reduced set cost, labor cost (both direct and indirect) and material handling, increased process and product quality, process flexibility,communication, productivity, teamwork,innovation, efficiency and responsiveness, resources utilization, improved worker motivation, integrate different manufacturing activity and lower overhead cost (Kumar, 2010).

2.6.3. Cellular Manufacturing or Cellular Layout

In cellular manufacturing machines and workstations that so arranged that a smooth and uninterrupted flow of material and product takes place throughout the value stream (Singh, 1993). Cellular manufacturing is considered as a foundation stone in implementation of lean manufacturing. Cellular manufacturing is a model that can accommodate right product mix with lesser possible wastes. In this concept equipment are tightly connected in cells so that many stages or all stages of a production process can occur within a single cell or a series of cells (Selim et al., 1998). Cellular manufacturing helps to achieve many of the objectives of lean manufacturing due to its ability to facilitate in elimination of many non value-added activities from the production process such as waiting times, bottlenecks, transportation and works-in-progress inventory. Another feature of cellular manufacturing is that responsibility for quality is clearly assigned to the worker in a particular cell and he/she therefore cannot blame workers at upstream stages for quality problems. Operators or workers are trained to work in a synchronized way so that whole manufacturing cell works as a one set of machine where work in process inventory is replaced with single piece flow concept (Bazargan-Lari, 1999). Input and output areas are defined and each part travels through each machine following first in and first out (FIFO) principle. It fulfills the concept of lean manufacturing as and when customer requires a product, parts start travelling right through the cell in single piece flow. Parts need not wait for their turn for processing and hence throughput time is greatly reduced (Balakrishnan and Cheng, 2007). A prerequisite for cellular manufacturing is the reliability of equipment as there is no buffer between the workstations to take care of interruptions and once machine is on a breakdown, the whole cell is stopped. Some of the major advantages associated with cellular manufacturing are reduced work in progress inventory, material handling equipments like bins, trolleys etc, reduced transportation, lead time, rework and scrap, improved floor space utilization, productivity, teamwork, flexibility and enhanced visibility (Bulgak et al., 2009).

2.6.4. Total Quality Management (TQM)

Product quality is a significant issue for the manufacturing organisations since long time. Initially; development was focused on part inspection to control the product quality. Afterwards it shifted from quality control to quality assurance (Ireland and Dale, 2001). In the 1990s, TQM got developed as a universal tool among the manufacturing organisations. Different definitions of TQM have been presented by researchers over time. Some of them state TQM as a company culture which brings customer satisfaction via continuous improvement with active participation of all the employees in the company (Dahlén et al., 1995). Shiba (1993) describes TQM as an approach consisting of many tools for enabling organisations to attain high level of customer satisfaction in a fast changing world(Shiba, 1993). Many organizations have implemented TQM in last two decades for improving the quality of the product to gain the competitive advantage over competition. TQM offers a set of practices that accentuates the concept of continuous improvement to reduce rework, rejection and finally to meet customer requirements in terms of quality through teamwork and involvement of employee. TQM supports the idea that everyone in an organization must focus on product quality improvements to achieve the primary goal of the organisation. The major constituents of TQM are supplier relations, benchmarking, quality measurement, and continuous process improvement. Supplier relation involves the chain of interactive relationship between manufacturing segments for producing parts. It advocates the concept of buyer-supplier relation among various firms as well as various work stations considering the output of a firm becomes input for the other firm and output of one workstation becomes input for the other station. The concept of considering next user as a customer improves quality. Benchmarking is the component of TQM referring to the adoption of best practices to achieve the quality performance targets like product reliability and cost. Quality measurement is the measurement of improvement of quality performance by making use of statistical tools. Continuous improvement is the process of focusing on the consistent efforts to achieve the quality improvements.

Some researchers describe TQM as a continually developing management system containing tools, methods and values with the aim of increased internal and external customer satisfaction with a condensed quantity of resources (Hellsten and Klefsjö, 2000). TQM is also seen as the answer to requirement of enhanced overall quality performance (Vokurka and O'Leary-Kelly, 2000). Hendricks and Singhal (1996) studied 60 companies and concluded that TQM has led organisations to enhanced profit margins. The significant correlations of TQM implementation and operational performance are established by many researchers(Agus and others, 2011; Hendricks and Singhal, 1996).

2.6.5. Lean Six Sigma

Nowadays many organisations adopt sigma programs globally, but in the mid-1980s, the first organisation who commenced six sigma programs was Motorola (Rancour and

McCracken, 2000). In 1988, prestigious Malcolm Baldrige award for National Quality was received by Motorola; hence interest about six sigma got increased within other manufacturing organisations (Pyzdek, 2001). Six sigma can be explained as an approach that requires manufacturing organisations to considerably improve their results by monitoring and improving every business activity such that wastage of resources is reduced while customer satisfaction is increased (Magnusson et al., 2003). The backbone of six sigma is to attain improvement by reducing variation in business activities with focused improvement projects to increase consistency(Deif, 2012). The intention of reducing variation in business activities and finally in the product and service is to improve customer satisfaction (Antony and Desai, 2009). The acceptance criteria and the target for six sigma is to attain 99.99966% quality level which means the only 3.4 parts of a million may be defective (Magnusson et al., 2003).

2.6.6. Zero Defects

One of the important manufacturing excellence habit is to aim for zero defects. The objective of zero defects is to make certain that products are defect-free in all respects; this may be achieved with the adoption of continuous manufacturing process improvement (Karlsson and Ahlström, 1996). Manual efforts are always required to manufacture a product, even if the manufacturing lines are automated to large extent there is requirement of human intervention at any point of time. Human errors are always probable to occur and result in production of defective parts. These errors or defects if detected at the end of the process, rather than at a early stage of manufacturing, causes significant productivity loss. One of the tool used to ensure zero defect is poka-yoke. This tool was developed and practiced by Toyota motors to achieve business excellence .

Poka-yoke is an independent defect control mechanism that makes sure that all the parts passing through value stream are defect free. Poka yoke may be prevention type or detection type. In prevention of poka-yoke the manufacturing of defective part is prevented by some means and is most preferred. This results in saving of the resources consumed in production of defective part. The detection poka-yoke does not let defective parts pass to the next process and thus avoiding the passing of defective parts through value stream and saving in terms of further value addition into a defective part in addition to getting defective parts mixed with good parts (Feld and Noonan, 2011).

2.6.7. Total Productive Maintenance

Practicing total productive maintenance(TPM) is the prerequisite for establishment of lean manufacturing environment for any organisation. Unavailability of equipment due to unplanned breakdown is the major concern to the concept of on-time delivery of product quality parts to the customers(Ahuja and Khamba, 2007). The breakdown of one equipment may put whole value stream on halt so it becomes imperative for the organisations to keep all the equipment in high reliable state. The TPM is the approach to counter this issue by keeping the equipments in healthy state throughout the productive time. Preventive maintenance, corrective maintenance, and maintenance prevention are three most important part of the TPM concept. Preventive maintenance deals with the regular checks for all the equipments and organise a planned maintenance before the equipment breaks down all of a sudden. Preventive maintenance prevents unplanned breakdown of equipments and saves a lot of wastage in any manufacturing environment (Ahuja and Khamba, 2008). Corrective maintenance is related with identification of frequent issues faced by manufacturing organisations and dealing with them proactively. This may regarding improvement of basic condition of the equipment or decision making on replacement of equipment to avoid long breakdown hours adversely impacting the manufacturing. Maintenance prevention is the advance stage of maintenance and need intellectual inputs to improve the design of the equipment in such a way that the equipment is modified in order to prevent the requirement of maintenance.

2.7. ELEMENTS OF LEAN MANUFACTURING

The first step in a lean manufacturing implementation is to recognize the non value adding activities in the system and to achieve this, different tools and techniques have been put into practice. The basic purpose of all these activities is to get better quality of product and reduce the cost by eliminating all the forms of waste in the manufacturing system(Chowdary and George, 2011). Prerequisite of lean manufacturing implementation is to involve the employees to remove the waste from the system by making their processes more capable and utilizing resources in an efficient way (Shah and Ward, 2003). Researchers argued that reduction in inventory can be helpful in maintaining competitiveness in recessionary times(Kumar and Kumar, 2015; Singh et al., 2009).

Several elements of a lean manufacturing system are discussed by various researchers. Some major elements are inventory reduction, wastage identification, set up time reduction, quality at source, pull system, lead time reduction, continuous improvement, continuous flow,cycle time reduction, layout improvement, total productive maintenance, quick changeovers ,statistical process control and employee involvement. Employee's involvement has been discussed by many researchers as the main aspect of lean manufacturing implementation to identify and reduce the waste from the manufacturing system to utilize the required resources in an effective manner (Shah and Ward, 2003). When data reduction method was carried out to collapse several lean manufacturing elements into a lesser number, it was observed that some elements of lean manufacturing are used as element of lean manufacturing with different name but functionally they are similar and overlapping each other creating confusion in the literature. This does not essentially mean discrepancy, however it challenges the clarity of the concept. Table 2.4 depicts the major lean manufacturing elements discussed by various researchers. Review of literature revealed that inventory reduction is discussed in 77% of research articles where as wastage identification is discussed in 74%, quality at source in 69%, lead time reduction in 67%, continuous improvement in 64%, cycle time reduction in 56%, reduced information barriers in 54%, layout improvement in 54% , total employee involvement in 44%, pull System in 44%, quick changeovers is discussed in 36% of reviewed research articles.

Some elements have been discussed with comparatively lesser frequency. The rationale behind lesser space gained by these elements may be because of the fact that these elements are newly added to lean manufacturing system or lesser practiced but necessarily it does not mean that they are lesser important in lean manufacturing implementation. Few of such elements are like line balancing which is discussed 8%, line pace 10%, manpower reduction 10%, load leveling (Heijunka)10%, improve overall equipment efficiency 13%, JIT deliveries13%, flexible manufacturing 13%, small lot size15%, improving equipment uptime 21%, takt time working 23%, safe working 23%, standardization. 23%, reduce variability23%, set up reduction 26%, de-bottlenecking 26%, error proofing 28%, good housekeeping 28%, process control 28%.

Table 2.4: Elements of lean manufacturing discussed by various researchers

Lean Manufacturing elements / Researchers	Inventory reduction	Total Employee Involvement	Error proofing/poka-Yoke	Set up reduction.	Improve OEE.	De-bottlenecking	Line pace	Wastage identification	Equipment uptime	Quality at source.	Takt Time working	Small lot size	Continuous improvement	Good Housekeeping	Manpower reduction	Load leveling (Heijunka)	Reduced information barrier	Cycle time reduction	Quick changeovers	Process control.	Lead time reduction	Safe working	Standardization.	Reduce variability.	JIT deliveries	Flexible manufacturing.	Layout improvement.	Line Balancing	Pull System
Belokar et al., 2012	✓							✓			✓		✓				✓	✓			✓			✓			✓		
Chen and Meng 2010	✓					✓	✓	✓		✓	✓		✓				✓				✓						✓		✓
Dombrowski et al., 2012								✓					✓				✓				✓						✓		
Ahuja and Khamba 2007	✓	✓			✓			✓					✓					✓			✓	✓							
Rahman et al 2010	✓	✓	✓	✓		✓		✓		✓			✓	✓				✓	✓		✓					✓			✓
Silva 2012	✓							✓			✓		✓	✓			✓	✓			✓	✓					✓		✓
Anand and Kodali 2008	✓	✓		✓	✓	✓		✓		✓		✓	✓		✓		✓	✓	✓	✓	✓					✓	✓		
Gurumurthy and Kodali, 2009	✓	✓								✓			✓	✓			✓	✓		✓	✓	✓	✓			✓	✓		✓
Saraswat et al 2014	✓					✓					✓						✓	✓			✓						✓		
Chen and Hua Tan, 2011	✓	✓		✓				✓		✓		✓	✓	✓		✓		✓	✓		✓				✓		✓		✓
Singh et al 2009	✓	✓		✓		✓	✓	✓		✓			✓					✓			✓								
Singh et al 2010 a	✓		✓	✓				✓	✓	✓	✓		✓		✓		✓	✓	✓		✓			✓					✓
Singh et al 2010 b	✓	✓	✓	✓			✓	✓		✓			✓				✓			✓	✓		✓						
Pepper and Spedding 2010	✓							✓		✓	✓		✓	✓			✓	✓	✓	✓				✓			✓		
Singh et al 2010 c																													✓
Kumar Vikas 2010	✓		✓	✓		✓		✓		✓		✓	✓					✓	✓	✓	✓		✓				✓		✓
Mohanty et al 2006	✓	✓						✓					✓				✓				✓			✓				✓	✓
Nordin et al 2010		✓												✓											✓				
Bhamu et al 2012	✓		✓					✓	✓									✓			✓								
De Haan and Yamamoto, 1999	✓	✓		✓				✓		✓			✓			✓	✓			✓			✓	✓			✓		✓
Amasaka 2002						✓				✓							✓			✓					✓				
Chowdary and George 201I	✓							✓	✓	✓			✓	✓			✓	✓	✓		✓	✓					✓		✓
Chan et al., 2010																									✓				
Wong and Wong 2009	✓		✓		✓			✓		✓	✓		✓	✓	✓	✓	✓		✓			✓	✓				✓	✓	
Wong and Wong 2011	✓							✓			✓		✓										✓				✓		✓
Upadhye et al 2010	✓	✓	✓	✓	✓			✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓					✓		
Wong et al 2009		✓	✓					✓					✓	✓		✓					✓	✓		✓			✓		✓
Nordin et al 2011	✓									✓													✓						
Antony and Desai 2009			✓							✓								✓		✓				✓					
Ferdousi, 2009	✓	✓						✓	✓	✓		✓	✓				✓	✓			✓						✓		✓
Narain et al 2004	✓								✓	✓											✓					✓	✓		
Taj and Morosan 2011	✓						✓	✓	✓	✓		✓		✓				✓	✓	✓	✓	✓	✓				✓		✓
Ahuja and Khamba 2008	✓	✓	✓		✓	✓		✓		✓			✓					✓	✓		✓	✓							
Kumar and Kumar 2012	✓	✓	✓					✓		✓			✓							✓						✓	✓		
Oehmen et al 2012	✓	✓						✓		✓			✓				✓						✓	✓					✓
Kumar et al 2004																									✓				
Mohanraj et al 2015				✓		✓		✓		✓							✓	✓	✓		✓						✓		
Deif 2012	✓							✓	✓	✓	✓						✓	✓	✓		✓			✓					
Joshi and Naik 2012	✓					✓		✓	✓	✓							✓	✓			✓							✓	
Count	30	16	11	10	5	10	4	29	8	26	9	6	25	11	4	4	21	22	13	11	26	9	9	9	5	5	21	3	16

2.8. ENABLERS OF LEAN MANUFACTURING

Oehmen et al, (2012) suggested that all the lean manufacturing elements must be properly understood, implemented and measured for successful implementation. It is very difficult to take care each of these elements individually without any structured approach (Oehmen et al., 2012). To understand the perspective and applicability of each enabler they are mapped with performance measures which are achieved by implementation of lean manufacturing. It is imperative to assign the domain to which the enabler has its impact in lean manufacturing implementation. This is achieved by careful review of the existing literature. The identified relation between lean manufacturing enablers and lean elements is depicted in table 2.5.

Table 2.5: Lean Manufacturing Enablers - Elements relationship matrix

		Lean manufacturing enablers						
S. No.	Lean Manufacturing elements	Kaizen	Lost Time Analysis	5 S	Autonomous maintenance	Value steam Mapping	Visual management	Standard Work
1	Inventory reduction				*	*	*	*
2	Total Employee Involvement.	*		*		*	*	
3	Error proofing (poka-Yoke)	*	*					
4	Set up reduction.	*	*			*	*	*
5	Improve OEE.		*		*	*	*	*
6	De-bottlenecking		*		*			
7	Pace maker process					*		
8	Wastage identification		*			*		*
9	Equipment uptime	*		*	*			
10	Quality at source	*					*	*
11	Takt Time working					*		
12	Small lot size					*		
13	Continuous improvement	*		*	*			
14	Good Housekeeping	*		*			*	*
15	Manpower reduction					*		*
16	Load leveling (Heijunka)					*	*	*
17	Reduced information barriers	*				*	*	
18	Cycle time reduction	*	*			*		
19	Quick changeovers		*	*				*
20	Process control.	*			*		*	*
21	Lead time reduction					*		
22	Safe working	*		*	*			*
23	Standardization.			*	*	*	*	*
24	Reduce variability.		*	*	*			*
25	JIT deliveries			*		*		
26	Flexible manufacturing.				*	*		
27	Layout improvement.					*		*
28	Line Balancing		*			*		*
29	Pull System					*	*	*
	Count	11	9	9	10	19	11	16

The approach of lean manufacturing implementation involves dividing all the elements into few major components called enablers with concrete recommendation for the implementation of the lean elements in a synchronized way so that the desired results may be achieved (Kumar and Kumar, 2015). Each enabler contains a number of lean manufacturing elements and some elements contribute to more than one enabler.

Lean element is illustrated as the prerequisite of lean manufacturing implementation. To achieve the improved results, lean enablers may be considered as the tool to achieve the implementation of various elements. The co-relationship matrix (table 2.5) shows the direct relationship of enablers and lean manufacturing elements. From the matrix it is visible that value stream mapping have direct relation with 19 elements out of 29 elements, standard work 16, visual management and kaizen11each, autonomous maintenance 10, lost time analysis 9 and 5S has direct relationship with 9 out of total 29 elements of lean manufacturing.

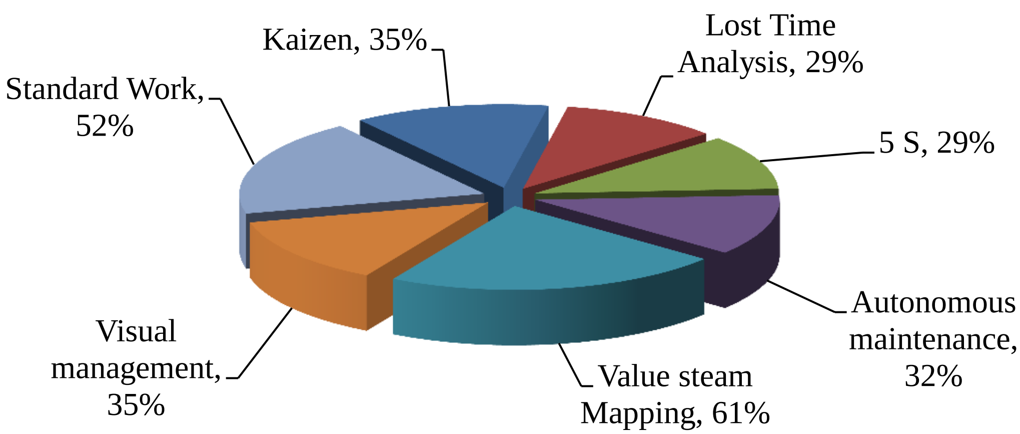


Figure 2.2: The identified enablers covering lean manufacturing elements

Twenty nine percent of lean manufacturing elements are covered by 5S,in the same way lost time analysis covers 29% of the lean elements, autonomous maintenance 32%, kaizen 35%, value stream mapping 61%, visual management 35% and standard work covers 52% of all the lean manufacturing elements. Each element is covered by one or the other enabler of lean manufacturing by 2.7 times on average hence ensuring superior implementation of all elements of lean manufacturing. The various enablers of lean manufacturing are described in next section.

Value Stream Mapping: Value stream mapping is significant enabler of lean manufacturing (Saraswat et al., 2014). It is getting more space in research papers and is widely discussed by many researchers (Belokar et al., 2012; Halpin and Kueckmann, 2002; Hines and Rich, 1997; Seth and Gupta, 2005; Silva, 2012). Value stream mapping can improve overall efficiency of operations by visually displaying the flow of material, and information(Vendan and Sakthidhasan, 2010). This helps in identifying the potential area of improvement with the application of lean manufacturing tools (Bo and Mingyao, 2012). Value stream mapping enables to understand the status of current condition with identification of waste through 'current state mapping' and design the target condition with reduced waste by 'future state mapping'(Mohanraj et al., 2015). It also helps in making road map to reach to 'future state' through use of various lean tools (Saraswat et al., 2014).The objective of value stream mapping is to recognize, display and reduce waste in the manufacturing process. The analysis of the process information is done by gathering information from shop floor employees who contribute in observing various processes (Vendan and Sakthidhasan, 2010). At the same time it is adopted by many practitioners in industries based on benefits gained through its implementation (Kumar and Kumar, 2012). Silva (2012) presented a case study identifying 52 processes out of 63 as non value adding activities hence identification of opportunity of elimination of waste in the manufacturing processes. By eliminating the non value adding activities the lead time got reduced from 23,916 minutes to 11,951 minutes and increase in value adding ratio from 0.087 % to 0.22 % (Silva, 2012). Goriwondo et al., (2011) presented a case study on the implementation of value stream mapping for reducing waste in the manufacturing environment and observed reduction of defects by 20%, reduction in inventory by 18% and reduction in unnecessary motion by 37% (Goriwondo et al., 2011). Belokar et al.(2012) presented a case study in an automobile industry on implementation of value stream mapping and reported 67% improvement in cycle time reduction by reducing the non value adding activities (Belokar et al., 2012). Rumbidzayi Muvunzi et. al (2013) investigated value stream mapping in a tile manufacturing company in a Southern Africa economic region. The results observed increase in productivity by 40% quantitatively from 20.22 k tiles per month to 28.35k tiles per month. Reduction in defect rate was observed from 245 numbers per day to 10 defects/day i.e. 96% reduction through application of value stream mapping.

Kumar & Kumar (2015) presented a case study on value stream mapping and measured its impact on operational performance. The findings demonstrated that smaller Plan, Do, Check and Adopt(PDCA) cycles has enabled team to understand the root cause of the waste and alternativess have been developed causing reduction in in-process inventory from 11500 nos. to 6700 nos. to the tune of 41%. Process lead time has been reduced from 3.83 days to 2.23 days. This case study revealed the effectiveness of value stream mapping tool in identifying and eliminating of a variety of wastes in the manufacturing system.

With theimplementation of value stream mapping, push production (scheduling for each process individually) is replaced with pull production where scheduling is done at one place and production order remains equal to the customer demand. Implementation of value stream mapping involves many elements of lean manufacturing such as total employee's involvement, set up reduction, wastage identification, manpower reduction, load leveling, reduced information barriers, lead time reduction, standardization, just-in-time deliveries, layout improvement, line balancing and pull production system etc. The results observed by researchers indicate the significance of value stream mapping in manufacturing system.

Lost Time Analysis: Lean manufacturing principles are relevant to any business process but mainly they have been been practiced in manufacturing industry (Kumar and Kumar, 2016). The core objective of lean manufacturing is to identify and eliminate waste from the system through continuous improvement process driven by involvement of employees. Continuous improvement culture is attained by resolving process troubles and thus reducing consequential losses. In any manufacturing environment, time is is considered as money. Time lost in preparation for the process, resolving the issues, speed losses etc. reduces the utilization of capital invested in material, equipment, human and other essential commodities meant for performing the assigned task (Kumar and Kumar, 2012). These losses produces a negative impact on cash flow and finally on organisational performance. Work orders intended to meet customer requirements must be performed with faster pace by proper monitoring, analyzing and reducing the lost time. In any manufacturing environments reduction of lost time is one of the most effective and important strategies (Kumar and Kumar, 2016).

The purpose of lost time analysis is to decrease the losses occurring during manufacturing and improve productivity and quality by reducing all types of wastes. Philosophy of lost time analysis states that each manufacturing entity has its own losses that reduce the output of useful resources (Dal et al., 2000b). First of all; focus must be given on elimination of these losses but if it is not possible to eliminate, they must be targeted for reduction because they consume costly resources like increased working hours or additional spending on capital equipments. These losses have unusual reason and unusual solutions. Efforts are essentially required to focus improvements to eliminate the root causes for these losses (Barker, 1994). Distinguishing and taking care of these losses is termed as ‘Lost Time Analysis’. The first step in lost time analysis is to make lost manufacturing time and output visible. Efforts must be focused for making improvement on reduction of the lost time and increasing output per unit time period. Performance enhancement starts with gathering data and subsequently, analyzing it for the purpose of identifying the basic root cause and determining countermeasures (Ward and Zhou, 2006).

There are some significant aspects that are required to be taken care of for successful implementation of lost time analysis enabler. The involvement of all employees is essential to recognize lost time, improve and keep performance improvements sustained (Nahmens and Ikuma, 2009). Accuracy of the collected data will help in identifying the real issues. Selection of the focus area for improvement is equally important. Lost time analysis must put all efforts for improvement of the main critical and specific root causes of the lost time. Validation of improvements will ensure the effectiveness of the enabler. Improvements achieved through implementation of lost time analysis have positive impact on effective utilization of equipment and productivity(Salehi et al., 2013). In the absence of measurement of value adding activities, the organisation cannot remain competitive in delivering product to customer due to excess investment for the same output and poor utilization of the existing resources (Barker, 1994). Implementation of lost time analysis improves overall efficiency of equipments (Dal et al., 2000). The researcher has presented the significance of lost time analysis and its impact on manufacturing performance of industry. The implementation of lost time analysis contribute significantly towards lean manufacturing implementation (Kumar and Kumar, 2012).

The results discussed by researchers on implementation of lost time analysis enabler and benefits gained highlights the contributions of lost time analysis enabler in lean manufacturing implementation initiatives (Cachon and Terwiesch, 2009). The knowledge and motivation obtained by employees in performing such improvement cycle may support in growth of lean culture in the organisation and could result in bigger impact on manufacturing performance. The purpose of lean manufacturing is fulfilled here by means of reduction of non value adding time as a form of waste (Motwani, 2003). This could be achieved by using lost time analysis enabler with structured approach containing some specific steps. The improvement in manufacturing capacity of the observed manufacturing cell has achieved reduction of labor cost per part by increasing output with same number of workmen and equipments consequently having direct impact on financial results. At the same time participation of employees in improvement of operational parameters has constructive impact on morale of employees and might be helpful for the industries in obtaining better productivity, cost competitiveness, improved flexibility with reduced inventory and in staying competitive in global market(Kumar and Kumar, 2016; Motwani, 2003). Through implementation of lean enabler 'lost time analysis' lost time is identified, analyzed and eliminated. Implementation of lost time analysis uses many elements of lean manufacturing such as improved OEE (overall equipment effectiveness), debottlenecking, set up reduction, wastage identification, cycle time reduction, reduced variability etc. The outcome discussed by researchers from implementation indicates the significance of lost time analysis in manufacturing system.

Standard Work: The aim of standard work enabler is to decrease process variability by standardizing working during operations and improve productivity and quality by eliminating all types of waste (Hall, 2004). Standard Work is the process of making standards of doing all activities and formalization them such a way that they are followed by the operators actually during performing his task in operating machines to manufacture a part or to inspect the part after manufacturing(Kumar and Kumar, 2012). In the process of implementation of standard work; value chain of the entire manufacturing is mapped in terms of flow of material, deployment of operator and utilization of man and machine (MacDuffie, 1995). Basic information about man and machines are recorded and analyzed hence making standard work a dominating enabler of lean manufacturing. Many researchers has presented real life example of improvement gained through implementation of standard work enabler (Kumar and Kumar, 2015).

Standard Work facilitates in achieving improvements involving all the employees (Wood and Bandura, 1989). The main objective of standard work as lean manufacturing enabler is to, work efficiently without wasteful motions, set the standard and allows visibility of areas of improvement (Narain et al., 2004), allow labor flexibility, respond to variations in customer demand, achieving line balancing among all processes in terms of production timing (Saurin and Ferreira, 2009), reduce variability between operators and highlights variation inherent to the process(Miller et al., 2010), help to quantify and secure the gains from other improvement activities and finally to work efficiently without wasteful motions(Motwani, 2003).

It is observed that implementation of standard work has resulted in improvement of labor productivity, reduction in work-in-process inventory and improved flexibility (Saurin and Ferreira, 2009). These improvements have financial impact as saving of one operator will reduce labor cost and hence have direct impact on the financial results. Concurrently, employee's involvement in the improvement of operational resultst will have a positive impact onthe morale of employees. Implementation of standard work involves use of lean manufacturing elements such as quality at source, load leveling, quick changeover, process control, standardization, safe working, pull system, line balancing and layout improvement. Standard work is a revolutionary enabler of lean manufacturing for improving overall manufacturing environment in manufacturing organisations (Chan, 2001).

5S: 5S is a lean manufacturing enabler that has been used in companies to deliver improvements not only in manufacturing but in all segment of business (Kumar and Kumar, 2015). The 5S, as a enabler of lean manufacturing, has five key words; Sort, Shine, Simplify, Standardize and Sustain. The aim of 5S is to create systematic, standard, efficient and effective workplace for all the employees (Laureani and Antony, 2010). The philosophy of 5S is easy to understand but implementing and sustaining 5S requires significant commitment and effort. 5S provides an essential support to the other lean manufacturing enablers like lost time analysis, visual management, standard work, kaizen and autonomous maintenance (Chen and Meng, 2010). Description of all the five steps of 5S is as follows.

1st S is ‘Sort’ which means clearing out all unnecessary items. The aim of 1st S is to have the object in the area which is required for the process. If unnecessary items are not removed from work place, they will occupy the space and it is difficult to progress with even the most basic workplace improvements (Kumar and Kumar, 2012). Having non-essential items in the workplace will reduce efficiency by increasing transport distances, searching for the correct item, double or multiple handling, destroying visibility, obstructing access to more needed items, having non-essential items is a potential safety risk and the last but not the least, jumbled environments are harder to clean(Chen and Meng, 2010). Sorting through the work area and removing any non-essential item needs a team which will decide which items are required and which are not. Non-essential items should be sorted according to how often they are needed and then stored or disposed off. After implementation of 1stS the workplace that contains only the needed items is easier and more efficient to work in. Employees have made the first essential step to improve their workplace.

2nd S is ‘Shine’ which means keeping the work place clean, visible and safe. The aim of 2nd S is to prevent dirt and contamination from reoccurring by eliminating the sources of dirt and by making cleaning an everyday work activity. Cleaning of the workspace and every necessary item is essential. The implementation of 2nd S delivers a clean, pleasant and efficient working area and identifies the opportunities for small, continuous improvements (Pranckevicius et al., 2008).

3rd S is ‘Simplify’ which means organizing the items or tools with an approach of a place for everything and everything in place. The aim of 3rd S is to simplify the process of using items or completing tasks. 3rd S is an activity for simplifying processes minimizing waste, makes everything easy to find, use and return, simplifying is the first step towards visual control, makes work area simplefor things to become easily accessible.

4th S is ‘Standardize’ which means establishing standards for sort, shine & simplify. The aim of 4th S is to ensure the current standards achieved for sort, shine and simplify are monitored and maintained. The benefits gained from previous steps will be lost if the improved condition is not maintained. Additionally, employee's morale will hurt if their efforts do not deliver continuous results. Improvements can only become part of the culture if they are maintained. Completing the sort, shine and simplify steps will deliver an improved workplace, but the benefits can only be captured if the improvements are sustained in the long term (Laureani and Antony, 2010).

5th S is 'Sustain' which means seeking further improvements. The aim of 5^{th} S is to involve every employee in the sustenance of improvement. By using employee energy and innovation to continuously improve the 5S condition will lead to a cycle of improvement and reward. (Pranckevicius et al., 2008) presented a case study on 'role of 5s techniques' in the journey of lean implementation. The research observed that 5S is amazingly simple, and yet effective validating the 5S techniques to achieve a dramatic improvement in the process (Pranckevicius et al., 2008). The case study highlighted the benefits of 5s through behavioral operations research and observed 5S as supportive in improvement of manufacturing performance of the systems. Time and effort used to sort, shine and simplify will pay back by introducing a safer, organized, productive and efficient workplace. Lean manufacturing necessitates that a culture develops which embraces changes and continually improves its own work area. 5S's as a lean tool are usually more simple and straightforward and involve the employees and demonstrates quick results (Laureani and Antony, 2010).A dedicated and disciplined 5S process can maintain the improvements made, but it is only through motivation, encouragement and empowerment that a culture can be developed which will continue to improve (Laureani and Antony, 2010).

Kaizen: Kaizen is a lean manufacturing enabler which initiates continuous improvement by giving employees the skills, encouragement and opportunity to make positive changes (Kumar and Kumar, 2012). The aim of kaizen is to implement improvement actions through Kaizen events effectively and efficiently. The gains from a kaizen event can be significant, but it is only through sustaining these changes and implementing further cycles of improvement that company's vision can be achieved (Ellram, 2000). Improvement gained from a kaizen has major significance to the business. If effectively implemented, kaizen enabler is a powerful tool to begin the improvement process and to make a major impact on the performance of the business. The core of the kaizen is its implementation, where ideas and suggestions are implemented in the work area and refined before permanent integration. Changes must focus on improving the system as a whole, rather than sub-optimising an element of it (Smith et al., 2012). For example, OEE improvement efforts should focus on the bottleneck machine. Verify the original aim of the improvement against the anticipated effects on the performance indicators. In a successfully implemented and sustained kaizen, the improvements will be reflected in the performance indicators of the organisation (Monden, 2002).

Modarress et al (2005) revealed the impact of kaizen on product cost. Kaizen activities focus on the elimination of waste through saving of resources in the manufacturing stage with small improvement cycles targeted towards the product cost reduction (Modarress et al., 2005). Monden (2002) conducted a study at Boeing to identify the significance of kaizen on organizational performance. In Boeing, the cost reduction targets are assigned to all the divisions on a yearly basis. Then, the kaizen team starts working on the set targets. Usually, only those costs are considered which are directly controllable by the manufacturing team at division level. The reduction of cost in each successive phase supports in reduction of final product cost and improved profits (Monden, 2002). This way, the effective Kaizen events have the potential to make massive improvements to performance (Modarress et al., 2005). This ability and willingness of all employees to incorporate improvements into their everyday activities is crucial to embed continuous improvement within the company (Imai, 2012). Implementation of kaizen require some elements of lean manufacturing to be practiced such as total employee's involvement, quality at source, continuous improvement, good housekeeping, process control and safe working (Kumar and Kumar, 2012).

Autonomous Maintenance: The philosophy of autonomous maintenance in lean manufacturing is used to deliver improvement mainly in productivity with the enhanced equipment effectiveness. Autonomous maintenance is about finding and applying cost-effective ways of avoiding performance deterioration (Eti et al., 2004). There are a number of publications (Hartmann, 1992; Nakajima, 1988; Suzuki, 1992) on the significance of lean enabler autonomous maintenance. The aim of autonomous maintenance is to develop the operator to become responsible for maintaining the machine in the optimum condition. Autonomous maintenance is an incremental process where skills and knowledge are transferred from maintenance and process specialists to the daily operator of the machine. As these skills are transferred, the ability to respond proactively to potential issues will increase and an increasing number of maintenance tasks can be efficiently and effectively performed by the operator. This includes the detection of problems or potential problems and their resolution since the quality of maintenance significantly affects business profitability (Eti et al., 2004). Autonomous maintenance tasks ranges from cleaning and lubrication, through replacing parts, to the overhaul of an entire machine (Tajiri and Gotō, 1992). At the core of autonomous maintenance; operator skill is increased in many ways, such as increasing involvement in maintenance tasks performed on the machine. As operators are increasingly involved to maintain their machines at the optimum condition, their knowledge and skill will increase. The cycle is repeated to take advantage of increased skill levels by the transfer of more maintenance tasks. The machine improvement activity will also allow operators to gain better understanding of the optimum condition of the machine and will increase their ability to respond proactively. As with all elements of lean manufacturing, involving the operators in these improvements will increase the sustainability of improvements and the benefits gained.

Nakajima (1988) described the plan of 20 Japanese manufacturing companies who created a research group on the subject of improved asset utilization by implementing autonomous maintenance program and realized the high significance of the program. Nakajima, 1988 studied the Japanese company 'Tokai Rubber Industries' for the implementation of autonomous maintenance programme and revealed the significant benefits gained by the organization(Nakajima, 1988). Researchers; Ireland & Dale presented a case study of three manufacturing companies on autonomous maintenance. In all three companies; suitable support was provided by the senior management to facilitate the implementation of autonomous maintenance as a result significant performance improvement was noticed (Ireland and Dale, 2001). The benefits from any autonomous maintenance program can only be realized in the long term organizational performance indicators. Following the success of autonomous maintenance in Japan the western companies started to show interest in the subject. Researchers has published the empirical study and analysis on the subject (Hartmann, 1992; Nakajima, 1988; Sekine and Arai, 1998; Suzuki, 1992). Most of the academic papers has focused on the impact of autonomous maintenance on the productivity improvement (Maggard and Rhyne, 1992).Tsang and Chan (2000) presented a case study of manufacturing organisations in China and argued that self maintenance of equipment by operators has significant impact on equipment reliability thus impacting the operational performance indicators e.g. quality and cost(Tsang and Chan, 2000).

Ahuja and Khamba (2008) conducted a large scale study in 80 Indian organisations through a survey to measure the impact of self maintenance of equipment by operators and observed significant enhancement in all aspects of manufacturing performance measured by productivity, quality, cost, delivery, safety and morale. The elements of lean manufacturing closely associated with autonomous maintenance are overall equipment effectiveness (OEE), de-bottlenecking, equipment uptime, continuous improvement, process control, safe working and reduce variability (Sekine and Arai, 1998).

Visual Management: In today's global marketplace, customer is willing to pay only for value added activity. Customer is not ready to pay for any kind of inefficiencies of processes or wastages present in the system such as unnecessary motion, unnecessary time spent in searching for tools, information or data (Kattman et al., 2012). However, sometimes it might not possible to completely eliminate the wastages but it should be made transparent to all the stakeholders. The amount of wastage present in the manufacturing system is manifest in bottom line of the company (Kattman et al., 2012). The aim of visual management enabler of lean manufacturing is to enable everyone to immediately see deviations from the optimum state of work and working, and to enable immediate corrective action (Mestre et al., 2000). It is imperative to understand the significance of visual management concept for the organisation (Tezel et al., 2009). This is achieved by designing a system of visual indicators which will make visible when a process is not operating at its optimum. These visual indicators must be quick and easy to interpret (Neese and Kong, 2007). The system must also give clear and concise direction for the actions that are necessary to correct the issue and return to the optimum operation.

Visual management systems can be applied to physical items (e.g. tools or materials) as well as information (e.g. performance metrics or work instructions). Effective visual management relies on the active involvement of all people. Team involvement to implement the visual management systems makes a real difference to the performance of the workplace. Visual management is defined with various names by many researchers; although the concept remains same. Below are the depictions of various names synonymous to visual management concept.

Table 2.6: Visual management discussed by various researchers

Visual management concepts	Researchers
Visual Management	(Imai, 2012; Liff and Posey, 2004; Liker and Hoseus, 2009; Parry and Turner, 2006)
Visual workplace	(Galsworth, 2004, 1997; Greif, 1991; Hirano and Talbot, 1995)
Visual control	(Liker, 2004; Schonberger, 1986; Shingo and Dillon, 1989)
Visual factory	(Aik, 2005; Bilalis et al., 2002; Sugimori et al., 1977)
Shop floor management	(Galsworth, 2005; Parry and Turner, 2006)
Visual tools	(Parry and Turner, 2006; Tezel et al., 2009)
Visual communication	(Kattman et al., 2012b; Mestre et al., 2000)

Sugimori et al (1977) published the first papers on the highly praised Toyota Production System. In this paper they highlighted the integration of visual management with operational and managerial actions (Liker, 2004). Visual management is a technique that endeavors to improve organisational performance by connecting the vision of the organisation, its goals, core values and culture with other management systems, workplace basics. Visual management indicators directly deal with one or more of the five human senses such as sight, hearing, feeling, smell and taste (Liff and Posey, 2004). These indicators communicate the meaningful information about the current status of the processes which are relevant, correct, necessary, self-explanatory and motivating which facilitates people and making sense in the organisational context by simply looking through (Greif, 1991).

The visual workplace helps in improving the operational performance by making information available, facilitating workers for making fast decisions through empowerment and being self directing and without failing to get noticed about any deviations (Kattman et al., 2012).The principles of visual management are central to the effective implementation of the other lean manufacturing enablers like 5s, lost time analysis, standard work and autonomous maintenance. As one of the lean manufacturing enablers in the workplace, visual managenet plays a key role in the optimization of performance OEE % and people productivity, inventory levels stocks and safety etc. This process can be applied to other forms of information transfer within the workplace (Kattman et al., 2012).. This includes tools, work-in-progress (WIP) inventory levels, machine status, performance metrics, etc. Visual management can be used to organize the workplace. Managing items such as tools and materials offers increased efficiency and quality of work (Kattman et al., 2012). Visual management can be used for creating visibility of production progress with higher focus on critical processes and increased responsiveness to the customer. Visual Management supports in improving the quality performance by reducing the risk of quality issues escaping, and by focusing improvement efforts. Visual management of risk areas and incident response tools improves the safety of all employees. Information regarding productivity, sales and quality can be simply obtained through visual charts (Adams et al., 1999). Visual Management technique is effectively used by manufacturing and service organisations extensively (Tezel et al., 2009). Visual management communicates with illustration, so that places happen to be self-explanatory, self-ordering, self-regulating and self-improving (Galsworth, 1997). A simple andon light can be improved by adding a clock which begins timing whenever the machine stops. Andon lights and Andon boards may increase efficiency by reducing the response time to attend stopped machines, making it easier for one person quickly to see the status of the factory and preventing concerns being passed to the next process (Neese and Kong, 2007). Visual Management systems may improve the safety of all employees by tackling the causes of risk, by making all personnel aware of areas or types of risk and by ensuring a quick and effective response to incidents. Visual management systems can highlight quality issues and solutions to improve the quality of products that are supplied to the immediate customer and end consumer. For example, marking the tolerance range on gauge faces helps increase quality standards. Out of specification parts are easily visible and adjustments can be made to solve the arising problem. Lean elements such as total employee involvement, load leveling, overall equipment effectiveness, quality at source, good housekeeping, reduced information barrier, process control, standardization and pull system are integral parts of visual management enabler of lean manufacturing(Liff and Posey, 2004; Parry and Turner, 2006).

2.9. ORGANISATIONAL PERFORMANCE

Organisational performance is the measure of the achievement of overall goals and objectives. It may be defined as the measure of the pursuance of the action plans that lead to the success of the organisation in terms of efficiency and effectiveness. Development of industrialization is the key ingredient in the development of the nation. Successful organisations play a major role in success of the nation. Organisation determines the financial, societal and political progress of the country(Kirchhoff, 1977). Organisational performance is the focus area for any company as they can grow and progress through continuous performance. In the management research it is one of the most important variables in measuring the organizational performance. In the academic literature; the concept of organizational performance is very common but it is hard to describe with one single universally accepted definition. Definition of organizational performance in 1950's was defined as "the extent to which an organization, viewed as a social system fulfilled their objectives" (Georgopoulos and Tannenbaum, 1957). During that time performance was evaluated based on work performed, number of people employed and the structure of the organisation. Later organizations have begun to explore new ways to evaluate their performance so performance was defined in the 60s and 70s, as "the ability of the organization to exploit its environment for accessing and using the limited resources" (Kirchhoff, 1977; Yuchtman and Seashore, 1967). New dimensions of performance were added to assess the organisations with different angles.Until the 1980's and 90's, the organisational objectives became more complex than before. Organisations which were able to achieve their objectives successfully with minimum consumption of resources were considered as more successful. The ratio of consumption of resources to the output as "efficiency" and the ratio of accomplishment of goals against the target as the "effectiveness" was considered as the measure of organisational performance (Venkatraman and Ramanujam, 1986). Venkatraman and Ramanujam (1986) presented a model of overall business performance as organizational performance. This model suggested that the financial and operational performance domains are subsets of business performance, which is a subset of organizational effectiveness representing the organisational performance. Figure 2.3 depicts the model suggested by Venkatraman and Ramanujam (1986).

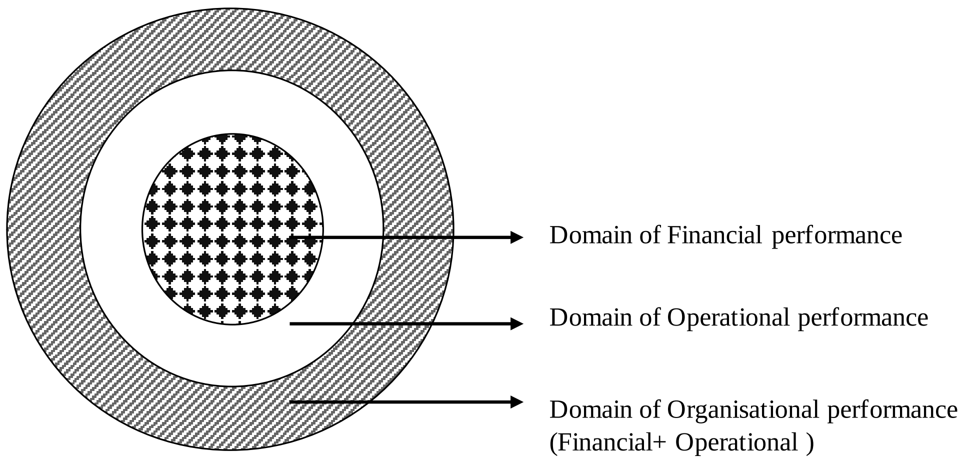


Figure 2.3 Modified model of Venkatraman and Ramanujam (1986) explaining organizational performance.

Common understanding for a success of the organisations got developed that numerous indicators of performance are important. It was felt necessary to quantify the results to measure the performance level of the organization. Researchers (Gavrea et al., 2011; Goga, 2014; Lebas and Euske, 2006; Maduenyi et al., 2015) provided a bunch of descriptions to represent the idea of organizational performance:

- Effectiveness (accomplishes its goals) is essential but the efficiency (use of minimum possible resources for the same output) if equally important (Lusthaus et al., 1999)Performance is dynamic, needs assessment and analysis.
- It is imperative to quantify the results to measure the performance level(Lusthaus and Adrien, 1998).

- Finally the organisational performance is a combination of financial and nonfinancial indicators which represent the degree of accomplishment of the goals results (Kaplan and Norton, 1996; Lebas and Euske, 2006). This includes operational performance and financial performance.

Various dimensions of organisational performance disussed by researchers is depicted in table 2.7.

Table 2.7: Organisational performance measures used in archival data studies

Research articles			Operational performance						Financial performance			
Researcher's name	Year of study	Numbers of companies studied	Productivity	Quality	Cost	Delivery	Safety	Morale	Inventory turn ratio	Profitability	Share of business	Revenue growth
Inman & Mehra	1993	NA			X				X	X		
Billesbach & Hayen	1994	NA							X	X		
Flynn, et al	1995	NA		X								
Chang & Lee	1995	NA	X	X		X			X	X		
Hudson & Nanda	1995	NA		X	X	X			X	X		
MacDuffie	1995	62	X	X	X				X	X		
Balakrishnan, et al	1996	46	X	X					X	X	X	X
Sakakkibara, et al	1997	NA	X	X	X	X			X	X		
Koufteros et al	1998	NA	X		X	X						
Easton & Jarrell	1998	108	X	X					X	X	X	X
Claycomb et al	1999	NA								X		X
Samson & Terziovski	1999	1200	X	X	X				X			
Callen, et al	2000	NA	X	X	X				X	X		X
Fullerton & McWatters	2001	NA										
Shah	2002	NA	X	X	X	X		X				
Biggart & Gareya	2002	74	X	X	X	X			X	X		
Kinney & Wempe	2002	201	X	X	X	X			X	X	X	X
Fullerton, et al	2003	253	X						X	X	X	X
Olsen, 2004	2004	NA	X	X	X	X			X	X	X	X
Suhong Li et al.	2004	NA	X	X	X	X			X	X		X
Agarwal et al	2006	NA	X	X	X	X			X			
Ahuja and Khamba	2008	NA	X	X	X	X	X		X	X		
Anand & Kodali	2008	NA			X	X			X	X	X	X
Bozarth et al	2009	NA	X	X	X	X			X			
Wong & Wong	2010	NA	X	X	X	X			X	X		
Bhim Singh et al	2010	NA	X	X	X	X			X	X		
Norani Nordin et al	2010	NA	X	X	X	X			X	X	X	X
Vikas	2010	NA	X	X	X	X		X	X			
Rahman et al., 2010	2010	NA	X	X	X	X			X			
Rahman et al	2010	187	X	X	X	X			X	X		
Chen	2011	224	X	X	X	X			X	X		X
Krisztina & Zsolt	2011	711	X	X	X				X			
Yang et al	2011	309	X	X	X	X			X	X	X	X
Shahram Taj and Cristian	2011	65	X	X	X	X	X		X	X		X
Wong Y C & Wong K Y	2011	NA	X	X	X	X	X		X	X		X
José M & Macarena S	2012	NA	X	X	X	X			X	X		
Laureani & Antony	2012	101	X	X	X	X			X	X		
Roger and Sohal	2012	NA	X	X	X	X				X		
Azharul K & Zaman K A	2013	NA	X	X	X	X			X			
Maroofi F	2013	NA	X	X	X	X		X	X			
Manimay Ghosh,	2013	79	X	X	X	X	X		X	X		X
Mishra et al	2013	NA	X	X	X	X			X			
James Roh et al	2014	NA	X	X	X	X	X		X	X		
Dombrowski & Mielke	2014	NA	X							X		
Ioannis Belekoukias	2014	140	X	X	X	X	X		X	X		
Biman Das et al	2014	NA	X	X	X	X			X	X		
Tortorella & Fogliatto	2014	NA	X	X				X		X	X	X

Note: Cell with X indicates that the column topic is adressed at least to a minimal degree

Researchers argued organisational performance as combination of operational and financial performance(Carton, 2004). In this arrangement operational performance included all non-financial results of the organizations whereas the area of financial performance is restricted to financial outcomes(Carton, 2004; Combs et al., 2005). The nonfinancial performance dimensions (operational performance) are measured against given targets as productivity, quality, cost, delivery safety and morale. The financial performance dimensions are identified as profitability, stock turn ratio, revenue growth, and share of business.

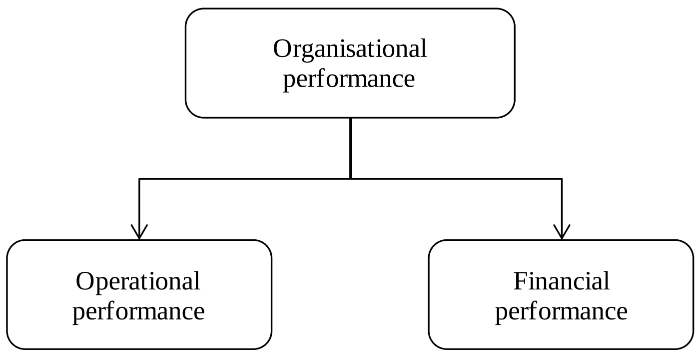


Figure 2.4: Organisational performance model

Source: Venkatraman and Ramanujam (1986) and Robert B. Carton (2004)

2.9.1. Operational Performance

Operational performance is outcome of the synergy between the resources in planning and execution to create the desired results(Belekoukias et al., 2014). The operational results are non financial i.e. how efficiently the resources are utilized to generate the results? Operational performance is measured against given targets such as productivity, quality, cost, delivery safety and morale(Maroofi et al., 2012).

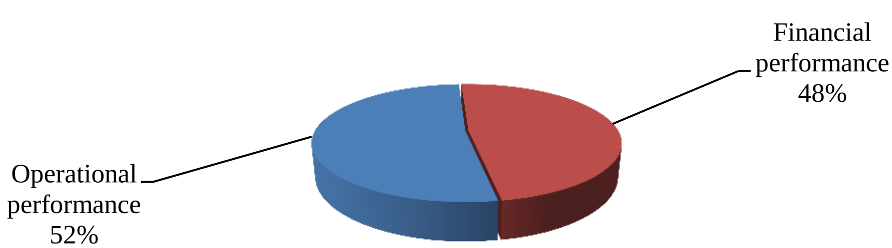


Figure 2.5: Organisational performance as discussed by various researchers

Operational performance is pertaining to performing the work, in addition to the achieved results or it may be termed as the result of work as they present the relationship to the target of an organization and the stake holders including customer, supplier and employees(Joshi and Naik, 2012). It is observed that operational performance is measured to the tune of 52% and financial performance is measured to the tune of 48% in the reviewed research papers for measuring the impact of lean manufacturing on organizational performance in manufacturing industries.

Moving forward for performance measurement, it is observed that within operational performance, productivity is measured in the reviewed researches by 85%, quality 83%, cost 79%, delivery 70% safety13% and moral is measured to the tune of 9%. Safety and morale have not been given much importance in measuring operational performance by researchers. One of the reason may be that it does not give monitory benefit hence may not be on top priority; nevertheless involvement and morale of the people have been identified as key dimension of lean manufacturing implementation by almost all the researchers but measurement of safety and morale as a outcome of the system seems to be missed out by many researchers.

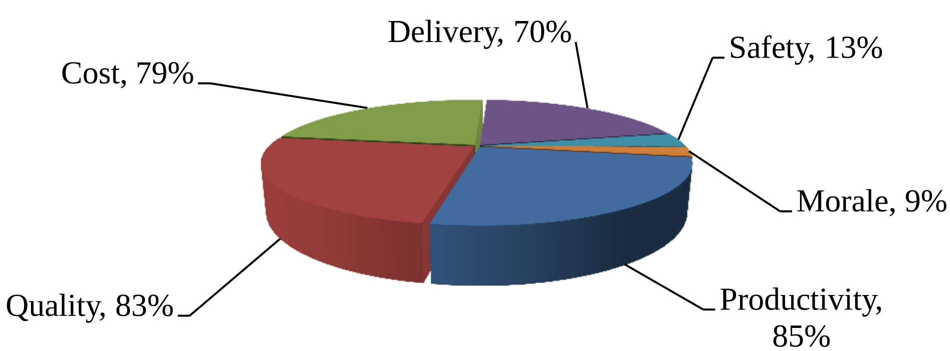


Figure 2.6: Operational performance as discussed by various researchers

Since operational performance measurement is one of the most important parameter for any organization. This indicates how well strategies are translated into measurable results(Olsen, 2004). In the last two decades specially, a wide range of performance measurements have been proposed and adopted by many organisations. Researchers have proposed a few non financial measures of operational performance to get a balance score card for measuring the operational performance of the organisation. Improvement in manufacturing processes enhances operational performance. A solid and efficient manufacturing base is essential for smooth product flow throughout the value stream. The implementation of best practices in operations reduces complications and non value adding activities for operations.

Productivity: Productivity is a measure of the ability of manufacturing processes to produce a product. More precisely, it is the measure of how well the resources are being utilized to produce the output. This is used to measure the efficiency of manufacturing of the organisation (Wong et al., 2009). Productivity may be defined as an index or the ratio of output relative to the input hence becomes a vital parameter to monitor the operational performance. Productivity may be monitored in many ways such as labor productivity, capital productivity, energy productivity or machine productivity etc. productivity can be improved by either reducing the input for the same output of increasing the output from the same input(Bhamu et al., 2012). But requirement of output is generally decided by customer demand so reduction of input is adopted by many manufacturing organisations by reducing the waste from the manufacturing system through utilizing the resources in a more efficient manner(Das et al., 2014). Manufacturing organisations adopts lean manufacturing for waste reduction and to get maximized output from the same or reduced input(Rahman et al., 2010). Productivity has become a vital measure of impact of lean manufacturing on operational performance(Rahman et al., 2010). Researchers proposes that productivity is the appropriate scale to measure the operational performance(Misterek et al., 1992). Researchers have observed a positive and direct relationship between lean manufacturing implementation and improvement in productivity (Wong and Wong, 2011).

Quality: Quality is considered as one of the most essential characteristic of manufacturing. Strong competition in the market has enforced organisations to deliver high quality products and services in order to keep the customer delighted and retained. Researchers (Kumar, 2010) have reported that customers maketheir buying decision based on product quality hence perceived quality of product is directly connected to increase in sales and profits. Quality of product and service is possibly the prime requirement that companies needs to work on for increased profits, increased market share, reduced costs and improve overall business performance. Researchers have revealed a positive relation between product quality and the organizational performance (Chang and Lee, 1995; Flynn et al., 1995). Researchers have defined quality as the essential parameter that must be attained by every organisation to achieve the competitive advantage(Bhamu et al., 2012) .

Cost: The cost of manufacturing is inversely proportional to the operational efficiency hence cost becomes a vital indicator of operational efficiency (Jonsson and Lesshammar, 1999). The large fraction of the entire costs of manufacturing may be attributed to losses occurred in manufacturing the product (Dahlén et al., 1995). It is beneficial to use cost as a factor of operational measures financial measures becomes more important from management perspective(Jonsson and Lesshammar, 1999).Cost may be measured with various sub parameters such as personnel cost including salary and training cost, equipment maintenance cost, defect cost, cost of poor quality such as segregation and rework cost, energy cost, material cost etc. Consumption of various resources may be tracked via different sub parameters of cost monitoring.

Delivery: The most important to the organization are its customers. Delivery of the product connects the organization with the customer. Delivery of goods and services is the key determinant in customer satisfaction(Chen and Meng, 2010). Delivery performance has emerged as the imperative measure of the evaluation of operational performance (Gunasekaran et al., 2004). The delivery time refers to the time elapsed between placing the order and the delivery of finished product to the customer. Lower delivery time refers to the better response time and helps in getting a competitive advantage over competitors. There are different aspects of delivery performance such as customer order fill rate, on-time delivery rate in percentage, percentage of finished goods in transit indicating inventory turns etc. Deliver performance can be adversely effected by various losses in manufacturing or delivering the goods to customer. Decrease in the inventory levels can be achieved by increasing the efficiency in the system. It is essential part of operational performance and hence may be measured and worked upon for continuously improved results. The indicators of delivery performance should be specific, measurable, achievable, relevant and time bound(Hallgren and Olhager, 2009; Taj, 2008).

Safety: Traditionally, safety was dealt as a subject separate from manufacturing performance. Nowadays safety is considered as an integral part of manufacturing performance. Risk assessment for every activity, equipment, process, material and every individual is performed to ensure safe working environment. Any unsafe activity or action is analyzed and reduced or eliminated to improve embedded safety in the manufacturing system. Any potential risk is considered as a waste in lean term because any violation of safety may result in major or minor accident or loss of property to the organisation resulting in tangible cost like compensation cost or intangible cost such as loss of productivity, time loss, employee's turnover etc. Hence prerequisites of lean manufacturing is the incorporation of safety in every manufacturing related activity starting from ordering of material to delivering the product to customer so safety is considered as an imperative measure of operational performance and a critical success factor for lean(Tortorella and Fogliatto, 2014).

Morale: Morale of the employees refers to the level of satisfaction of the employee with the assigned job to him and his ambition to achieve the common goal of the organization (Bruhns, 2015). Morale of the employee plays a very important role in the success of an organization (Nagaraja, 2007). A key feature to ensure high morale of the employee is to create positive and transparent working environment of the organisation where managers communicates to their employees (Utomi and Rahman, 2014). The low morale refers to negative feeling that may result in decrease in productivity, decrease in quality of work and lack of discipline finally affecting the organisational performance adversely (Utomi and Rahman, 2014). Low morale of the employee poses a risk to the success and even survival of the organization(Tortorella and Fogliatto, 2014). High morale refers to a state of positive feelings among the employees with the willingness to follow the instructions and ready to cooperate with co-workers and hence having a feeling of empowerment (Sageer et al., 2012). Globalization and competition have enforced the organizations to keep morale of the employee high to be successful in the market (Pathak et al., 2015). Well appreciated employees with high morale are more productive and contribute more towards the goal of the organization(Parvin and Kabir, 2011). Morale of the employees has turn out to be an important part of management strategies and hence focus is given to manage the morale of the employees (Abdulla et al., 2011; Bethke-Langenegger et al., 2011).

2.9.2. Financial Performance

Financial performance refers to the degree to which an organization achieves profit oriented outcomes. Researches shows that lean manufacturing implementation are positively related to financial performance. Eight of the seventeen studies have used financial performance measures and observed significant relationships between lean manufacturing practices performance measures. Five studies indicated increases to stock returns ratio derived from study of archival stock returns ratios. Borade and Bansod (2010) presented a more comprehensive research of Indian organisations on that included significant relation with stock return ratio and profitability improvement in vendor-managed lean practices of inventory control(Trifilova et al., 2010).

Financial performance is more related with business performance by two characteristics financial and market performance viewpoint. The financial performance may be denoted by many indicators, but we have considered four aspects of financial performance measures viz. Profitability, inventory turns, share of business and revenue growth. Financial factor wise performance measured by researchers is inventory turns ratio 83%, profitability 72%, revenue growth 34% and share of business to the tune of 19%. It is revealed that researchers tend to look impact of lean manufacturing on reduction of inventory and increase in profitability as compared with revenue growth and increase in share of business as impact of lean manufacturing. All the four identified factors are vital for measurement of financial performance.

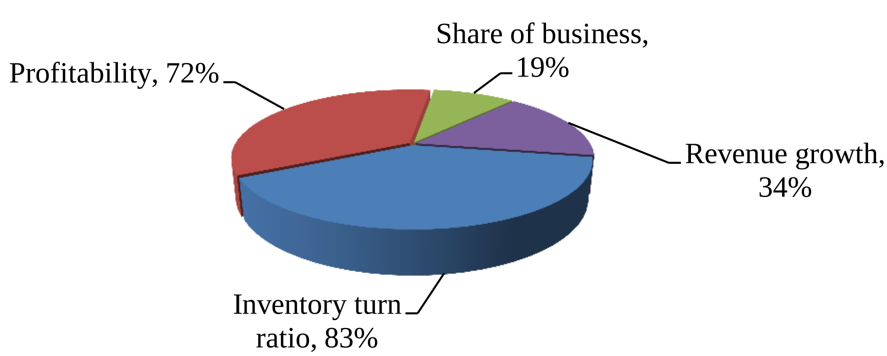


Figure 2.7: Financial performance as discussed by various researchers

Yang et al (2011) presented a research article on impact of lean manufacturing on financial performance of manufacturing organisations(Yang et al., 2011). Lean manufacturing was conceptualized as a second-order construct with three sub-dimensions of lean manufacturing factors. Organisational performance was determined using market performance and financial performance considering measures for sales growth, market share, financial performance as return on assets (ROA) and return on sales (ROS). Impact of lean manufacturing practices was tested on market performance and observed a significant relationship between lean manufacturing and market performance. Similarly the impact of lean manufacturing practices was tested on financial performance. The outcome of the study indicated that strong relationship exists between lean manufacturing and financial performance supporting the earlier findings in literature (Fullerton et al., 2003; Fullerton and Wempe, 2009).

Profitability: Profitability is the capability of an industry to produce profits. Profit may be defined as the surplus of the revenue subsequent to payment of all operating cost associated with generating the income. Operating cost may include manufacturing the product, sales general and other administration cost related to business activities. Profitability may be monitored in the form of return on assets (ROA), return on net asset (RONA) and return on sales (ROS).

Inventory turnover ratio: The inventory turnover ratio is a universal measure of the financial performance of any manufacturing organisation (Demeter and Matyusz, 2011). It reflects the management and utilization of assets including product inventory throughout the value stream (Shah and Ward, 2003). Overhead costs are reduced by having a minimum level of inventory and, hence improving the financial efficiency of the organisation. The inventory turnover ratio may also be referred as to determine the number of times the inventory is sold by an organisation within one year. Inventory turnover ratio is calculated by dividing the quantity of product sold in numbers by the quantity of product available in value stream at any point of time. But In the financial inventory turn ratio is calculated by dividing the cost of goods sold by the cost of inventory at any point of time. In a study Schonberger, (2003) revealed that increase in inventory turn ratio is the result of lean manufacturing implementation.

Market Share: It is a measure of financial growth as a consequence of customer satisfaction. Customer satisfaction is initiated when the expectation of the customer over quality and price are met as a result of on time delivery of good quality product at lower cost (Anderson et al., 1994). Yang et al (2011) define market share as the degree to which an organisation is able to obtain a share of business in the market in its segment of operation. Nordin et al (2010) revealed that the increase in market share is the driving factor to the implementation of lean manufacturing to the tune of 27.9%. Market share is a prime factor of financial performance as market share reflects the competitive edge over competitors (Anand and Kodali, 2008; Gurumurthy and Kodali, 2009).

Revenue Growth: Revenue growth is the vital measure of business growth. Revenue growth is the increase in revenue year over year. Researchers revealed the impact of lean in increased revenue growth(Yang et al., 2011). It includes the impact of change in product cost in addition to earning due to new business. Focus of operational performance improvement due to the implementation of lean manufacturing results in the reduction of product cost in line with the expectation of customers but it has a negative impact on revenue growth.

2.10. CHAPTER SUMMARY

In this chapter the existing literature is reviewed exploring the lean manufacturing. In the literature review section, following gaps are identified:

Gap 1: There are many elements of lean manufacturing, few of them are synonymous to each other and are used by various researchers with different names hence it creates mix-up. The existing research articles discuss only a few elements of lean manufacturing hence it necessitates to consolidate all the lean manufacturing elements which may be used for establishing the level of lean manufacturing.

Gap 2: Organisational performance is measured considering few factors responsible for organisational performance but the measurement of organisational performance using operational performance and financial performance factors collectively, is missed out in the existing researches.

Gap 3: The correlation between the factors responsible for lean manufacturing implementation and factors responsible for measurement of organisational performances considering all the practice and performance factors is not available in the context of Indian industry.

Gap 4: The quantification of the impact of lean manufacturing implementation on the organisational performance of Indian industries has not been reported in the literature reviewed.

A synthesis of the research articles related to lean manufacturing and performance measurement has been done. From the existing literature, twenty nine elements and seven enablers of lean manufacturing are identified. These factors are expected to have suitability in measuring the level of implementation of lean manufacturing in the Indian context.

The concept of organizational performance measurement is also reviewed in research articles. Literature review supported the fact that there are many schools of thoughts for measuring the organisational performance. This incorporated an evaluation of differing viewpoint of organizational performance containing the operational performance scorecard and financial performance measures. Available research has not yet established a set of universally agreed on factors for measuring organizational performance. The Venkatraman and Ramanujam model (1986) state that it is appropriate to measure the organisational performance with two aspects i.e. operational and financial performance. Taking Venkatraman and Ramanujam model into consideration, the factors of operational and financial performance are observed. Six factors of operational performance and four factors of financial performance are identified based on literature review. Nevertheless, the review has provided guidelines for the development of some situational models for performance measurement that may be used across the population of the organizations. The following chapter will concentrate on the development of the measurement models and finally will observe the correlation between the lean manufacturing implementation and organisational performance.

CHAPTER IV

SURVEY OF INDIAN INDUSTRIES

4.1. INTRODUCTION

Subsequent to the identification of research problems, research objectives and research questions; the plan and rationale of philosophical framework are to be explored. The objective of this research is to examine the impact of lean manufacturing practices on organizational performance in Indian industry. During the literature review it was observed that there are no commonly accepted and specific guidelines for the implementation of lean manufacturing across the Indian industries. It was observed that there are total 34 elements which are directly related to the implementation of lean manufacturing practice and some elements are co-related hence, 29 various elements have been identified in the literature review as unique to lean manufacturing. Seven lean enablers have been identified as 5s, Kaizen, lost time analysis, visual management, autonomous maintenance, standard work and value stream mapping. The most appropriate approach of measuring the implementation of lean manufacturing is presumed to measure the status of implementation level of each of lean enabler as independent variables. Level of implementation of lean manufacturing practices was measured using the survey method.

In the literature review, it was observed that researchers used factors, in random, to measure the performance of organizations. Organisational performance was found to be measured or related with two factors viz. the operational performance and the financial performance. Operational performance is considered as the effectiveness and efficiency of the manufacturing and it is more related with internal activities where lean manufacturing is mainly practiced. Whereas, financial performance describes how the organization is able to interact with the outside environment and maintain its competitive position in the market segment by keeping its profitability in better shape, maintain share of business, keeping higher inventory turns ratio and maintaining the intact revenue growth. It was decided that both performance parameters i.e. operational and financial performance parameters need to be considered as dependent variables and also need to be measured independently to obtain the overall representation of the organisational performance. Survey based research studies were supposed to measure the lean practices implementation and gauge the performance level to test the empirical relationship between lean manufacturing practices and organizational performance.

In last decade appreciable number of empirical research studies have been presented describing the measurement methods of lean practices. Research studies by Rachna Shah (2006), Taj, (2008), Wan & Chen, (2008) initiated establishing and testing different measures of lean manufacturing. However these studies revealed that a significant level of perceived performance improvement has been achieved through implementation of lean practices. Lack of empirical support was observed in some of research studies to measures performance. Leaving the concerns apart for a while, it is imperative for researchers to validate the methods used to measure the performance of parameters of lean. By focusing on lean enablers, discussed in previous section (chapter 2), as major lean practices in India and considering them as indicative of lean manufacturing practices, it becomes rational to conduct a survey . It was observed that survey instrument is concise and adequate to seek a satisfactory response from the industrial professionals for achieving realistic coverage of lean practice- performance spectrum.

The formulation of the structure of research methodology was the key objective of this section. There are three prominent segment of measure coming out of the discussion so far. The first section of research area turns out to gauge the level of lean practices implementation across the Indian industries. The second section consists of measuring operational performance and financial performance as a measure of the organisational performance. The third section comes out to establish a correlation between lean practices, operational performance and financial performance. The purpose of this research is to investigate the impact of lean manufacturing implementation on organisational performance of the Indian industries. Thus this chapter raises three propositions about the correlations among lean manufacturing implementation and organisational performance are as follows:

1. Lean manufacturing practices impacting the operational performance (H1),

2. Lean manufacturing practices impacting the financial performance (H2),
3. Operational performance impacting the financial performance (H3).

4.2. LEAN PRACTICES AND OPERATIONAL PERFORMANCE

In a general sense, lean manufacturing is a well accepted system to achieve the best in class result for the organizations. In this section relation between structured lean practices and operational performance is argued. Many survey based research studies supports the opinion that performance improvement can be measured effectively with practice performance with simple linear combinations. Strategic deployment of lean practices and performance improvement is presented by many researchers. This has increased the credibility of conventional measures of lean performance typically expressed in forms associated with productivity quality, cost, delivery, safety and morale (Bayou and De Korvin, 2008; Shah and Ward, 2007; Shan, 2008; Taj, 2008; Wan and Frank Chen, 2008). Statistical techniques are used by the majority of researchers using regression and structural equation modeling. All the studies reveal positive relationships between lean manufacturing implementation and operational performance. This proposition may help in understanding the correlation between implementation of lean manufacturing and impact on operational performance. Hence the following proposition is put forward in Hypothesis (H1):

Table 4.1: Hypothesis investigating relation between lean practices and operational performance

S. No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
H1	Lean Manufacturing practices implementation does not have significant impact on operational performance of manufacturing organisations in the Indian context.	Lean Manufacturing practices implementation has significant impact on operational performance of manufacturing organisations in the Indian context.

In the above hypothesis the investigation of relationship between lean practices versus operational performance is discussed. Further, it becomes imperative to assess the impact of lean manufacturing practices on operational performance as well as on its implementation cost. Unless the magnitude of lean manufacturing practices is known on operational and final performance of an organization, the practitioners will be in a dilemma whether the lean enabler, which they have chosen to implement, will have a significant impact on the operational or financial performance. . To answer these concerns, this research study puts forward the following theoretical model of comparing implementation of lean manufacturing practices with respect to operations performance:

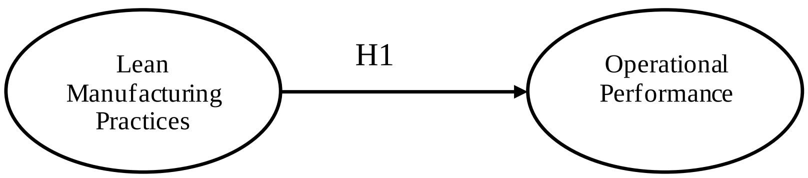


Figure 4.1: Conceptual model of lean manufacturing practices versus operations performance

Lean manufacturing practices are sought as driver for operational performance improvement. There are seven enablers of lean manufacturing through which measurement of implementation level of lean manufacturing practices can be performed. Hence it is imperative to examine the contribution of each enabler in the implementation lean manufacturing. To measure the contribution of individual enabler in establishing the level of lean manufacturing implementation the following propositions are hypothesized:

Table 4.2: Hypothesis investigating contribution of various factors in lean manufacturing implementation

S. No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
$H1a_1$	'**5S**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**5S**' enables lean manufacturing practices significantly in Indian industries.

$H1a_2$	'**Kaizen**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Kaizen**' enables lean manufacturing practices significantly in Indian industries.
$H1a_3$	'**Lost time analysis**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Lost time analysis**' enables lean manufacturing practices significantly in Indian industries.
$H1a_4$	'**Visual management**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Visual management**' enables lean manufacturing practices significantly in Indian industries.
$H1a_5$	'**Autonomous maintenance**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Autonomous maintenance**' enables lean manufacturing practices significantly in Indian industries.
$H1a_6$	'**Standard work**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Standard work**' enables lean manufacturing practices significantly in Indian industries.
$H1a_7$	'**Value stream mapping**' has no significant impact on enabling lean manufacturing practices in Indian industries.	'**Value stream mapping**' enables lean manufacturing practices significantly in Indian industries.

Several researchers have validated on the improvement in operational performance of the organisations as a result of the implementation of lean manufacturing (Doolen et al., 2006; Doolen and Hacker, 2005; Kennedy and Widener, 2008). The identified source of improvement may be summarized as a result of reduced inventory, reduced breakdown time, improved work space utilization, product quality, improved labor productivity, reduced cycle time, reduced lead time, equipment utilization improvement, high inventory turns and improved safety and morale of the employees. Since the improvement in performance is considered desirable, therefore identification of a comprehensive set of preferred performance parameters is required. Six major performance parameters were identified based on the literature review; Productivity, quality, cost, delivery, safety and morale. Further, it is imperative to analyze the impact of each operational performance parameter on the overall operational performance of the organisation. To determine the contribution of individual performance parameter in establishing the operational performance of the industry, the following propositions are hypothesized:

Table 4.3: Hypothesis investigating the contribution of various factors for measuring the operational performance.

S. No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
$H1b_1$	‘**Productivity**’ does not significantly impacts the operational performance of the organisation in Indian industries.	‘**Productivity**’ significantly impacts the operational performance of the organisation in Indian industries.
$H1b_2$	‘**Quality**’ does not significantly impacts the operational performance of the organisation in Indian industries.	‘**Quality**’ significantly impacts the operational performance of the organisation in Indian industries.
$H1b_3$	‘**Cost**’ does not significantly impacts the operational performance of the organisation in Indian industries.	‘**Cost**’ significantly impacts the operational performance of the organisation in Indian industries.
$H1b_4$	‘**Delivery**’ does not significantly impacts the operational performance of the organisation in Indian industries.	‘**Delivery**’ significantly impacts the operational performance of the organisation in Indian industries.
$H1b_5$	‘**Safety**’ does not significantly impacts the operational performance of the organisation in Indian industries.	‘**Safety**’ significantly impacts the operational performance of the organisation in Indian industries.

H1b$_6$	'**Morale**' does not significantly impacts the operational performance of the organisation in Indian industries.	'**Morale**' significantly impacts the operational performance of the organisation in Indian industries.

The lean manufacturing practices are measured by seven enablers of lean and operational performance of the organisation is measured with the six performance parameters as discussed in previous section. In statistics, latent variables are variables that are not directly observed but are rather inferred (through a mathematical model) from other variables that are observed (directly measured). Mathematical models that aim to explain observed variables in terms of latent variables are called latent variable models. Hence, in this proposal, both variables i.e. lean manufacturing practices and operational performances turns out to be the latent variables and are measured through measureable variables. Figure 4.2 shows mathematical model or conceptual model for examining relation between measured variables and latent variables for comparing lean manufacturing with operational performance. The hypothesis formulated for each case is also shown in the figure 4.2.:

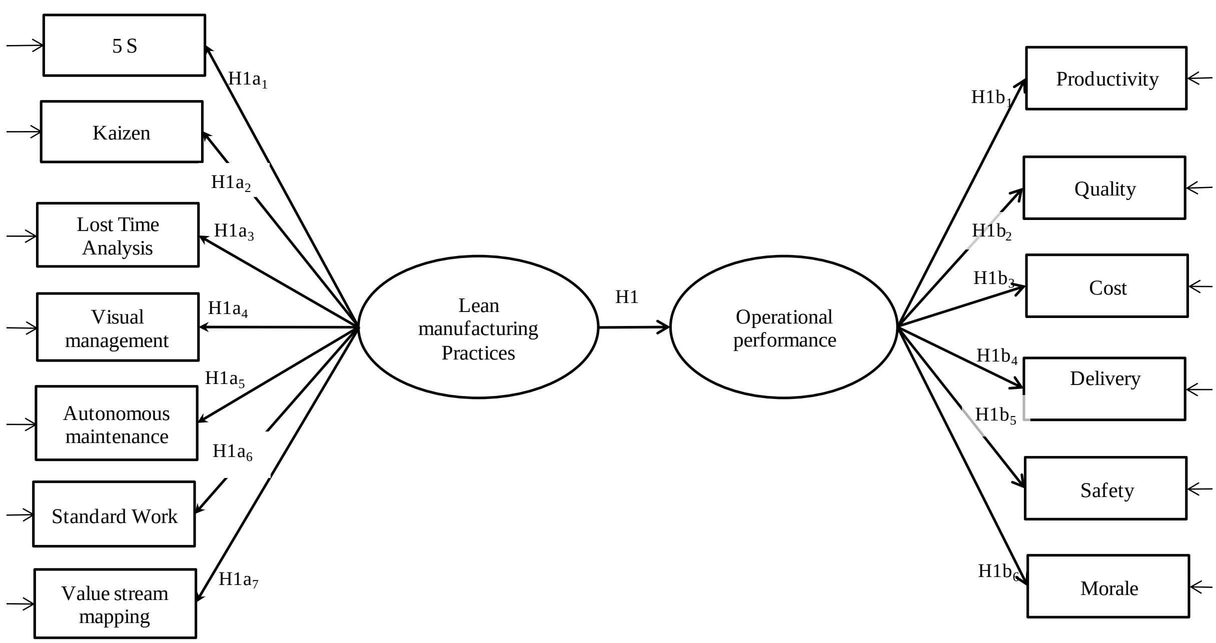


Figure 4.2: Conceptual model of examining relation between lean manufacturing practices and operational performance.

4.3. LEAN PRACTICES AND FINANCIAL PERFORMANCE

Researchers continued to establish a base work for financial performance measures (Baines et al.,(2006), Emiliani (2006), and Holweg (2007) presenting chronological viewpoint on impact of lean on financial results and thus further developing the superior understanding on outcome of the lean manufacturing implementation. Financial performance is the result of multifaceted set of operational results and internal and external business environment. In this research a simplified approach is adopted to analyze the organisational performance encompassing operational and financial parameters. The adoption of highly sophisticated financial performance parameters has been avoided to conduct simple and straightforward research that supports transparency.

Purpose is to maintain easy to understand approach for the lean practitioners and academicians having fair knowledge about lean manufacturing. The expected viewers for this research are manufacturing professional and academicians so they are protected from the manipulation of financial performance data statistics by simple, well accepted and popular financial performance parameters: inventory turns ratio, revenue growth, profitability and market share. All the four financial performance parameters are well understood by professional community and helpful in gathering the data during conducting the survey.

The improvement in financial performance is highly desirable. There are studies indicating impact of lean manufacturing on financial performance such as profitability, revenue growth, Inventory turns ratio improvement and increased share of business. In fact, a few studies have used financial performance measurement as subset of overall impact of lean on performance of the organisation. Moreover, the extent of implementation level of lean manufacturing is limited. So, the studies sometimes fall short in establishing the impact of lean practices on business results. The proposed study has considered the data collection from the industries through survey instrument. The collected data can be used to compare lean practices and various performance parameters. Here, the comparison structure follows one factor at a time approach as operational performance may have direct impact of lean manufacturing practices but financial performance may depend upon other business environmental circumstances other than the implementation of lean manufacturing. The impact of lean manufacturing on financial performance is measured by comparing lean manufacturing practices with four financial performance parameters viz. Inventory turn ratio, revenue growth, profitability and market share. Hence the following proposition is put forward in Hypothesis (H2):

Table 4.4: Hypothesis investigating relation between lean practices and financial performance

S. No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
H2	Lean Manufacturing practices implementation does not have significant impact on financial performance of manufacturing organisations in Indian context.	Lean Manufacturing practices implementation has significant impact on financial performance of manufacturing organisations in Indian context.

To answer the question of comparing implementation of lean manufacturing practices with respect to financial performance, the following theoretical conceptual model is offered:

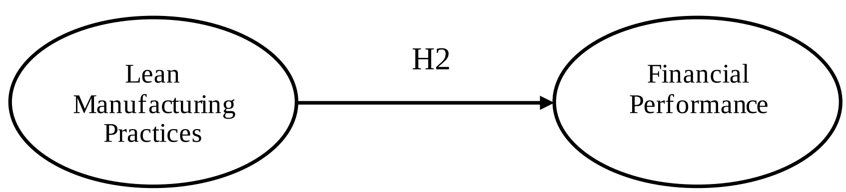


Figure 4.3: Conceptual model of lean manufacturing practices versus financial performance

Researchers have considered various financial performance parameters to measure the performance of the organisation. Though some researcher presented positive impact on inventory turns ratio with improved lean manufacturing practices(Ellinger et al., 2002) but earnings per share was not found significant (Boyd, 1991).Revenue growth was not considered as a measure of organisational performance in these researches. In this research the gain of lean manufacturing on financial performance is measured with four financial performance parameters viz. inventory turn ratio, revenue growth, profitability and market share so it is imperative to examine the significance of each financial performance parameter in representing overall financial performance of the organisation. To satisfy the question the following proposition is offered:

Table 4.5: Hypothesis investigating contribution of various factors in measuring financial performance

S. No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
$H2c_1$	**'Inventory turns ratio'** does not significantly impacts the financial performance of the organisation in Indian industries.	**'Inventory turns ratio'** significantly impacts the financial performance of the organisation in Indian industries.
$H2c_2$	**'Revenue growth'** does not significantly impacts the financial performance of the organisation in Indian industries.	**'Revenue growth'** significantly impacts the financial performance of the organisation in Indian industries.
$H2c_3$	'**Profitability '**does not significantly impacts the financial performance of the organisation in Indian industries.	'**Profitability**' significantly impacts the financial performance of the organisation in Indian industries.
$H2c_4$	**'Share of businesses'** does not significantly impacts the financial performance of the organisation in Indian industries.	**'Share of businesses'** significantly impacts the financial performance of the organisation in Indian industries.

As discussed in the previous section regarding lean manufacturing practices and operational performance, same way financial performance is measured using four measured variables to conclude upon financial performance of the organisation with the inclusion of various hypotheses identified in the previous section. Consequently, conceptual model for examining comparing lean manufacturing with financial performance using hypothesizes is depicted below:

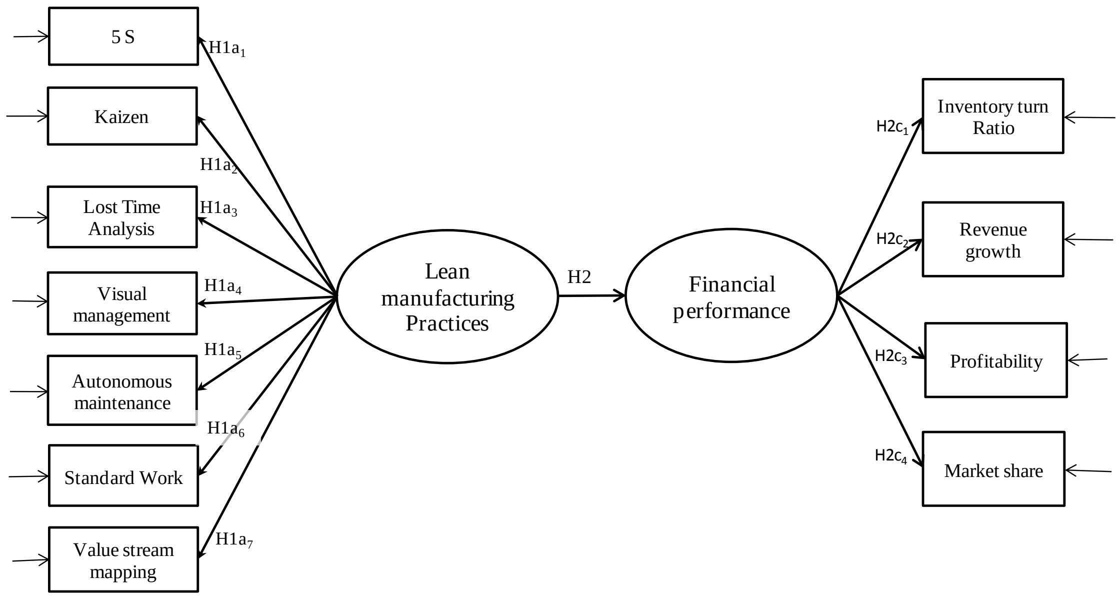


Figure 4.4: Conceptual model for examining relation between lean manufacturing practices and financial performance.

4.4. OPERATIONAL PERFORMANCE AND FINANCIAL PERFORMANCE

First hypothesis (H1) argues about the correlation between lean practices and the operational performance. Second hypothesis (H2) is about verifying the correlation between lean practices in the financial performance. This distinctive set of correlation can be observed between operational performance and financial performance score hence another hypothesis is identified.

Table 4.6: Hypothesis investigating relation between operational performance and financial performance

No.	Null hypothesis (H0)	Alternate hypothesis (Ha)
H3	Operational performance does not have significant impact on financial performance of manufacturing organisations in Indian context.	Operational performance has significant impact on financial performance of manufacturing organisations in Indian context.

It is observed in literature review that lean practices impacts some factors of organisational performance. Some researches revealed impact of lean manufacturing on financial performance. Hence some correlation may exist between operational performance and financial performance. Therefore to validate this argument the following proposition is put forward in Hypothesis (H3). To answer the question of comparing operational performance with financial performance, the following theoretical conceptual model is offered.

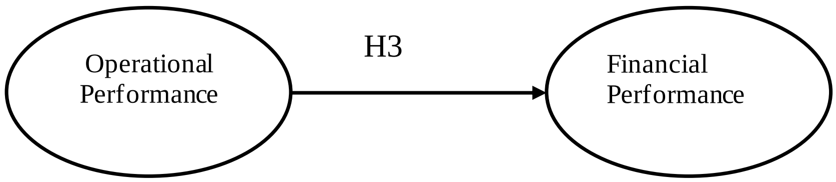


Figure 4.5: Conceptual model of operational performance versus financial performance

There may be a disconnect considering the fact that operational performance may or may not have direct impact on financial performance since it may be affected by additional business environment factors in addition to change in the operational performance. Conceptual model is proposed by making a structured comparison of operational performance and financial performance. Operational performance is measured by measurable parameters viz. productivity, quality, cost, delivery, safety and morale whereas financial performance is measured by measurable parameters viz. Inventory turn ratio, revenue growth, profitability and market share.

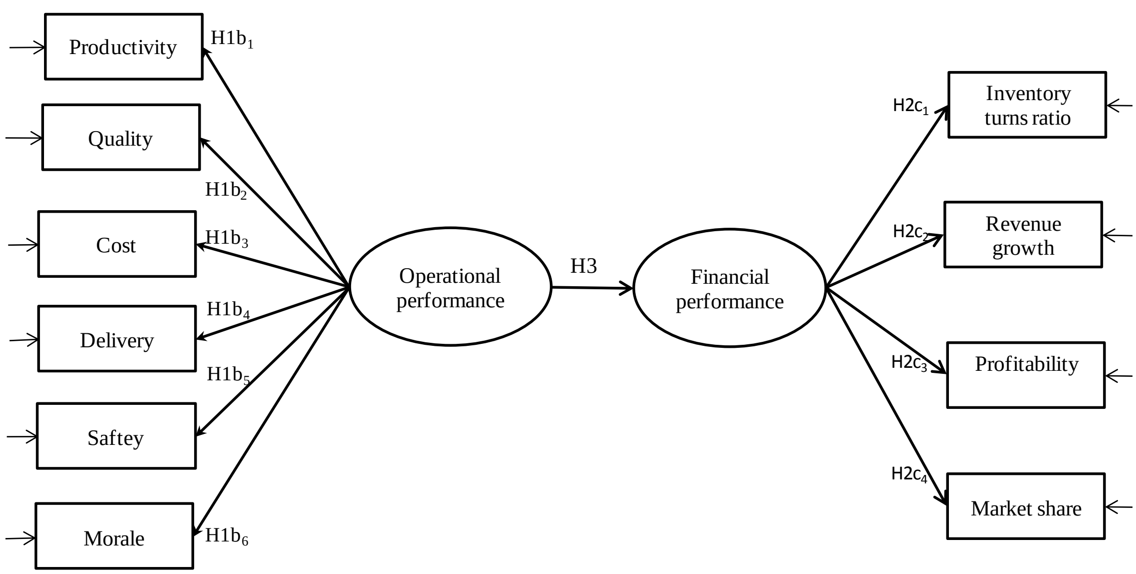


Figure 4.6: Conceptual model for examining relation between operational performance and financial performance.

4.5. INTEGRATING THE LEAN MANUFACTURING PRACTICE WITH ORGANISATIONAL PERFORMANCE

The primary investigation of correlation between lean manufacturing with operational performance, lean manufacturing with financial performance and operational performance with financial performance may be integrated to form the proposed model for the research. Going forward this model may further elaborate for observing the relevant data from the domain of research. Figure 4.7 depicts the basic structure of research model with the propositions discussed.

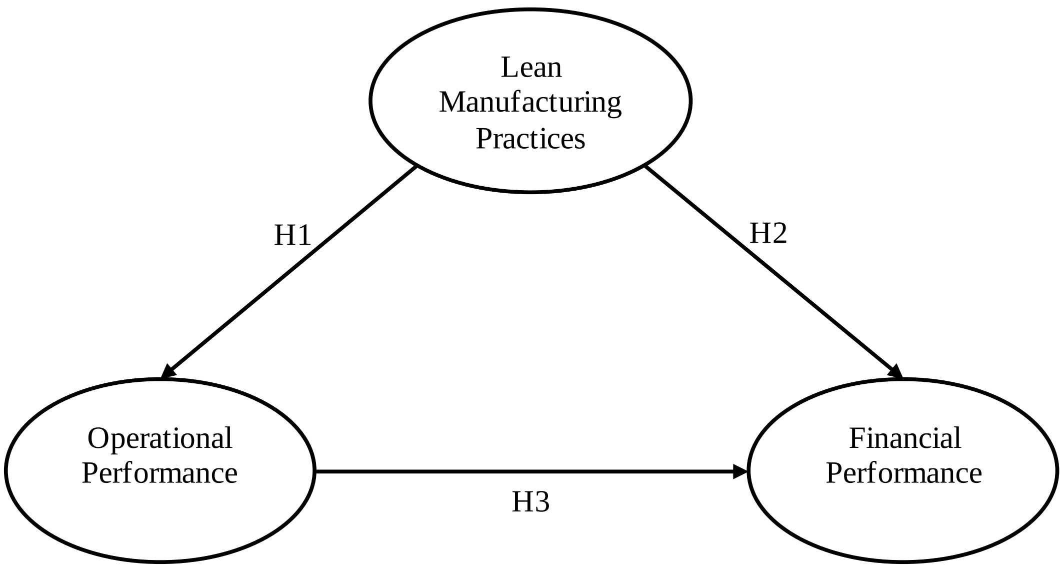


Figure 4.7: Conceptual model of lean manufacturing practices, operational performance and financial performance

4.6. DESIGN OF RESEARCH METHODOLOGY

As discussed earlier, the research methodology is based on extensive literature review, exploratory survey and gathering data with survey with appropriate questionnaire. The research methodology is based on guidelines set by researchers (Anderson and Gerbing, 1988; Churchill Jr, 1979; Rai et al., 2006; Vokurka and O'Leary-Kelly, 2000). Detailed flow chart and step of research methodology are depicted in figure 4.8.

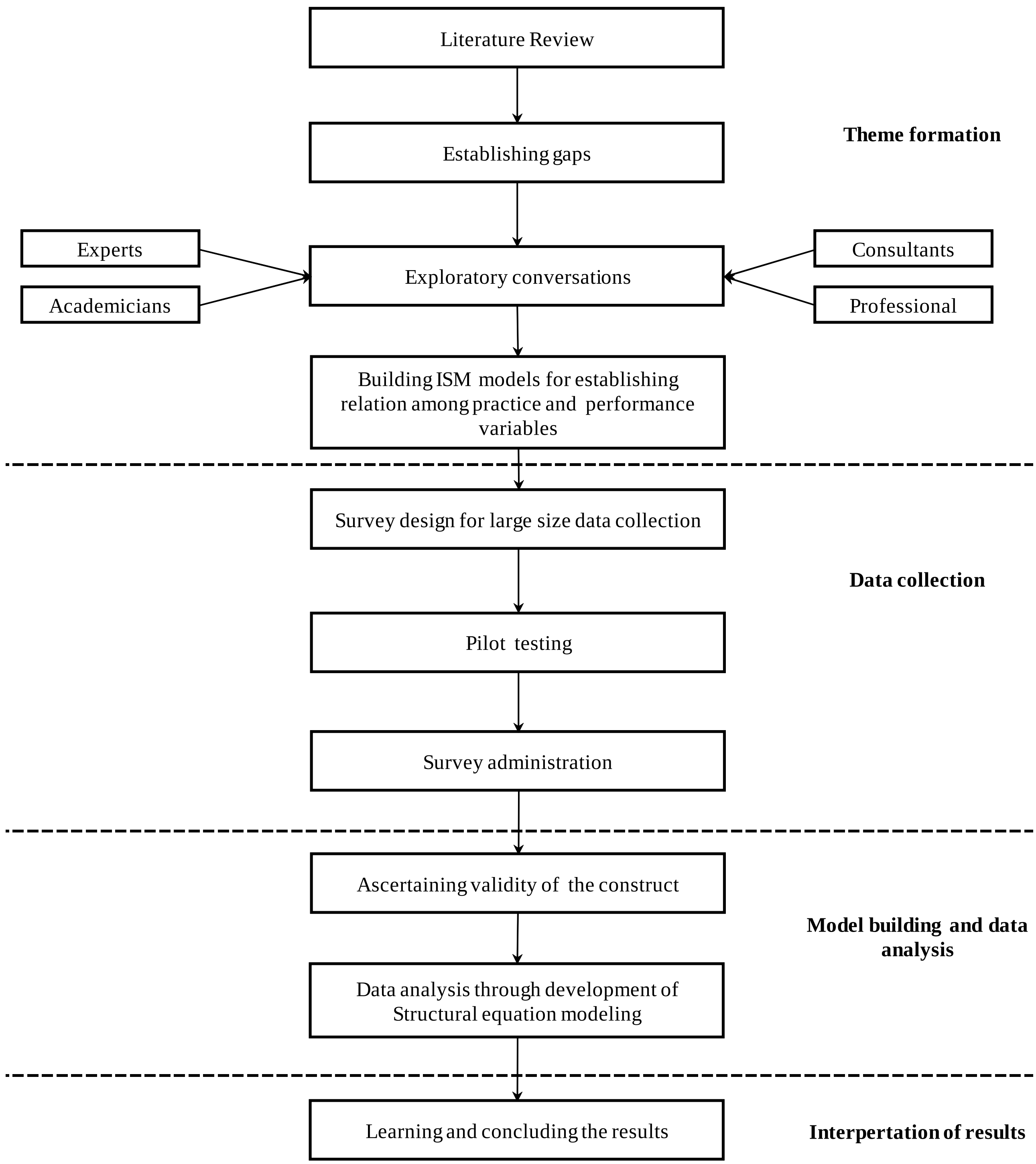


Figure 4.8: An overview of research methodology used for modeling to determine the impact of lean manufacturing on organisational performance.

4.6.1. Exploratory Conversation

Though literature review is fundamental element of research but it may not cover all aspects of the subject under investigation hence exploratory conversation gains importance (Forza, 2002). Coming across the gaps in the theoretical model development and research it was intended that exploratory conversation with professional and experts may be the best way to present the status of lean manufacturing implementation in Indian industry and to assess its impact on organisational performance after implementation of lean manufacturing practices. Based on the guidelines of Parsuraman et al. (1988),Gerbing and Anderson (1998), Seth (2006) on deriving the relevant factors list on the subject , the relevant factors from the literature were discussed with four lean consultants, eight lean practitioners from different levels and different organisations and four academicians. The exercise involved in-depth discussion on the subject and conducted for the following intention:

- Understand the importance of lean manufacturing implementation in Indian manufacturing industry.
- Creating inventory of all elements of lean manufacturing and then filter out the lean elements which are synonymous and can be grouped together to achieve a final and unique lean manufacturing elements list.
- Allocate the various lean elements under the lean enabler head used by researchers and practitioners.
- Finalize the list of most relevant performance parameters to measure the organisational performance.

The outcome of the exploratory interview is the followings:

- It was observed that all the twenty nine lean manufacturing elements were distributed under seven lean manufacturing enablers used to measure the level of lean manufacturing implementation. No lean manufacturing element was left out ensuring measurement of lean implementation from every aspect.
- Organisational performance was considered to be measured in two aspects viz. operational performance and financial performance.

- Six measures of operational performance measurement were concluded which are directly related to efficiency of manufacturing operations.
- Four measures of financial performance measurement were concluded covering purely business results.
- The initial questions were finalized to be asked during survey data collection related to each factors for measuring the status considering the relevance of item and the length of question paper.

4.6.2. Establishing relation among practice and Performance variables through Interpretive Structural Modeling

The intention of this study is to observe the impact of lean manufacturing implementation on organizational performance in the context of Indian industry. Hence one of the vital parts of this research is to observe the relationships among factors responsible for implementation of lean manufacturing and same for the factors responsible for measuring the organizational performance. The correlation and rank of each factor of lean practices and correlation and rank of the factors of organisational performance is planned to be identified using Interpretive Structural Modeling (ISM) technique while the survey based research is used to estimate the impact of lean manufacturing on organisational performance using Structural Equation Modeling (SEM) in the context of Indian industries

4.6.3. Survey Design

Design of survey covers all actions related to data collection such as sampling and questionnaire development. Sampling is vital in survey research it includes clear understanding of the subject, population, sample and sampling plan (Forza, 2002). Sample refers to the subset of population and sampling plan refers to the process of selecting the number of elements from the population so that the correct and adequate representation of characteristic of the population can be gathered for study (Forza, 2002). Subject refers to the lean manufacturing and organisational performance in this study and population refers the entire group of respondents, industries, demography from where researcher wants to collect the data. In many cases respondent do not wish to disclose the identity of themselves and their organisation on some or many questions so general question related to respondent's profile and organization's profile were kept optional.

4.6.4. Building the Measurement Model for the Study and Arrangement of Variables.

i) Measurement model for measuring the lean manufacturing practices

As discussed in the previous section lean manufacturing practice consists of seven enablers i.e. 5S, kaizen, lost time analysis, visual management, autonomous maintenance, standard work and value stream mapping. To measure the lean manufacturing practice in the Indian manufacturing industry it is necessary to gauge the level of implementation of each enabler or factor of lean manufacturing practices. The figure 4.9 depicts the measurement model of lean manufacturing practices as latent factors and lean enablers as measurable factors.

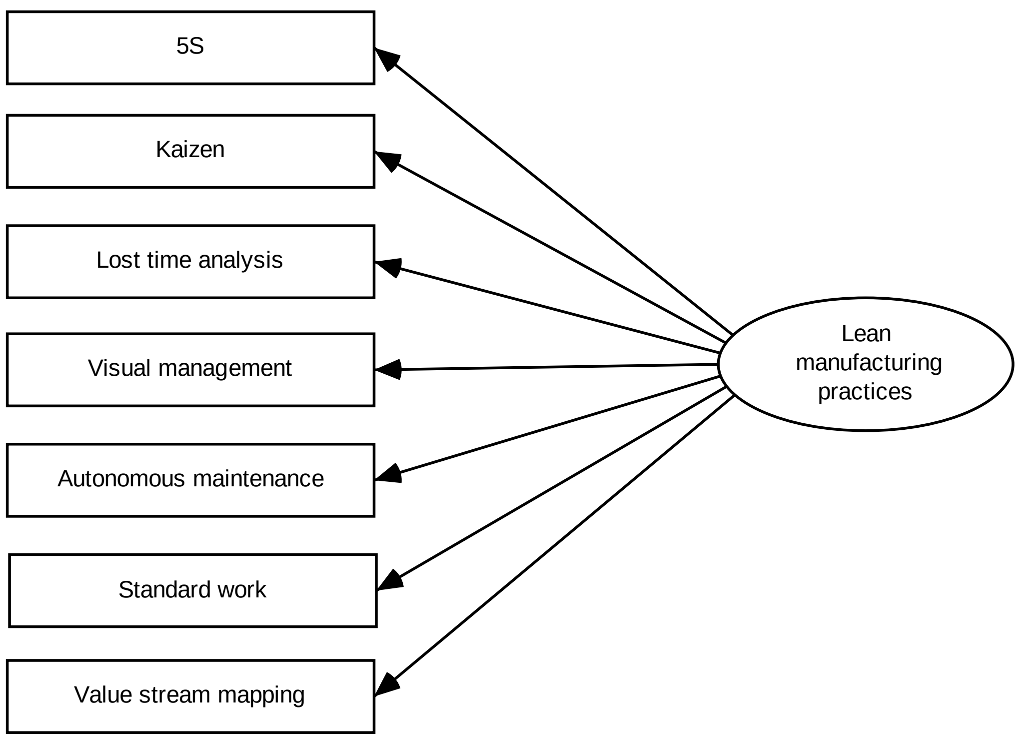


Figure 4.9: A Model of lean manufacturing practices

ii) Measurement Model for Measuring the Operational Performance

As discussed in the previous section; operational performances consists of six performance measurements i.e. productivity, quality, cost, delivery, safety and morale. To determine the operational performances of the Indian manufacturing industry it is necessary to measure the level of each operational performances factor. The figure 4.10 depicts the measurement model of operational performances as latent factor measured by six measurable operational performances factors i.e. productivity, quality, cost, delivery, safety and morale.

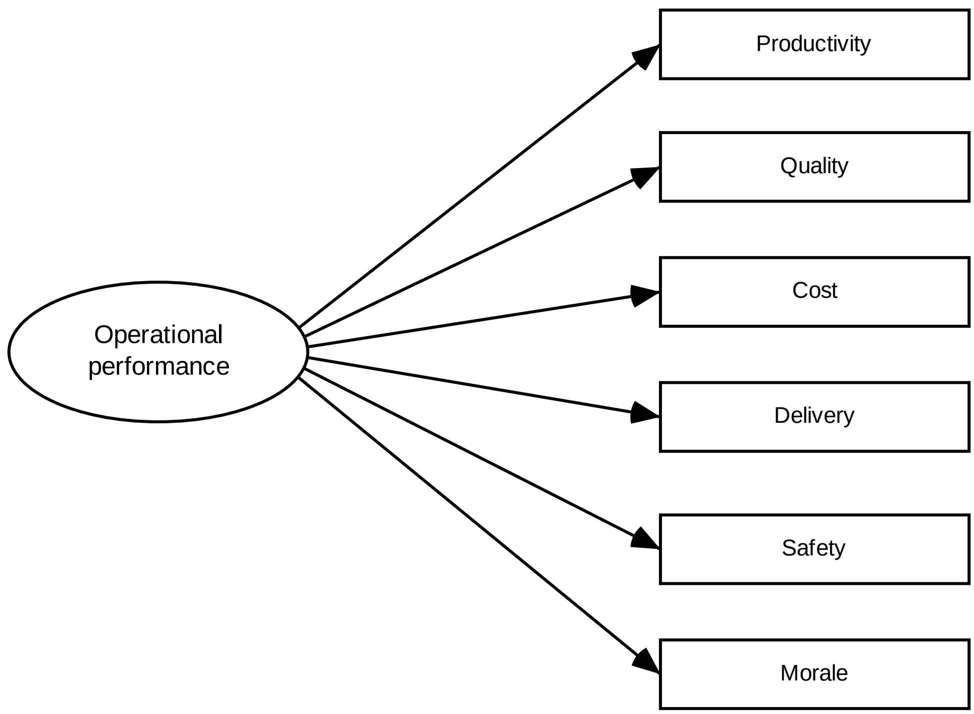


Figure 4.10: Organisational performance model

iii) Measurement Model for Measuring the Financial Performance

As discussed in the previous section; financial performance consists of four performance measurements i.e. inventor turns ratio, revenue growth, profitability and market share. To determine the financial performances of the Indian manufacturing industry it is necessary to measure the level of each financial performances factor. The figure 4.11 depicts the measurement model of financial performances as latent factor measured by four measurable financial performances factors i.e. inventor turns ratio, revenue growth, profitability and market share.

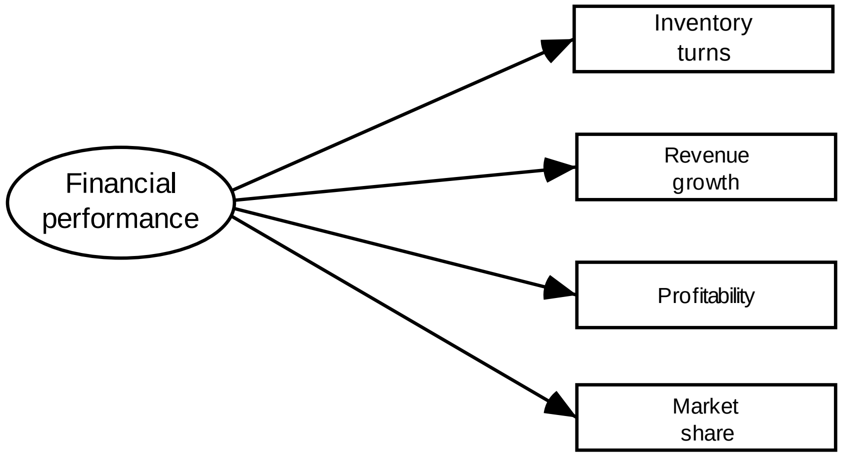


Figure 4.11: Financial performance model

4.6.5. Development of Questionnaire, Content and Design

A questionnaire was developed with the most relevant items to the subject which are easy to understand. Misinterpretation of the question may lead to unreliable and irrelevant response. To make sure the simplicity of questionnaire, the language in questions were kept to the understanding level of the respondents. Closed ended questions were asked to choose from five alternatives from one to five on Likert scale keeping in mind that closed ended questions with limited alternatives to respondent are quick to answer and easy to code the gathered information (Saunders et al, 2005).

Further factors of lean manufacturing practices cannot be measured directly so the measurement of each factor can be performed with determining the level of implementation of some elements related to each factor contributing to measure of lean manufacturing practice implementation. After consultation with the professional and academia few relevant questions were prepared which represents true picture of the factors or enablers of lean manufacturing. Here 5S was implicit to be measured with three questions, and same way kaizen with three, lost time analysis with four questions, visual management with four questions, autonomous maintenance with four questions, standard work with four questions and value stream mapping with five questions. Following construct model is employed to measure the full implementation of lean manufacturing practices.

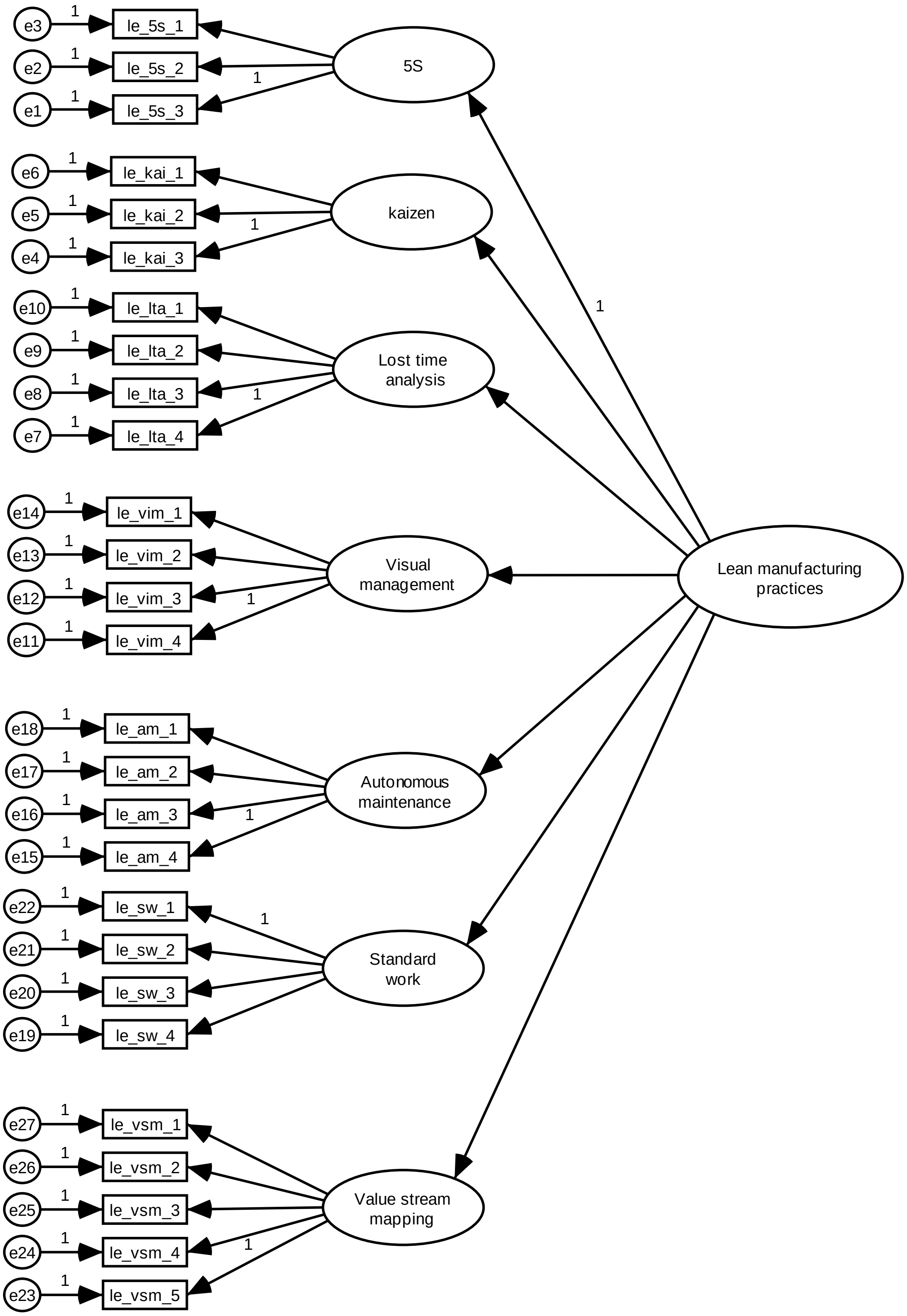


Figure 4.12: Conceptual Model of lean manufacturing practices with associated items or questions

The lean manufacturing practice originally represented by 27 questions or items hypothesized to be grouped into seven dimension or factors or enablers. The lean enablers as factors and question as items are depicted in table below.

Table 4.7: Lean manufacturing Factors -- item wise

Factors	Item name	Item label
5 S	le_5s_ 1	5S training is delivered to each employee
	le_5s_ 2	5S is practiced throughout the plant.
	le_5s_ 3	5S is monitored periodically and improvement actions are initiated
Kaizen	le_kai_1	Suggestion scheme is in place and working.
	le_kai_2	Kaizen process is practiced by shop floor person.
	le_kai_3	Kaizen meeting is held periodically
Lost Time Analysis	le_lta_1	Lost time is monitored on bottle neck machines
	le_lta_2	Lost time data is analyzed and actions are initiated
	le_lta_3	Setup time reduction is practiced on machine.
	le_lta_4	Periodical review of bottleneck process or equipment is in place
Visual management	le_vim_1	Equipments are identified with sinages
	le_vim_2	Process parameters are displayed on shop floor
	le_vim_3	Andons are connected to equipments interventions
	le_vim_4	Manufacturing performance is displayed on shop floor
Autonomous maintenance	le_atm_1	Operators are involved in improving equipment conditions.
	le_atm_2	Equipment operational efficiency improvement projects are undertaken by shop floor person
	le_atm_3	Shop floor teams works for basic condition improvement of machines.
	le_atm_4	There is a chase for reduction of cycle time
Standard Work	le_stw_1	Cell balancing is evaluated periodically and actions are initiated
	le_stw_2	Standardized work instructions are available on work centers
	le_stw_3	Work sequence and content are same even the operator changes
	le_stw_4	Cellular manufacturing concept is employed in equipment lay-outing.
Value stream mapping	le_vsm_1	Rate of production is controlled by customer requirement.
	le_vsm_2	Cycle time and operating efficiency is monitored periodically
	le_vsm_3	Value stream mapping is performed periodically
	le_vsm_4	FIFO is followed between production stations where ever designated.
	le_vsm_5	Production lot formation is controlled by Heijunka system.

Factors of operational performances cannot be measured directly so the measurement of each factor can be performed with determining the level of performances of some elements related to each factor contributing to measure of operational performances. After consultation with the professional and academia few relevant questions were prepared which represents true picture of the factors operational performances. In this study productivity was implicit to be measured with four items or questions, and same way quality with five, cost with four questions, delivery with four questions, safety with three questions, and morale with three questions. Following construct model is employed to measure the operational performances of Indian industry.

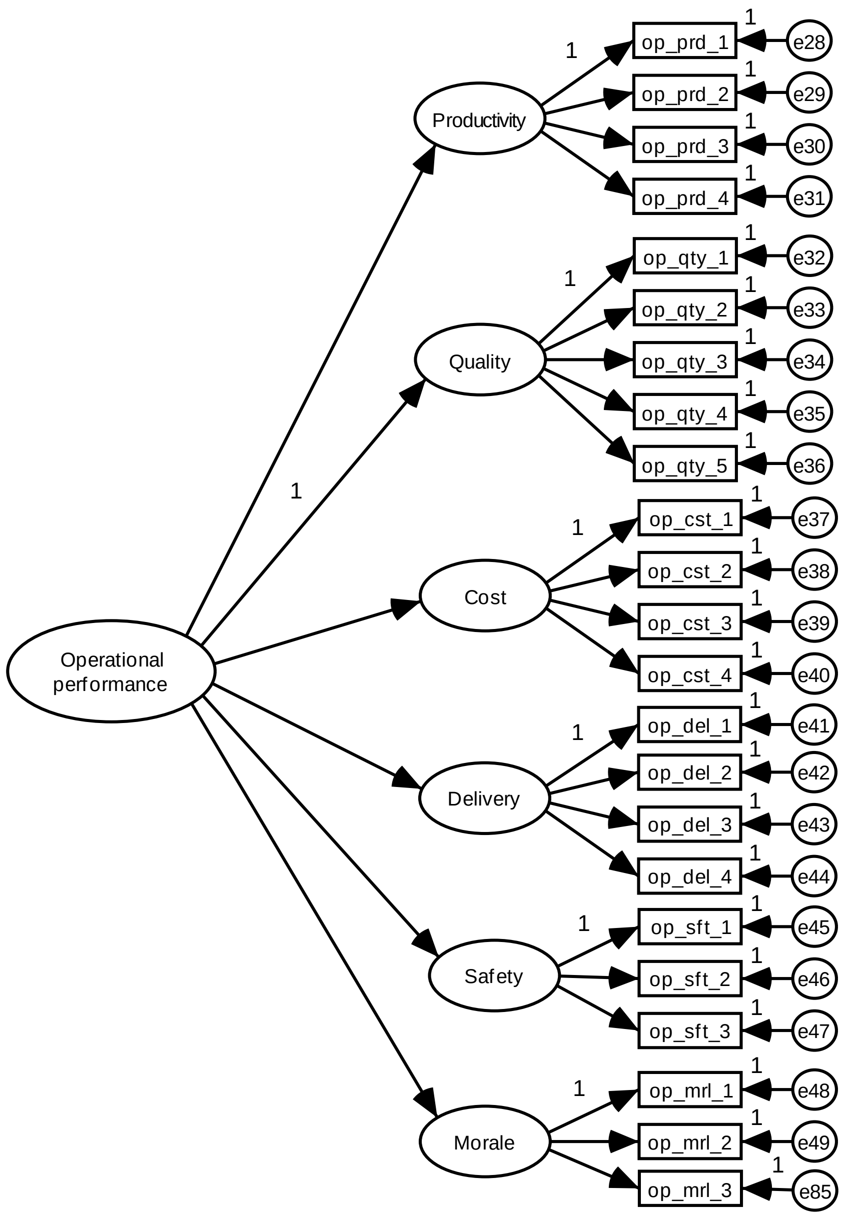


Figure 4.13: Conceptual Model of organisational performance with associated items.

The operational performance is represented by 23 questions or items hypothesized to be grouped into six operational performances parameter factors or enablers. The operational performances factors and question as items are depicted in table below.

Table 4.8: Operational performance item wise factors

Operational performance Factors	Item or question name	Item label
Productivity	op_prd 1	Changeover time reduction
	op_prd 2	Increase in productivity
	op_prd 3	Reduction in unplanned breakdown
	op_prd 4	Improvement in OEE
Quality	op_qlt 1	Reduced inspection,
	op_qlt 2	Reduced rework,
	op_qlt 3	Reduced scrap
	op_qlt 4	Reduced numbers of customer complaints
	op_qlt 5	Reduced cost of poor quality (COPQ)
Cost	op_cst 1	Reduction in inventory cost
	op_cst 2	Reduction in distribution expenses
	op_cst 3	Raw material yield improvement
	op_cst 4	Reduction in utility cost
Delivery	op_dly 1	Improved delivery rating of supplier
	op_dly 2	Improved delivery rating to customer
	op_dly 3	Reduced throughput time
	op_dly 4	Improved flexibility
Safety	op_sty 1	Reduced numbers of first aid cases
	op_sty 2	Reduced numbers of accidents
	op_sty 3	Improved actions on safety improvement
Morale	op_mrl 1	Improved core competencies of employee
	op_mrl 2	Increase in no. of Kaizens per head
	op_mrl 3	Employees participation in trainings

Factors of financial performances cannot be measured directly so the measurement of each factor can be performed with determining the level of performances of some elements related to each factor contributing to measure of financial performances. After consultation with the professional and academia few relevant questions were prepared which represents true picture of the factors financial performances.

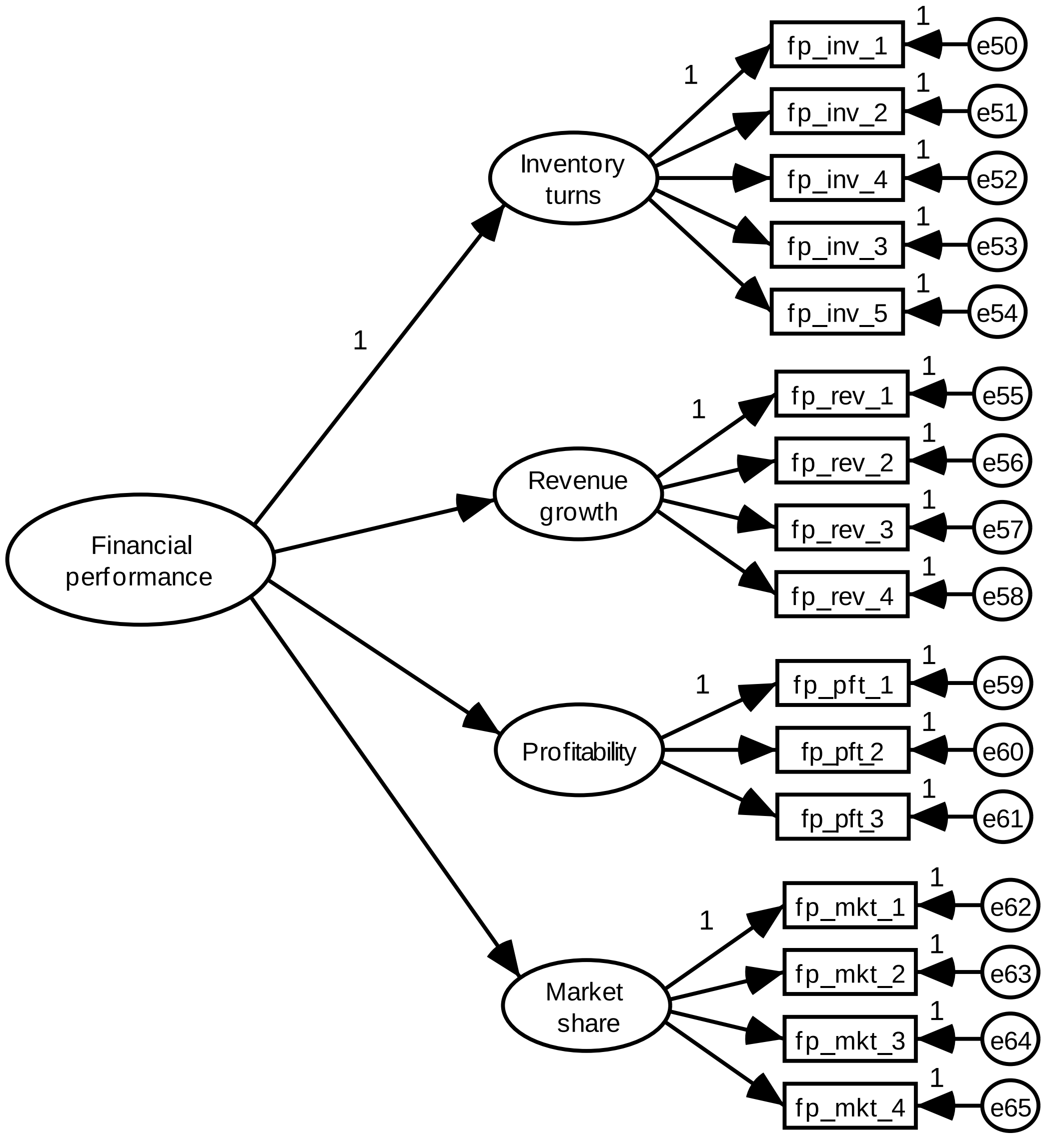


Figure 4.14: Conceptual Model of Financial performance with associated items.

In this study inventory turns implicit to be measured with five items or questions, and in the same way revenue growth with four, profitability with three questions, market share with four questions. Following construct model is employed to measure the financial performance of Indian industry.

The financial performance is represented by 16 questions or items hypothesized to be grouped into four financial performances parameter factors. The financial performances factors and question as items are depicted in table below.

Table 4.9: Financial performance item wise factors

Factors of financial performance	Item name	Item label
Inventory turns	fp_inv 1	Inventory analysis is performed periodically
	fp_inv 2	Product follows unidirectional flow while manufacturing.
	fp_inv 3	Production order is generated by next station through pull system.
	fp_inv 4	Inventory turns is improving year over year
	fp_inv 5	Overall reduction in inventory cost year over year
Revenue growth	fp_rev 1	Increase in revenue per customer
	fp_rev 2	Increase in revenue year over year
	fp_rev 3	Increase in product price with value addition
	fp_rev 4	Addition of revenue source i. e. consultancy, royalty income etc
Profitability	fp_pft 1	Increase in profitability of plant
	fp_pft 2	Return on working asset (ROWA)
	fp_pft 3	Improved cash flow
Market share	fp_msa 1	Existing customer are retained
	fp_msa 2	Increase in demand from customers
	fp_msa 3	Increase in share of business per customer
	fp_msa 4	Added new customers

Keeping all the guidelines into consideration and inputs from exploratory interviews, a questionnaire was developed to measure the status of lean manufacturing implementation and organisational performance. The questionnaire contained five questions related to respondent viz. respondent's name, designation, department, total experience and service length with current industry. Seven questions were kept related to the organisation containing name of the organisation, nature of business, product, demographic location number of employees in the plant and annual turnover. Total 27 questions were asked regarding status of lean manufacturing implementation, 23 questions regarding operational performance and 16 question regarding financial results. (Refer table 4.10)

Table 4.10: Table showing the initial list of identified items for various factors

Key measures		Subject or factor	Initial numbers of items finalized to measure the identified factors
General information		Respondent's profile	5
		Company's profile	7
Lean manufacturing practices		5 S	3
		Kaizen	3
		Lost Time Analysis	4
		Visual management	4
		Autonomous maintenance	4
		Standard Work	4
		Value stream mapping	5
Organisational performance	Operational performance	Productivity	4
		Quality	5
		Cost	4
		Delivery	4
		Safety	3
		Morale	3
	Financial performance	Inventory turns	5
		Revenue growth	4
		Profitability	3
		Market share	4

4.6.6. Pilot Testing

The pre- test of the designed questionnaire was considered to be essential; hence limited numbers of respondents were selected from various levels of job responsibility and different industry type for validating the suitability of questionnaire. The designed questionnaire was circulated to industry professionals, academicians, consultant to validate the relevance. Suggestions were incorporated to the questionnaire. After modification of questionnaire, first test sample was collected in person from five academicians, four consultants and 21 professionals from the industry at all levels. The final questionnaire was used for gathering the data for study.

4.6.7. Survey Administration

Survey administration consists of mode of collecting the data, target companies and respondents, timings of the information gathering in case of in person data collection. For getting responses from many high level professionals, prior appointments were managed to describe the questionnaire content, purpose of information gathering, assurance for non disclosure of information other than research purpose and keeping confidentiality where ever asked by respondents. In some cases permission was taken from the authorities to gather the data from executives working in the plant. In most of the cases interviewer was sitting next to respondent and supporting him in filling the responses. It also helped the interviewer to cross check that all the questions has been answered and if there are some unanswered items, respondent was requested to complete the responses which increased the success rate of complete responses. In many cases respondents could not answer the responses so questionnaire was left with him and later it was collected on the scheduled time. A mail questionnaire was also circulated to distance plants with a cover note consisting request to answer the questions. The follow up mails were sent after every two weeks to each target respondents where response was pending. Appreciation mail was also sent to each respondent for accomplishing the responses of survey question.

4.6.8. Ascertaining Validity of the Model

The objective of construct validity is to confirm the reliability and validity of the model. Validity of the construct represents the goodness of the model. Reliability analysis evaluates the consistency and stability in observations whereas validity is concerned with whether the right factors are being measured or not. In this study cronbach's alfa coefficient alpha is used to ensure the measure of reliability of the collected data. The assessment of validity of the measurement scale was performed based on recommendation from O'Leary-Kelly and Vokurka (1998). The alfa value was calculated using SPSS 10.0.

Exploratory factor analysis (EFA) was used to determine the validity of the model. EFA is a diagnostic approach to abbreviate the cluster of empirical indicators into a lesser set of composite factor with bare minimum loss of information (Hair et al., 2006). The key intention of EFA is to recognize the empirical indicator those are strongly linked to particular latent variables estimated through measured variables. The correlation between the variables is called factor loading. In the study the direct Oblimin rotation analysis was carried out and all the factors were considered as significant to represent the latent variable under observation.

As the structure of factors is achieved for a set of variables, its conformance is tested via confirmatory factor analysis (CFA). CFA is a multivariate technique to test the pre specified correlation. CFA gives advantage to researchers of being capable to evaluate the overall adequacy of measurement model. It confirms the model fit to the data using chi-square test. In this study Amos 16.0 was adopted to construct the model and tests the validity of causal relationship. The model was run and on Amos and various fit indices was examined for testing the fitness of the model. In order to achieve the model fitness, content and construct validity are validated theoretically and logically ensuring that survey has covered the domain of the subject of research (Sureshchandar et al., 2002).

4.6.9. Data Analysis through Development of SEM Modeling

In this chapter, three major hypotheses are developed to examine the correlation between lean manufacturing practices and organisational performance. In addition there are seventeen minor hypotheses for validation of the significance level of each factor for the latent variable used for the measurement of lean manufacturing practices, operational performance and financial performance, individually. Lean manufacturing practices are evaluated based on the level of their implementation within the organisations. Organisational performance is measured through the gain in terms of operational and financial performance improvement after implementation of lean manufacturing. As discussed in previous section lean practices are measured by lean manufacturing measurement model with seven factors, operational performance is measured by operational performance measurement model using six factors and financial performance is measured by financial performance measurement model using four factors. All three measurement models are connected together to form a structural equation model for representing the three main hypothesis i.e. H1, H2 and H3. Below is the depiction of structural equation model to measure the impact of lean manufacturing on organisational performance of Indian industry.

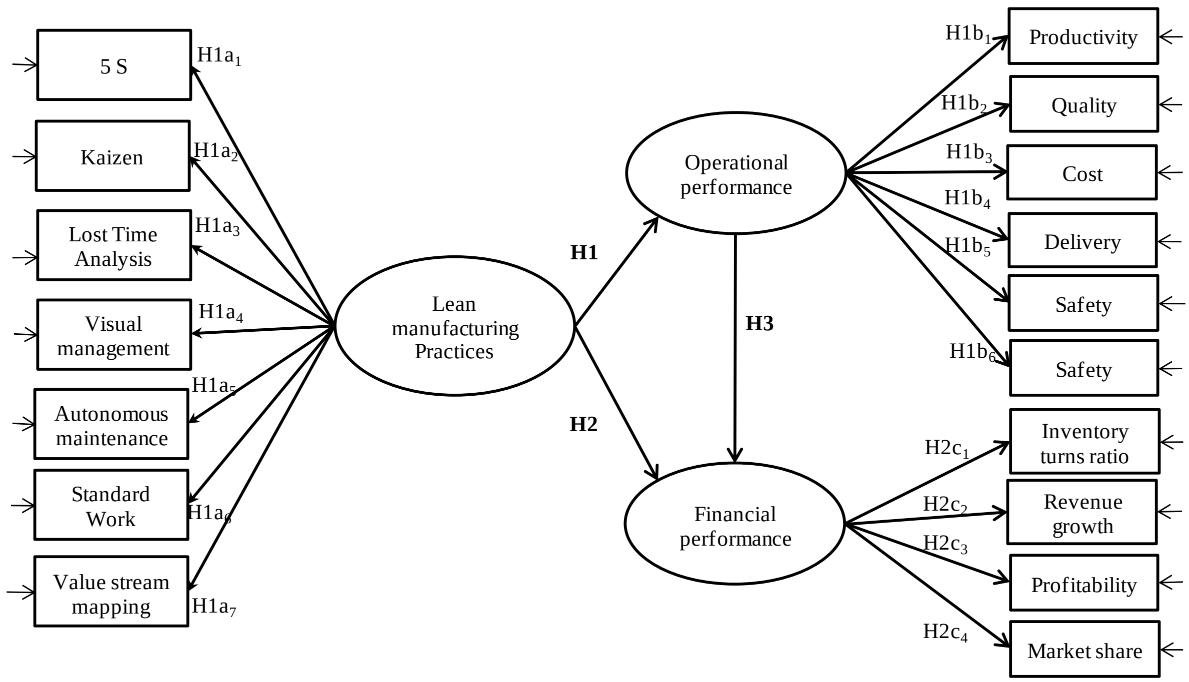


Figure 4.15: Conceptual model for examining relation between lean manufacturing practice, operational performance and financial performance.

The two major hypotheses pertaining to lean manufacturing practices implementation are framed to be associated positively with operational and financial performance (H1, H2). The third hypothesis was developed stating that operational performance should be positively associated with organisational performance (H3).

4.6.10. Learning and Concluding the Results

The insight and learning gained from model to present the impact of lean manufacturing on organisational performance of Indian industry is consolidated and presented. The testing of structural equation model is performed to validate the authenticity of the developed structural equation model. Association index of each factor with latent variable and among the latent variables is computed and presented.

4.7. CHAPTER SUMMARY

The research methodology is discussed in this chapter. The research process adopted is a rich combination of literature review followed by exploratory interview with academicians and practitioners. Starting from establishing the factors for each construct, development of questionnaire, validation testing and up to final analysis, various tools have been used to elaborate and justify the research steps. The adopted survey research has followed the established research guidelines. The research methodology is discussed and identified based on extensive literature review, exploratory discussions and gathering data from researchers and practitioners.

In this chapter three major propositions have been identified with respect to the relationship between lean manufacturing practices and organisational performance. Organisational performance is represented by two aspects i.e. operational and financial performance. The measurement models are developed for each latent variable with the identification of relevant items or questions for measurement of each variables viz. lean manufacturing practices, operational performance and financial performance. Two propositions are laid to measure the impact of lean manufacturing on operational and financial performance individually and an additional proposition was identified to measure the impact of operational performance on financial performance. Seventeen minor propositions are additionally identified to measure the correlation between each factor with the related latent variable. Finally a structural equation model is developed to examine the relation among all the latent and measured variables identified to measure the surrogate variables viz. lean manufacturing practice implementation, operational and financial performance. Comprehensive investigation of the data together with the significance of the model is covered in following chapters.

CHAPTER V

DEVELOPMENT OF MODELS FOR ANALYSING THE IMPACT OF LEAN MANUFACTURING PRACTICES

5.1 INTRODUCTION

The purpose of this research is to examine the impact of lean manufacturing implementation on organizational performance in the context of Indian industry. The first and foremost part of this study comes out to examine the relationships between perceived lean manufacturing implementation and organizational performance factors. Successful transformational change in the performance of the organisation is often after implementation of lean manufacturing practices; however results may vary from one organisation to other organisation. Although one of the change points may be organization's ability to understand the most influencing parameters of the lean practices; similarly the performance factors which are highly and positively being affected by lean manufacturing practices. If the driving factors of lean and driven factors of performance are known to the practitioners, there can be a significant turnaround in the organisational performance by focusing the efforts on the vital parameters. So it becomes imperative to identify the rank of each factor of lean manufacturing practices and in a similar way the rank of each factor of performance parameters based on their driving power and dependence power. In this chapter initially, lean practice and performance parameters are individually observed for their inter-relationship and ranks in terms of their driving power and dependence power using Interpretive Structural Modeling (ISM) technique. Then, a survey based research is applied to the lean practice-performance model using Structural Equation Modeling (SEM) technique to estimate the impact of lean manufacturing on organisational performance on Indian industries.

5.2 INTERPRETIVE STRUCTURAL MODELING (ISM) FOR LEAN PRACTICES AND ORGANISATIONAL PERFROMANCE PARAMETERS

All lean practice factors recognized in previous section are considered for Interpretive Structural Models to develop reachability matrix to assign the rank to the lean manufacturing practice parameters and performance parameters. ISM technique is adopted for development of the model to examine the relationships among the variables which influence the system under study. Here ISM approach is employed for analyzing the correlation between various lean practices factors in section (5.2.1) and for operational performance in the section (5.2.2) in the context of Indian industries. It helps in assigning the rank for the practice and performance variables in the order with which order they affects the entire structure.

5.2.1 ISM Model for Lean Manufacturing Practices

The objective of ISM is to make a decision about if variables are interconnected or not. If yes then is to know through ISM that how they are connected with each other. The decision in relation to their present correlation is taken by a team having detailed understanding about the system under study. This includes discussion of ISM method and MICMAC analysis. The following are the steps involved for implementing the ISM approach:

5.2.1.1 Step i: Recognition of Lean Manufacturing Practice Parameters

Primary step in using ISM is to recognize the variables. For this study various practice parameters of lean are considered as variables in the lean environment within the Indian industry.

Following seven enablers of lean manufacturing practice parameters identified in preceding section are selected as practice variables of lean manufacturing.

1. Lost time analysis,
2. Kaizen,
3. 5 S,
4. Visual management,
5. Autonomous maintenance,
6. Standard work and
7. Value stream mapping

5.2.1.2 Step ii: Development of Structural Self-Interaction Matrix

Initial relationship among the lean practice factors is studied with the construction of Structural Self-Interaction Matrix (SSIM). For various lean practice parameters; the pair-wise relationship among the variables is represented in SSIM. Four symbols are employed to indicate the correlation among the lean practice and performance parameters in the following order:

V – Variable i affect Variable j.

A – Variable j affects the Variable i.

X - Variable i and j affects each other.

O - Variable s i and j are not related.

Table 5.1: Structural self-interaction matrix for lean manufacturing practice factors

S. No.	Lean practice factors	1	2	3	4	5	6	7
1	Lost Time Analysis	1	V	A	O	A	A	A
2	Kaizen		1	X	V	V	O	V
3	5 S			1	V	V	O	O
4	Visual management				1	V	O	V
5	Autonomous maintenance					1	V	V
6	Standard Work						1	X
7	Value stream mapping							1

5.2.1.3 Step iii: Development of Initial Reachability Matrix

The Initial reachability matrix is derived from the Structural self-interaction matrix (SSIM) by replacing the V, A, X and O initials by either “0” or “1” based on following hypothesis:

- If the cell (i, j) has symbol “V”. It is substituted by “1” and the corresponding cell (j, i) is assigned “0” in initial the reachability matrix.
- If the cell (i, j) has symbol “A”. It is substituted by “0” and the corresponding cell (j, i) is assigned “1” in initial the reachability matrix.
- If the cell (i, j) has symbol “X”. It is substituted by “1” and the corresponding cell (j, i) is assigned “1” in initial the reachability matrix.
- If the cell (i, j) has symbol “O”. It is substituted by “0” and the corresponding cell(j, i) is assigned “0” in initial the reachability matrix.

Table 5.2: Initial reachability matrix for lean manufacturing practice factors

S. No.	Lean practice factors	1	2	3	4	5	6	7
1	Lost Time Analysis	1	1	0	0	0	0	0
2	Kaizen	0	1	1	1	1	0	1
3	5 S	1	1	1	1	1	0	0
4	Visual management	0	0	0	1	1	0	1
5	Autonomous maintenance	1	0	0	0	1	1	1
6	Standard Work	1	0	0	0	0	1	1
7	Value stream mapping	1	0	0	0	0	1	1

5.2.1.4 Step iv: Development of final Reachability Matrix

Based on the SSIM; a reachability matrix is formed and it is verified for transitivity. The transitivity made in ISM is a basic assumption about relationship among the different variables of the system. It is based on the assumption that if variable X has relation with variable Y and variable Y has relation with variable Z then variable X has essentially relation with variable Z. Final reachability matrix derived from initial reachability matrix is shown below:

Table 5.3: Final reachability matrix for lean manufacturing practice factors

S. No.	Lean practice factors	1	2	3	4	5	6	7	Driving power
1	Lost Time Analysis	1	1	***1***	***1***	***1***	***1***	***1***	7
2	Kaizen	***1***	1	1	1	1	***1***	1	7
3	5 S	1	1	1	1	1	0	***1***	6
4	Visual management	***1***	0	0	1	1	***1***	1	5
5	Autonomous maintenance	1	0	0	0	1	1	1	4
6	Standard Work	1	0	0	0	0	1	1	3
7	Value stream mapping	1	0	0	0	0	1	1	3
	Dependence power	7	3	3	4	5	6	7	

5.2.1.5 Step v: Level Identification

Final reachability matrix is used for identification of different levels for various lean practice parameters. Reachability set and antecedent set are determined for parameters from the final reachability matrix. The parameters in the matrix affecting the other practice parameters are contained in reachability and antecedent set. Consequently, the intersection is achieved for these sets for every lean practice and performance parameters. High rank lean practice parameters in the hierarchy of ISM model are considered as variables or parameters that are common in the intersection and reachability sets. The high ranked practice parameters do not facilitate supplementary variables to get the level higher than their individual level. The top level of practice parameters are recognized through this method and the same method is repeated in iterative way until level for all the variables is recognized (refer tables5.4 to table 5.6).

Table 5.4: 1st Iteration to estimate the rank of lean practice parameters

S. No.	Reachability set	Antecedent set	Intersection	Level
1	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	**I**
2	1 2 3 4 5 6 7	1 2 3	1 2 3	
3	2 3 4 5 7	1 2 3	2 3	
4	1 4 5 6 7	1 2 3 4	1 4	
5	1 5 6 7	1 2 3 4 5	1 5	
6	1 6 7	1 2 4 5 6 7	1 6 7	**I**
7	1 6 7	1 2 3 4 5 6 7	1 6 7	**I**

Table 5.5: 2nd Iteration to estimate the rank of lean practice parameters

S. No.	Reachability set	Antecedent set	Intersection	Level
2	2 3 4 5	2 3	2 3	
3	2 3 4 5	2 3	2 3	
4	4 5	2 3 4	4	
5	5	2 3 4 5	5	**II**

Table 5.6: 3rd Iteration to estimate the rank of lean practice parameters

S. No.	Reachability set	Antecedent set	Intersection	Level
2	2 3 4	2 3	2 3	**IV**
3	2 3 4	2 3	2 3	**IV**
4	4	2 3 4	4	**III**

5.2.1.6 The MICMAC Analysis

MICMAC analysis is employed for analyzing the driving power and dependence powers for all the lean practice parameters as variables used in ISM modeling. Driving power of a lean practice and performance parameters as a variable is achieved by adding all ones assigned for supplementary variable in the columns beside a variable in a row and dependence power is calculating by adding all ones assigned for supplementary variable in rows assigned for a variable in the column as shown in table 5.3. Lean practice parameters has been categorized for their dependence power and driving power they are categorized into four group as autonomous practice parameters, linkage practice parameters, dependent practice parameters and independent practice parameters. The diagram depicting the dependence power and driving power for lean practice parameters is shown below (figure 5.1).

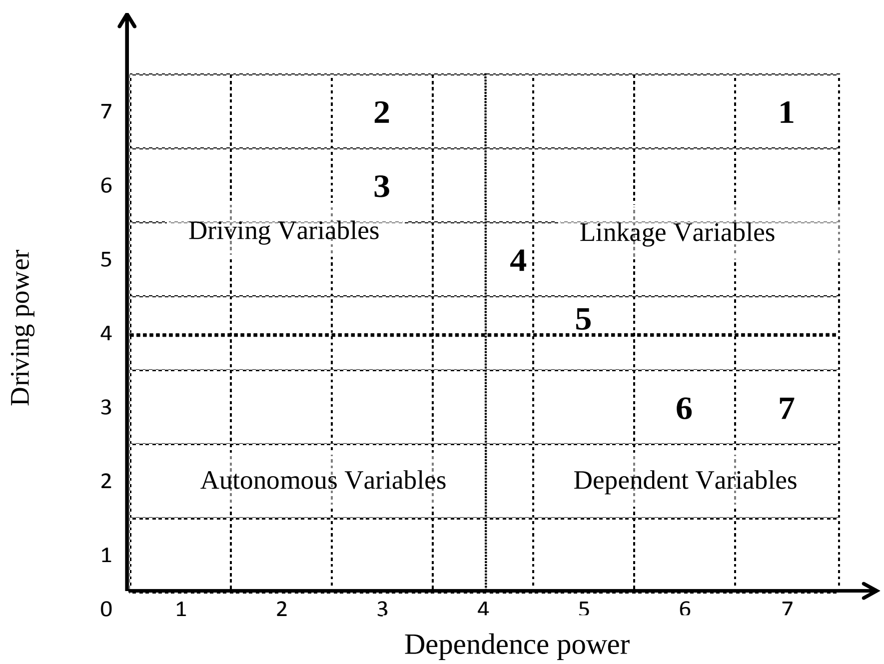


Figure 5.1: MICMAC Diagram for lean practice parameters

In the MICMAC diagram (figure 5.1) lean practice parameters no. 2 and 3 have highest driving power and low dependence power indicating their higher impact on lean manufacturing environment. Lean practice parameters no. 1 has driving power and dependence power to the tune of 7 each being highest in the system hence it is placed at the corresponding cell. Lean practice parameters no 4 and 5 also lies in the same segment with different order. In the same manner all the lean practice parameters are allocated the cells based on their driving power and dependence power. The intention of classification of the lean practice parameters is to examine the dependence power and the driving power of the individual variable. The independent variables as parameters are those parameters that have high driving power but their dependence power is weak. The lean practice parameters with high dependence power but low in driving power are variables no. 6 and variable no. 7 are dependent variable. Autonomous variable of lean practice in this case are those lean practice which has low driving and low dependence power. The autonomous practice parameters remains comparatively disengaged from the organization and they may not have any impact on other parameters. In the studied no lean practice parameters is observed as autonomous variable.

5.2.1.7 The ISM Model for Lean Manufacturing Practice

The ISM model for lean manufacturing practice parameters is constructed based on their levels identified in previous section (5.2.1.5). It is observed that 5s and kaizen and identified as drivers for lean manufacturing practices and has impact on other lean manufacturing practice parameters.

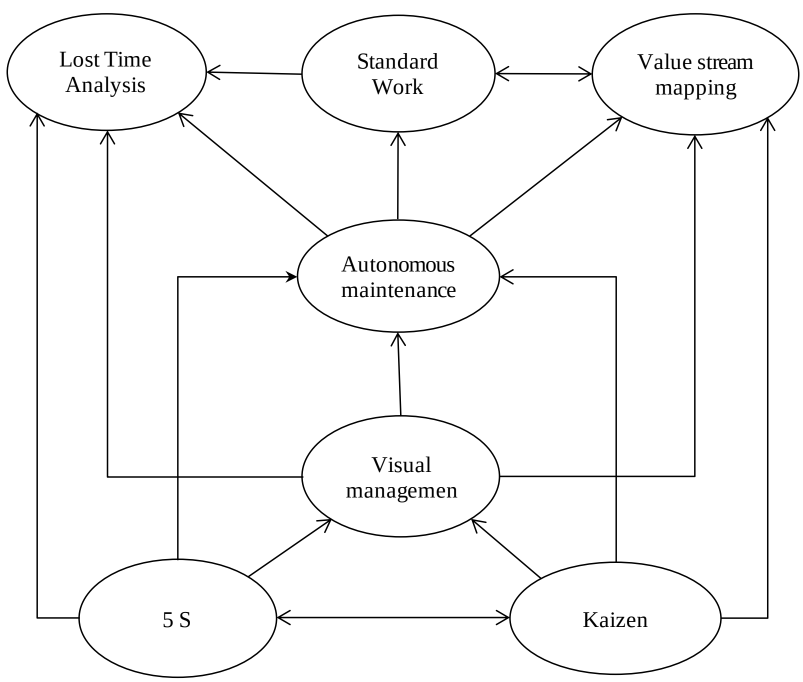


Figure 5.2: Final ISM based model for LM practice parameters

5s and kaizen have direct impact on visual management and autonomous maintenance hence enabling these factors to get implemented. Visual management and autonomous maintenance have been identified as linkage variables as they are affected by 5s and kaizen and they enables lost time analysis, standard work and value stream mapping to get implemented. Within the linkage variables visual management drives autonomous maintenance hence enabling in implementation. Final level of lean practice parameters contains lost time analysis, standard work and value stream mapping indicating their low driving power and high dependence power establishing that these can be implemented after implementing the first level parameters like 5s and kaizen followed by linkage variables as autonomous maintenance and visual management.

5.2.2 ISM Model for Organisational Performance Practices

In this section the organisational performance parameters recognized in previous section are considered for interpretive structural modeling to develop reachability matrix to assign the rank to various performance parameters. As in case of lean manufacturing same way ISM technique is adopted for development of the model for organisational performance parameters.

The objective of ISM is to examine the relationships among the various organisational performance parameters in. The decision in relation to their present correlation and discussion of ISM method and MICMAC analysis is taken by a team having detailed understanding about the organisational performance parameters used in this study. The following are the steps involved for implementing the ISM approach.

5.2.2.1 Step i: Recognition of Organisational Performance Parameters

Primary step in using ISM is to recognize the variables. For this study operational performance and financial performance parameters are considered as variables to represent the organizational performance parameters in the context of Indian industries. Six performance parameters are identified for operational performance and four performance parameters are identified for financial performance are identified in the previous chapter (Chapter no. 4). Following ten organisational performance parameters are selected for construction of ISM model.

Operational performance parameters

1. Productivity
2. Quality
3. Cost
4. Delivery
5. Safety
6. Morale

Financial performance parameters

7. Inventory turns ratio
8. Revenue growth
9. Profitability
10. Market share

Organisational performance parameters (1–10)

As per previous section (5.2.1.2); ISM techniques is applied for obtaining the SSIM for organizational performance parameters.

Table 5.7: Structural self-interaction matrix for organizational performance parameters

S. No.	Performance factors	1	2	3	4	5	6	7	8	9	10
1	Productivity	1	A	V	V	X	X	V	O	O	O
2	Quality		1	V	X	V	A	V	O	O	V
3	Cost			1	X	O	X	V	V	V	V
4	Delivery				1	O	X	V	V	V	V
5	Safety					1	V	O	O	O	O
6	Morale						1	O	V	A	O
7	Profitability							1	X	X	X
8	Revenue growth								1	X	X
9	Inventory turns ratio									1	X
10	Market share										1

5.2.2.2 Step ii: Development of Structural Self-Interaction Matrix

Relationship between the performance parameters is studied with the construction of SSIM matrix. SSIM is constructed for various organisational performance parameters as variables signifying the pair-wise relationship among the variables in the system. Four symbols i.e. V, A, X and O are employed to indicate the correlation among the performance parameters same as in the previous section (5.2.1.2) for lean practice parameters.

Table 5.8: Initial reachability matrix for organizational performance parameters

S. No.	Performance factors	1	2	3	4	5	6	7	8	9	10
1	Productivity	1	0	1	1	1	1	1	0	0	0
2	Quality	1	1	1	1	0	1	1	0	0	1
3	Cost	0	0	1	1	0	1	1	1	1	1
4	Delivery	0	1	1	1	0	1	1	1	1	1
5	Safety	1	0	0	0	1	1	0	0	0	0
6	Morale	1	1	1	1	0	1	0	1	0	0
7	Profitability	0	0	0	0	0	0	1	1	1	1
8	Revenue growth	0	0	0	0	0	0	1	1	1	1
9	Inventory turns ratio	0	0	0	0	0	1	1	1	1	1
10	Market share	0	0	0	0	0	0	1	1	1	1

5.2.2.3 Step iv: Development of Final Reachability Matrix

Based on the developed SSIM a reachability matrix is developed. Reachability matrix is verified for transitivity. The process was followed same as in the previous section (5.2.1.4); it was adopted for lean practice parameters. Final reachability matrix for initial reachability matrix is shown in table below.

Table 5.9: Final reachability matrix for organizational performance parameters

S. No.	Performance factors	1	2	3	4	5	6	7	8	9	10	Driving power
1	Productivity	1	***1***	1	1	1	1	1	***1***	***1***	***1***	10
2	Quality	1	1	1	1	0	***1***	1	***1***	***1***	1	9
3	Cost	0	***1***	1	1	0	1	1	1	1	1	8
4	Delivery	0	1	1	1	0	1	1	1	1	1	8
5	Safety	1	0	0	0	1	1	***1***	***1***	0	0	5
6	Morale	1	1	1	1	0	1	***1***	1	***1***	***1***	9
7	Profitability	0	0	0	0	0	***1***	1	1	1	1	5
8	Revenue growth	0	0	0	0	0	***1***	1	1	1	1	5
9	Inventory turns ratio	0	0	0	0	0	1	1	1	1	1	5
10	Market share	0	0	0	0	0	0	1	1	1	1	4
	Dependence power	4	5	5	5	2	9	10	10	9	9	

5.2.2.4 Step v: Level Identification

Reachability matrix is used for identification of different levels for various operational and financial performance parameters. Reachability set and antecedent set are determined for parameters from the reachability matrix. The parameters in the matrix affecting the other parameters are contained in reachability and antecedent set. Consequently, the intersection is achieved for these sets for every organisational performance parameter.

Table 5.10: 1st Iteration to estimate the rank of performance parameters

S. No.	Reachability set	Antecedent set	Intersection	Level
1	1 2 3 4 5 6 7 8 9 10	1 2 5 6	1 2 5 6	
2	1 2 3 4 5 6 7 8 9 10	1 2 3 4 6	1 2 3 4 6	
3	2 3 4 6 7 8 9 10	1 2 3 4 6	2 3 4 6	
4	2 3 4 6 7 8 9 10	1 2 3 4 6	2 3 4 6	
5	1 5 6 7 8	1 2 5	1 5	
6	1 2 3 4 6 7 8 9 10	1 2 3 4 5 6 7 8 9	1 2 3 4 6 7 8 9	
7	6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	6 7 8 9 10	**I**
8	6 7 8 9 10	1 2 3 4 5 6 7 8 9 10	6 7 8 9 10	**I**
9	6 7 8 9 10	1 2 3 4 6 7 8 9 10	6 7 8 9 10	**I**
10	7 8 9 10	1 2 3 4 6 7 8 9 10	7 8 9 10	**I**

Table 5.11: 2nd Iteration to estimate the rank of performance parameters

S. No.	Reachability set	Antecedent set	Intersection	Level
1	1 2 3 4 5 6	1 2 5 6	1 2 5 6	III
2	1 2 3 4 5 6	1 2 3 4 6	1 2 3 4 6	III
3	2 3 4 6	1 2 3 4 6	2 3 4 6	II
4	2 3 4 6	1 2 3 4 6	2 3 4 6	II
5	1 5 6	1 2 5	1 5	III
6	1 2 3 4 6	1 2 3 4 5 6	1 2 3 4 6	II

5.2.2.5 The MICMAC Analysis

MICMAC analysis is employed in analyzing the driving power and dependence powers for all the performance parameters as variables used in ISM modeling. Driving power of various performance parameters as a variable is achieved by adding all ones assigned for supplementary variable in the columns beside a variable in a row and dependence power is calculating by adding all ones assigned for supplementary variable in rows assigned for a variable in the column as shown in table 5.9. Organisational performance parameters has been categorized for their dependence power and driving power they are categorized into four group as autonomous performance parameters, linkage performance parameters, dependent performance parameters and independent and performance parameters. The diagram depicting the dependence power and driving power for organisational performance parameters is shown in figure 5.3.

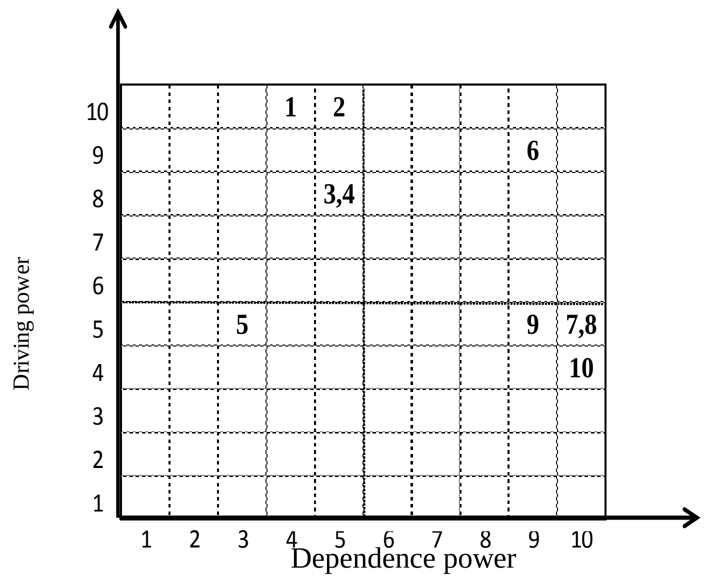


Figure 5.3: MICMAC Diagram for organisational performance parameters

The independent variables are those parameters which have high driving power but their dependence power is weak. Performance parameters no. 1 and 2 has highest driving power and low dependence power indicating their higher impact on other parameters of performance. Parameters no 3 and 4 also lies in the same segment with different order. Performance parameters no. 6 is only linkage parameters with driving power to the tune of 9 and dependence power to the tune of 9 in the system hence it is placed at the corresponding cell. In the same manner all the performance parameters are allocated the cells based on their driving power and dependence power. The parameters with high dependence power but low driving power are dependent parameters which are variable no.7, 8, 9 and 10 as shown in figure 5.3. Autonomous variables are those parameters which have low driving and low dependence power. The autonomous parameters remains comparatively disengaged from the organization and they may not have any impact on other parameters. In this study parameter number 5 is autonomous variable.

5.2.2.6 ISM model of Organisational Performance

ISM model of organisational performance parameters is constructed based on the rank and relationships among the various significant operational and financial performance parameters under the organisational performance in the Indian industries context.

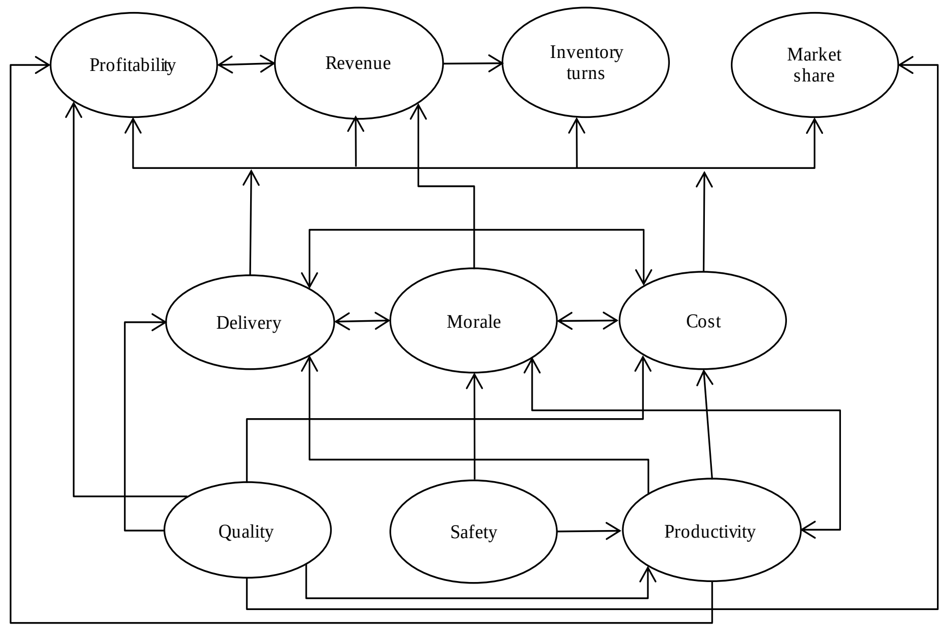


Figure 5.4: Final ISM based model for organisational performance parameters.

This model indicates that quality, productivity and safety are the driving parameters and have significant impact on others performance parameters. They have direct impact on second level parameters i.e. delivery, morale and cost. Profitability, revenue growth, inventory turns ratio and market share are identified as dependent variables as performance parameters indicating that these parameters will probably improve if product delivery, morale of employees and product cost is improved. It is revealed that to achieve improvement in delivery, morale and cost; organisations will have to make sure of the improvement in quality, productivity and safety in the Indian industries context.

5.2.3 Conclusions from the ISM Models of Lean Practice and Organisational Performance

The framework developed using ISM models is based on the opinion of experts about lean practice and organisational performance parameters under study. Successful implementation of lean can be ensured by knowing the ranking of various practice parameters and their rank. It is observed that 5s and kaizen are identified as drivers for lean manufacturing practices where as lost time analysis, standard work and value stream mapping are identified as the dependent parameters of lean manufacturing practices. Linkage variables are visual management and autonomous maintenance. This exercise reveals that India organisations should exercise 5s and kaizen practices at the start and this may enable the dependent enablers i.e. lost time analysis, standard work and value stream mapping to get implemented. In organisational performance parameters, inventory turns ratio, revenue growth, profitability and market share are placed at the at the highest level being an dependent parameters because they have high dependence power and comparably low driving power. These factors may not have impact on other performance parameters but they are dependent on many other performance parameters. Safety is identified an autonomous performance parameter which indicates that it does not support much in achieving top level performance goals directly. Morale has been identified as linkage performance parameters between driving parameters and dependent parameters.

In literature review it was observed that there is a lack of extensive work in establishing the direct and tangible relation among variables of lean manufacturing and organisational performance measurement in the perspective of Indian manufacturing industry. Consequently in next segment of the chapter structural equation modeling (SEM) technique is used to measure the tangible impact of lean manufacturing practice parameters on various organisational performance parameters.

5.3 DEVELOPMENT OF STRUCTURAL EQUATION MODEL FOR MEASURING THE IMPACT OF LEAN MANUFACTURING IMPLEMENTATION ON ORGANISATIONAL PERFORMANCE ON INDIAN INDUSTRY

This section outlines the approach adopted to answer the research problem detailed in literature review chapter. It covers the development and validation of structural equation models to establish and measure the impact of lean manufacturing implementation on organisational performance of Indian industry. It contains three major sections. The first part covers for collecting the empirical data through survey for research. The second section covers the validation of individual measurement model for lean manufacturing practices, operational performance and financial performance models. The third section covers the development of structural equation models in various combinations for measuring the impact of lean manufacturing implementation on organisational performance.

5.3.1 Collection of Data

This phase of the research involved large scale data collection. Survey methodology was used to collect the data from different manufacturing industries across India. The target population was anonymous and their selection was random in nature. The categories of respondents were engineers, managers and higher level designates from manufacturing industries having sufficient experience required for answering the questionnaire. The mode of collecting responses was either email or personal interview. One-to-one interview was extensively used to get higher rate of response, however emails were sent to distant respondents in order to reduce the cost of data collection. In some cases more than one responses were collected from the same manufacturing plant. To maintain rationality among responses, the respondents selected were from different geographical regions encompassing various segments of industries like automotive OEM (Original Equipment Manufacturer), tier-1 and tier-2 suppliers, farm equipments manufacturing, pharmaceutical, fast moving consumer goods and auto parts manufacturing industry. Five point Likert scale was used to answer the response. Total 78 nos. of questions were offered to answer including 27 questions on lean manufacturing implementation, 39 questions on organisational performance results, 12 questions were asked about the profile of the respondent and the industry. Total 271 people were individually contacted for getting their responses, out of which 254 responded appropriately. 252 mails were sent to various plants, only 69 numbers of manufacturing plants answered with complete responses at a comeback rate of 27.3%. The total collected responses were 66 from national capital region, 20 from North region, 73 from Southern region, 57 from Western region, 64 from Central India and 43 from other regions of India. Total 323 responses were collected for the assessment of status of lean implementation its and impact on the organisational performance.

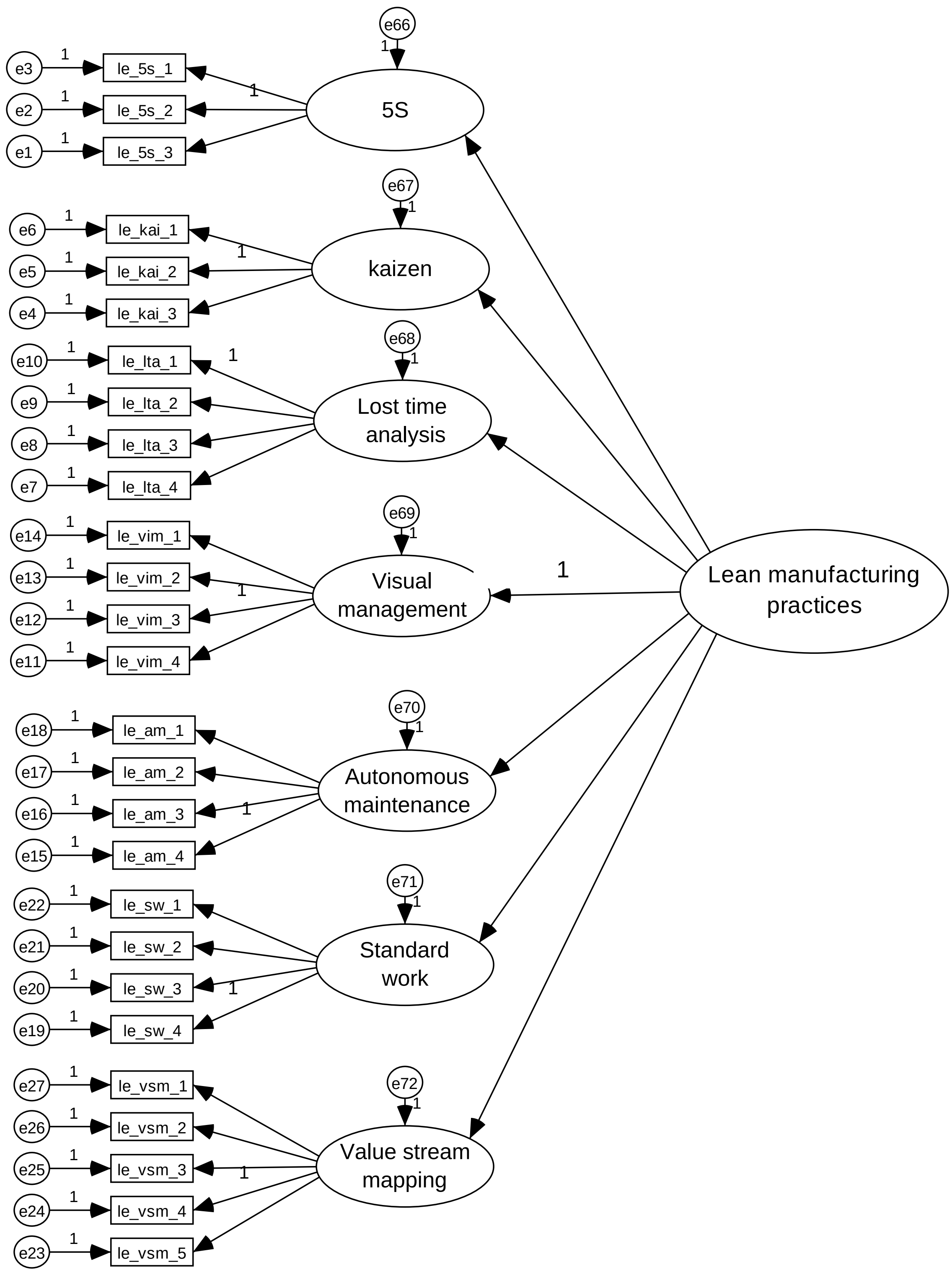


Figure5.5: Measurement model of lean manufacturing practices

5.3.2 Testing the Validity of the Lean Manufacturing Practices Model

The legality of the lean manufacturing practices model was tested with performing the confirmatory factor analysis (CFA) using the AMOS 16.0 software. Confirmatory factor analysis approach is most appropriate for statistically analyzing the validity of entire construct. The measurement variances are also decomposed into its element components. Validity of the constructs refers to whether various measures of the model and the variation and co-variances in the measurement are in compliance with the model fit and that would be tested for validity If the validity is observed as model fit it implies that the variations in the unobservable factor are due to the underlying traits of the item under testing with some random error. If the observed data does not fit the model; it implies that there is a lack of convergent validity within the variables developing discriminate validity concluding that the model represent the inappropriate attributes and cannot be used for further study.

5.3.2.1 Analysis of Lean Manufacturing Practice Data

The data was collected for the measurement of lean manufacturing practice within the Indian industries. This measurement comprised of seven factors and 27 items or questions to be answered by the respondents on 5 point scale Likert scale from 1 to 5 from “no implementation” to “full implementation” based on respondent’s opinion on implementation of lean manufacturing practices. First step is to estimate of reliability of the collected data.

5.3.2.2 Reliability

‘Reliability’ is a measure of consistency among the scales used to measure a latent variable (Shin et al., 2000). Strong correlation among the scales indicates high level of reliability of scales signifying that they are measuring the same latent variable construct (Hair et al., 2006). In this study, statistical analysis is used to ascertain the reliability of the scales. Cronbach’s alpha and factor analysis were used to determine the validity and reliability of the scales for model used in this research. Cronbach’s alpha was used to check the internal consistency of the scales. Any value more than 0.7 or higher is considered as adequate, with 0.6 being acceptable for new scales (Churchill Jr, 1979; Flynn et al., 1990; Nunnally, 1978). Reliability scores are calculated using SPSS software and output is shown in table below.

Table 5.12: Lean manufacturing practices – EFA results –Cronbach's Alpha

Case Processing Summary

		N	%
Cases	Valid	323	100.0
	Excluded[a]	0	.0
	Total	323	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.942	.942	27

The value of cronbach's alpha for factors measuring lean manufacturing practices is obtained as 0.942 which verifies internal consistency confirming the validity of the collected data.

5.3.2.3 Exploratory Factor Analysis

Second step is to assess the appropriateness of the factor analysis by performing exploratory factor analysis (EFA) with the use of Kaiser-Meyer-Olkin measure of sampling adequacy known as KMO and Bartlett's test. The value of KMO above 0.6 is considered as satisfactory for appropriateness of factor analysis (Vokurka and O'Leary-Kelly, 2000). Bartlett's test of sphercity provides the statistical probability that the correlation matrix has significant correlation among at least some of the variables. In data statistics, Bartlett's test is used to test if the data is collected from adequate populations. The Bartlett test can be used to verify the adequacy of the population from data is collected (Snedecor and Cochran, 1989).This test analyzed the variances across the samples (i.e. homoscedasticity or homogeneity). Some statistical tests, for example the analysis of variance, assume that variances are equal across groups or samples. Bartlett's test is sensitive to departures from normality. That is, if the samples come from non-normal distributions, then Bartlett's test may simply be testing for non-normality. The SPSS output for the data is shown in table below.

Table 5.13: Lean manufacturing practices – EFA results –KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.903
Bartlett's Test of Sphericity	Approx. Chi-Square	6.693E3
	df	351
	Sig.	.000

The Kaiser-Meyer-Olkin measure of sampling adequacy test scores is 0.903 which qualifies the requirements and verifies the adequacy of the sampling data. Moreover significance value is also zero against 0.05 as specified ascertains the suitability of the data for further analysis.

Table 5.14: Lean manufacturing practices – EFA results -total variance explained by lean manufacturing enablers as factors.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	10.837	40.136	40.136	10.837	40.136	40.136	5.992
2	2.029	7.515	47.651	2.029	7.515	47.651	6.188
3	1.918	7.103	54.754	1.918	7.103	54.754	5.367
4	1.900	7.038	61.793	1.900	7.038	61.793	6.291
5	1.586	5.874	67.666	1.586	5.874	67.666	5.185
6	1.306	4.836	72.502	1.306	4.836	72.502	5.623
7	1.069	3.960	76.463	1.069	3.960	76.463	5.586
8	.842	3.118	79.581				
9	.601	2.228	81.809				
10	.561	2.079	83.888				
11	.474	1.754	85.642				
12	.403	1.492	87.133				
13	.387	1.432	88.565				
14	.371	1.373	89.938				
15	.345	1.277	91.215				
16	.315	1.167	92.382				
17	.302	1.119	93.502				
18	.262	.970	94.471				
19	.245	.907	95.379				
20	.239	.886	96.265				
21	.203	.752	97.016				
22	.202	.747	97.764				
23	.171	.632	98.395				
24	.153	.566	98.962				
25	.141	.524	99.486				
26	.082	.305	99.790				
27	.057	.210	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

In order to gain more understanding, all the 27 items were subjected to a factor analysis utilizing the Principal Component Analysis (PCA) with Oblimin rotation procedure extracting all the items under the seven factors of lean manufacturing. The objective of this analysis was to sum up the information contained in 27 items in a smaller set of factors that represents the construct for measurement of lean manufacturing practices. In this study we have considered factors of eigen-value more than 1.0. This resulted in the extraction of seven factors explaining 76.463 percent of the total variance which shows that this set of factors explains a reasonable amount of variance which is prominent. Table 5.14 depicts the SPSS output for the items related to lean manufacturing practices.

Table 5.15: Pattern Matrix of lean manufacturing factors – EFA results

Pattern Matrix[a]

	Component						
	1	2	3	4	5	6	7
le_vsm_3	.849						
le_vsm_5	.828						
le_vsm_2	.755						
le_vsm_1	.738						
le_vsm_4	.733						
le_vim_1		.923					
le_vim_3		.892					
le_vim_4		.890					
le_vim_2		.851					
le_5s_1			.938				
le_5s_3			.933				
le_5s_2			.749				
le_am_4				.946			
le_am_2				.919			
le_am_1				.866			
le_am_3				.791			
le_lta_3					.847		
le_lta_1					.825		
le_lta_4					.783		
le_lta_2					.568		
le_sw_2						.940	
le_sw_1						.920	
le_sw_3						.477	
le_sw_4						.432	
le_kai_1							.918
le_kai_3							.702
le_kai_2							.692

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 12 iterations.

Next step of exploratory factor analysis involves the analysis through rotated factor solution using pattern matrix table. The purpose of presenting the items via pattern matrix is to test the item wise loadings and arrangement of the items under the various components or factors under study. The factor loading more than 0.4 is considered significant despite of the sign i.e. positive or negative. In the case under study it was observed that all items are highly related with the factors under which they are measured. Below table depicts the SPSS output of the data analysis.

No random stretch of the same items under more than one factor signifies the articulateness of the data towards factors. Out of 27 items, each factor has loading more than threshold limit of .4 stating a sound explanation for representation of all the seven factors of lean manufacturing practices. Further, component correlation matrix represents the relationship of factor with each other. Higher the value shows better relationship.

Table 5.16: Correlation Matrix of lean manufacturing Factors

Component Correlation Matrix

Co...	1	2	3	4	5	6	7
1	1.000	.350	.312	.374	.323	.355	.365
2	.350	1.000	.351	.383	.318	.352	.363
3	.312	.351	1.000	.333	.287	.355	.409
4	.374	.383	.333	1.000	.327	.396	.369
5	.323	.318	.287	.327	1.000	.344	.395
6	.355	.352	.355	.396	.344	1.000	.388
7	.365	.363	.409	.369	.395	.388	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

In this study, the correlation matrix table containing most of the values are more the threshold of 0.3. One correlation between component 3 and component 5 is 0.287 which is below the limit but may be acceptable for confirmation of data collected for further analysis and hence qualifying for data adequacy.

5.3.2.4 Confirmatory Factor Analysis of Lean Manufacturing Practice Model

The factor structure of the lean manufacturing practices needs to be validated through Confirmatory Factor Analysis (CFA) for the verification of model fit. Model requires to be recognized out of three categories as unidentified, just identified or identified. If a model has degree of freedom less than one it is observed as unidentified and cannot be considered fit for analysis. If a model has degree of freedom equal to one, then it is termed as just identified. In this case it is not adequate to consider such ‘model fit’ satisfactory for analysis. The requirement for identified model is that degree of freedom must be more than one. If the model is recognized as ‘identified’ it is observed fit for further test to verify adequacy of model fit. To perform measurement of model fit it is essential to consider below three important types of model fit i.e. absolute model fit, incremental model fit and parsimonious model fit.

5.3.2.4.1 Absolute Model Fit

Absolute fit is an indicator which determines how well a model fits the sample data (McDonald and Ho, 2002) and provides some direction for the proposed fitment requirement for the model. This measure provides the fundamental indication on how data fits into the proposed theory. Being different of incremental model fit , their estimates does not depends upon comparison with a baseline model but is as an alternative to gauge of how well the model fits in comparison to no model at all (Jöreskog and Sörbom, 1993). This category utilizes the assumption of measuring of chi-squared analysis, RMSEA, GFI, and AGFI. Absolute model fit necessitates following fundamentals condition for a balanced model fit.

i) Chi-square Value and Probability: After model is confirmed for identification (degree of freedom should be more than one for an ‘identified model’) it is required to check measure of chi square test to know how well the various factors are affecting the final output of the model. The chi-square value is the established measure for assessing overall model fit which evaluates the degree of discrepancy among the samples and integral co-variances matrices’ (Hu and Bentler, 1999). The chi-square to degree of freedom statistic is generally an indicator of ‘badness of fit’ (Kline, 2005) or is a lack of fit (Mulaik et al., 1989) as it provides an insignificant result at a threshold of 0.05(McIntosh, 2007). Whilst the test maintains its popularity as a measure of fit value but there is no universal consensus among the researcher about the exact acceptance criteria of the measure though recommendation of range varies from as high as 5.0 (Wheaton et al., 1977) to as low as 2.0(Tabachnick and Fidell, 2007). Computation of degrees of freedom, chi- square test and probability test is performed through Amos 16.0 software and below is the output from amos for lean manufacturing practices construct under analysis.

Table5.17: Lean manufacturing practices –degree of freedom and model identification

Number of distinct sample moments:	378
Number of distinct parameters to be estimated:	70
Degrees of freedom (378 - 70):	308

Table 5.18: Lean manufacturing practices – CFA results – chi-square and probability test

Chi-square	614.360
Degrees of freedom	308
Probability level	.000

In the given model degree of freedom is 308 and Chi-square value is 614.360 which indicates a fit ratio of chi- square to degree of freedom = 614.360 /308= 1.99 against the specified range from 1 to 5. This construct may be considered as a fit for analysis. Second check is probability level which is equal to zero up to three digits against minimum requirement of less than 0.05 validating the significance of the construct.

ii) Root Mean Square Error of Approximation (RMSEA): The second fit measure is the value of RMSEA. It was first developed by (Steiger and Lind, 1980). In recent years it has turn out to be as one of the most informative fit indices for model fitment' because of its sensitivity to the number of estimated parameters used in the model(Diamantopoulos et al., 2000). Cut-off range RMSEA has considerably discussed in the last two decades. It is commonly practice about the RMSEA that the lower limit of zero whereas the upper limit should not be more than 0.08. (MacCallum et al., 1996) recommended the values of RMSEA between the ranges of 0.05 to 0.10 to be as fair-fit and values stating that value above 0.10 signify poor fit. RMSEA value from 0.08 to 0.10 signifies an adequate fit and value mainly below 0.08 indicates a good model fit (MacCallum et al., 1996). Computation of RMSEA is performed through Amos 16.0 software and below is the output.

Table 5.19: Lean manufacturing practices – CFA results – RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.056	.049	.062	.076
Independence model	.241	.236	.246	.000

In this case RMSEA value is 0.056 against the specified limit of 0.08 maximum and is within the specified hence the model is considered fit for further analysis.

iii) Goodness of Fit Index (GFI): The value of GFI generally ranges from 0 to 1 with increasing the value with bigger samples. But if the degrees of freedom remains higher with increased to sample size, the GFI value decreases (Sharma et al., 2005). Besides this, it is also observed that the GFI increases as the number of parameters increases (MacCallum and Hong, 1997) as well as with large samples (Bollen, 1990; Shevlin and Miles, 1998). For general acceptance, usually an cut-off point of 0.90 has been agreed upon for the GFI value (Shevlin and Miles, 1998) however, some researchers suggests that when factor loadings and sample sizes are low a higher cut-off of 0.95 is more appropriate (Shevlin and Miles, 1998).

AGFI is related to the GFI which normalize the GFI on the basis of degrees of freedom, which reduces the model fit in more saturated models. In general, AGFI increases with the increased size of samples. As in the case of the value of GFI, the AGFI measure also range between 0 and 1 and it is commonly acknowledged that values of 0.90 or greater indicates a good model fit (Tabachnick and Fidell, 2007). GFI and AGFI were calculated using Amos 16 and below is the output of lean manufacturing constructed.

Table 5.20: Lean manufacturing practices – CFA results – GFI and AGFI test.

Model	RMR	GFI	AGFI	PGFI
Default model	.034	.883	.857	.720
Saturated model	.000	1.000		
Independence model	.290	.197	.135	.183

As discussed, ideal value for a perfect model fit should be more than 0.9 but as the sample size is very high in this study so the model output value of 0.883 for GFI and 0.857 for AFGI may be considered adequate for analysis of the structural model.

5.3.2.4.2 Incremental Model Fit:

Incremental fit is also known as relative fit (McDonald and Ho, 2002) or comparative model fit (Miles and Shevlin, 2007; Shevlin and Miles, 1998) which do not make use of the chi-square value but compare the chi-square value to a baseline model. For this type of models; the null hypothesis is that where all variables remain uncorrelated (McDonald and Ho, 2002). While checking for incremental model fit need to be verified for the following requirement

i) Comparative Fit Index (CFI): The Comparative Fit Index (CFI) was first introduced by (Bentler, 1990). This takes sample size into consideration (Byrne, 1998) that carry out the results even if the sample size is small (Tabachnick and Fidell, 2007). Generally remains least affected by the size of the sample. A cut-off criterion of CFI ≥ 0.90 is generally accepted; still some researchers argues that the value greater than 0.90 is essential in order to ensure that not good models are not accepted (Hu and Bentler, 1999). It can be concluded that a value of CFI ≥ 0.95 is acknowledged as indicative of good fit (Hu and Bentler, 1999).

ii) Normed-fit Index (NFI): The primary indices is the Normed Fit Index or NFI (Hu and Bentler, 1999). This statistic evaluates the model by comparing the $\chi 2$ value of the model to the $\chi 2$ of the null mode considering the null model as the model where all measured variables are uncorrelated. Generally recommended values for a good fit model should be NFI ≥ .9 (Hu and Bentler, 1999).

iii) Tucker-Lewis Index (TLI): If the model fit has problems of the non-normed, Tucker-Lewis index values may fall outside the 0-1 range. In a case of good model fit values ranges from .08 to 0.95(McDonald and Ho, 2002). CFI, NFI and TLI values were calculated using Amos 16 and the output of lean manufacturing constructed is depicted in below table.

Table 5.21: CFI and NFI test (Baseline Comparisons) for Lean manufacturing practices

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.911	.899	.954	.947	.953
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

In the give study the value of CFI, NFI and TLI are observed as 0.953, 0.911 and 0.947 respectively. These values are in line with the requirement of incremental model fit; the construct is validated for fitment for analysis.

5.3.2.4.3 Parsimonious Fit

Parsimonious Normed fit Index (PNFI) are the key indices for verification of Parsimony fit. In the complex models means nearly saturated model where the assessment depends on the sample data. This may result in an inaccurate hypothetical model that inconsistently produces better fit indices(Crowley and Fan, 1997; Mulaik et al., 1989). To resolve this issue, Mulaik et al (1989) have introduced parsimonious Normed fit Index (PNFI). Although there is no defined range is established for these indices, but some researchers proposes to obtain parsimony fit indices within the 0.50 to 0.90 region for a good model fit (Mulaik et al., 1989). The output values calculated through Amos 16 are depicted in table below.

Table 5.22: PCFI and PNFI test (Parsimony-Adjusted Measures)

Model	PRATIO	PNFI	PCFI
Default model	.877	.799	.836
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

While performing a CFA with two or more latent factors in AMOS, it is required to be provided the verification of convergent and discriminant validity. This needs to be tested for the Average Variance Extracted (AVE), Average Shared Variance (ASV), and Composite reliability (CR). The convergent validity was tested using stat tool package and results observed were in line with the threshold limit of CR> 0.7, CR> AVE and AVE >0.5. For discriminant validity the results were as per requirement i.e. MSV< AVE and ASV<AVE. Table below depicts the summary of model fit requirement verses observation of fit index for the measurement model of lean manufacturing practices.

5.3.2.5 Summary of Model Fit for Lean Manufacturing Practices Construct

The model of lean manufacturing practices complies and conforms to the all three types of model fit so this can be considered as valid model for further analysis and interpretation of results.

Table 5.23: Lean manufacturing practices- Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.99
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.56
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.883
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.953
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.911
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.947
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.836

5.3.3 Testing the Validity of the Operational Performance Model

The authenticity of the operational performance model was tested with performing the confirmatory factor analysis (CFA) using the AMOS 16.0 software for making structural Model.

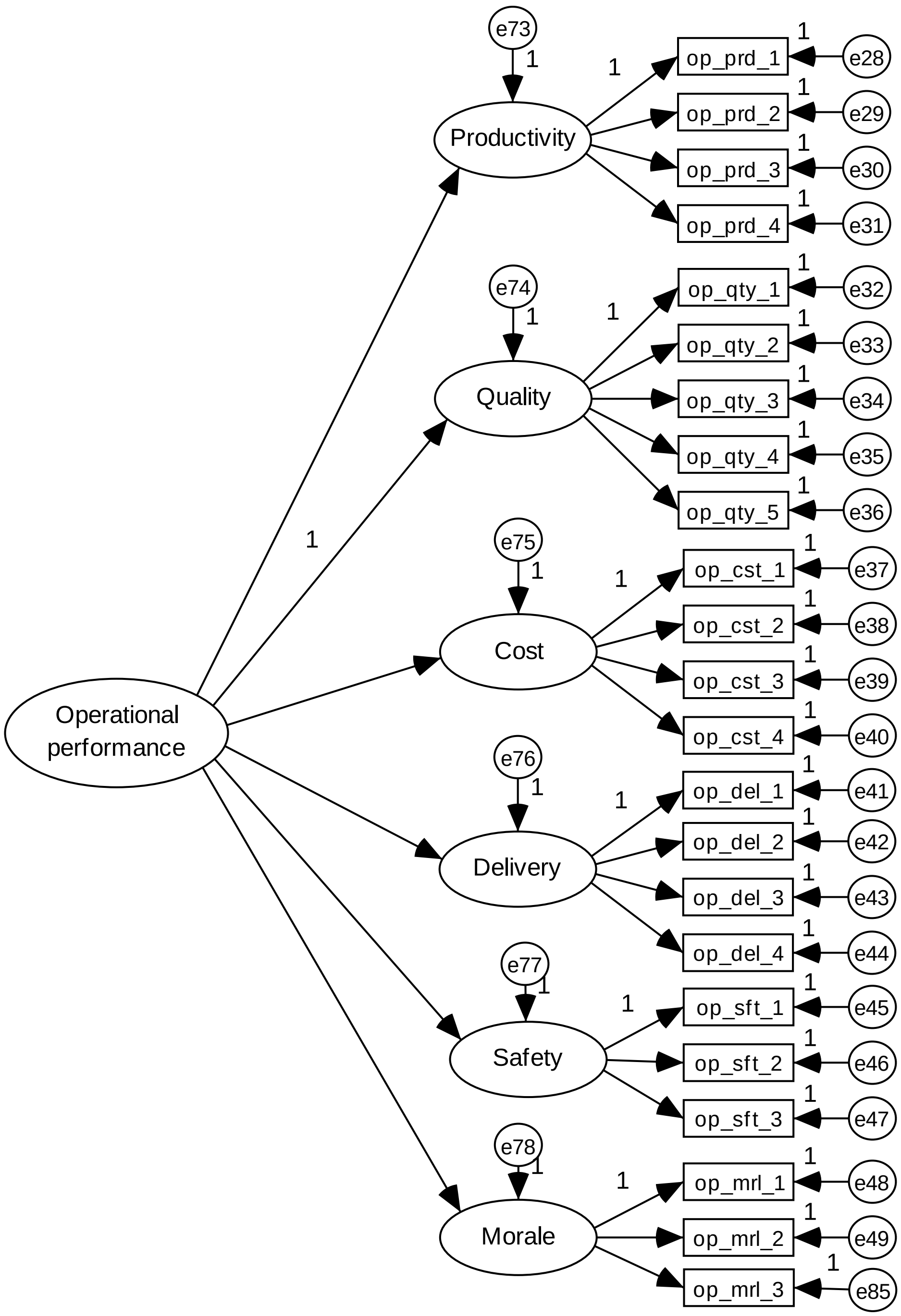


Figure5.6: Measurement model for measuring operational performance

Validity testing of the data, exploratory factor analysis and CFA approach is used to validate the collected data as discussed in the section 4.6.8.

5.3.3.1 Analysis of Operational Performance Data

The data collected for the measurement of operational performance within the Indian industries. This measurement comprised of seven factors and 17 items or questions to be answered by the respondents on 5 point scale Likert scale from 1 to 5 from “no gain” to “full gain” based on respondent’s opinion on operational performance. The analysis started with estimating the reliability of the collected data.

5.3.3.2 Reliability

‘Reliability’ is a measure of consistency among the scales used to measure a latent variable and strong correlation among the scales indicates high level of reliability of scales signifying that they are measuring the same latent variable construct. In this section, statistical analyses are used to ascertain the reliability of the scales. Cronbach’s alpha was observed to check the internal consistency of the scales. The validity of the operational performance construct was tested with performing the exploratory factor analysis using the AMOS 16.0 software for performing structural equation. Reliability scores for operational performance data were calculated using SPSS 16.0 software and output from SPSS is shown in table below.

Table 5.24: Cronbach’s Alpha value test for Operational performance parameters

Case Processing Summary

		N	%
Cases	Valid	323	100.0
	Excluded[a]	0	.0
	Total	323	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.929	.929	23

The value of Cronbach's Alpha for factors measuring lean manufacturing practices is observed as 0.929 with confirms to the validity of the collected data which indicates the reliability for the data as per guidelines discussed in previous section (5.4.2.2).

5.3.3.3 Exploratory Factor Analysis

Second step is to assess the appropriateness of the factor analysis by performing EFA with the use of Kaiser-Meyer-Olkin measure of sampling adequacy or KMO and Bartlett’s test. The value of KMO above 0.6 is considered as satisfactory for appropriateness of factor analysis as discussed in previous section (5.4.2.3). Kaiser-Meyer-Olkin measure of sampling adequacy or KMO and Bartlett’s test were performed using SPSS 16.0. The SPSS output for the data is shown in table below.

Table 5.25:– KMO and Bartlett’s test results for operational performance measurement data

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.889
Bartlett's Test of Sphericity	Approx. Chi-Square	5.143E3
	df	253
	Sig.	.000

The Kaiser-Meyer-Olkin Measure of sampling adequacy score is 0.889 which qualifies the validation of exploratory factor analysis against the requirements discussed in the previous section (5.3.2.3). The data collected for measuring operational performance verifies the adequacy of the sampling statistics. The significance value is also zero against 0.05 as specified for suitability of data for further analysis.

In order to gain a more understanding about data collected for measuring operational performance, all the 23 items were subjected to a factor analysis utilizing the Principal Component Analysis (PCA) with Oblimin rotation procedure extracting all the items under the six factors of operational performance. The objective of this analysis is to sum up the information contained in 23 items in a smaller set of factors that represents the construct for measurement of operational performance measures. Table below depicts the SPSS output for the items related to operational performance measures.

Table5.26: Operational performance parameters – total variance explained by all factors

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	9.024	39.236	39.236	9.024	39.236	39.236	5.322
2	2.085	9.064	48.300	2.085	9.064	48.300	5.044
3	1.765	7.676	55.976	1.765	7.676	55.976	4.954
4	1.575	6.849	62.825	1.575	6.849	62.825	4.847
5	1.429	6.214	69.039	1.429	6.214	69.039	4.720
6	1.121	4.875	73.914	1.121	4.875	73.914	5.232
7	.733	3.187	77.101				
8	.692	3.010	80.111				
9	.600	2.610	82.721				
10	.562	2.443	85.164				
11	.535	2.325	87.488				
12	.454	1.975	89.463				
13	.398	1.732	91.195				
14	.343	1.492	92.688				
15	.303	1.318	94.005				
16	.264	1.149	95.154				
17	.237	1.030	96.184				
18	.191	.830	97.015				
19	.182	.790	97.805				
20	.153	.665	98.470				
21	.141	.612	99.082				
22	.112	.487	99.569				
23	.099	.431	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

In this case eigenvalue more than 1.0 is possessed by all the six factors explaining 73.914 percent of the total variance which means this set of factor has explained reasonably amount of the total variance.

Further the step of exploratory factor analysis involved the analysis through rotated factor solution using pattern matrix table. The purpose of presenting the items via pattern matrix is to test the item wise loadings and arrangement of the items under the various components or factors under study. In the case under study it was observed that all items are highly related with the factors under with they are measured. Below table depicts the SPSS output of the data analysis.

Table 5.27: Operational performance parameters – EFA results – pattern matrix with all factors

Pattern Matrix[a]

	Component					
	1	2	3	4	5	6
op_del_4	.896					
op_del_2	.896					
op_del_1	.882					
op_del_3	.560					
op_cst_3		.903				
op_cst_2		.866				
op_cst_1		.823				
op_cst_4		.672				
op_sft_3			.939			
op_sft_2			.931			
op_sft_1			.914			
op_mrl_2				.945		
op_mrl_1				.924		
op_mrl_3				.868		
op_qty_1					.867	
op_qty_2					.790	
op_qty_3					.686	
op_qty_5					.508	
op_qty_4					.378	
op_prd_2						.771
op_prd_4						.768
op_prd_3						.762
op_prd_1						.562

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 9 iterations.

The results of rotated factor analysis shown in pattern matrix table are showing quite uniform items loadings for each factor. In this case study we have minimum three items loading per factor stating a sound solution by attaining all the all six operational performance parameters. The factor loading more than 0.4 is considered significant despite of the sign i.e. positive or negative. Out of 23 items, one item, (op_qty_4) has loading 0.378 against the significant loading threshold of 0.4 as discussed in section (5.3.2.3) but as factor loading is marginally less than threshold limit in one parameter only so researchers has decided to consider this item for further analysis.

Table 5.28: Operational performance parameters – EFA results – factors correlation matrix

Component Correlation Matrix

Co...	1	2	3	4	5	6
1	1.000	.313	.373	.287	.334	.441
2	.313	1.000	.332	.391	.307	.350
3	.373	.332	1.000	.316	.364	.327
4	.287	.391	.316	1.000	.331	.395
5	.334	.307	.364	.331	1.000	.391
6	.441	.350	.327	.395	.391	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

In this study, the correlation matrix table containing most of the values are more the threshold of 0.3, one correlation (between component 1 and component 4) is 0.287 which is below the limit hence may be acceptable for confirmation of data collected for further analysis and hence qualifying for data adequacy.

5.3.3.4 Confirmatory Factor Analysis of Operational Performance Measurement Model

The factor structure of the operational performance measurement model is to be validated through CFA for the verification of model fit. Operational performance measurement model was required to be recognized out of three categories as unidentified, just identified or identified as discussed in previous section (5.3.2.4). If the model is recognized as identified it is observed fit for further test to verify adequacy of model fit. To perform measurement of model fit it is essential to consider sequences of three model fit i.e. absolute model fit, incremental model fit and parsimonious model fit.

5.3.3.4.1 Absolute Model fit

Absolute fit is an indicator which determines how well a model fits the sample data and provides some direction for the proposed fitment requirement for the model. This model fit utilizes the assumption of measuring of Chi-Squared analysis, RMSEA, GFI, and AGFI. Absolute model fit necessitates following fundamentals condition for a balanced model fit as discussed in section (5.3.2.4.1) for measuring absolute goodness of model fit.

i) Chi- square value and probability: Chi- square value and probability validation is required to check to know how well the various factors are affecting the final output of the model as discussed in previous section (5.3.2.4.1). Amos 16 was used to obtain the result of the model and below is the output from Amos 16 for operational performance measurement model:

Table 5.29: – Degrees of freedom and model identification for Operational performance parameters

Number of distinct sample moments:	276
Number of distinct parameters to be estimated:	54
Degrees of freedom (276 - 54):	222

Operational performance measurement model has degree of freedom is 222 hence having degree of freedom more than one is recognized as identified so it is observed fit for further test to verify adequacy of model fit.

Table 5.30: Operational performance parameters – CFA results – Chi- square value and probability

Chi-square:	438.507
Degrees of freedom:	222
Probability level:	.000

In the given model degree of freedom is 222 and Chi-square value is 438.507which indicates a healthy ratio of Chi- square and degree of freedom ratio = 438.507/222= 1.97. Generally the ratio between1 to 5 it is considered as a adequate model for analysis as discussed in previous section (5.3.2.4.1). Next check is probability level which is equal to zero up to three digits against minimum general requirement of less than 0.05.

ii) Root mean square error of approximation (RMSEA): The second fit measure under absolute model fit is the value of RMSEA as discussed in details in previous section

(5.4.3.1). RMSEA value from 0.08 to 0.10 signifies an adequate fit and value mainly below 0.08 indicates a good fit. Computation of RMSEA for operational performance measurement model is performed through Amos 16.0 software and below is the output.

Table 5.31: Operational performance measurement model – CFA results – RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.055	.047	.063	.134
Independence model	.248	.243	.254	.000

In this case observed value of RMSEA is 0.055 against the specified limit of 0.08 and is observed within limit hence model fit is validated for RMSEA value.

iii) Goodness of fit index (GFI) : The value of GFI generally ranges from 0 to 1 with increasing with bigger samples and the higher number of parameters and decreases with higher degrees of freedom with increased to sample size as discussed in previous section (5.4.3.1). It is commonly acknowledged that values of 0.80 or greater indicate a good model fit. GFI and AGFI were calculated using Amos 16 and below is the output of lean manufacturing constructed.

Table 5.32: GFI and AGFI result for operational performance measurement model

Model	RMR	GFI	AGFI	PGFI
Default model	.041	.899	.875	.723
Saturated model	.000	1.000		
Independence model	.269	.236	.166	.216

For a perfect fit model it should be more than 0.9 but till value of GFI as 0.899 and value of AGFI as 0.875 may be considered adequate for further analysis of the model as this structural model is with complex structure. So we decided to go ahead with the further study.

5.3.3.4.2 Incremental Model Fit:

Incremental model fit or comparative model fit compares the chi-square value to a baseline model as discussed in previous section (5.3.2.4.2). For checking for incremental model fit this model need the following requirement

i) Comparative Fit Index (CFI): CFI was first introduced by Bentler that may carry out the results even if the sample size is small. A cut-off criterion of CFI ≥ 0.90 is generally accepted still, some researchers argues that the value greater than 0.90 is essential in order to ensure that not good models are not accepted. It is discussed in previous section (5.3.2.4.2) that value of CFI ≥ 0.95 is acknowledged as indicative of good fit.

ii) Normed-fit index (NFI): The primary indices is the Normed Fit Index or NFI is the statistic that evaluates the model by comparing the $\chi 2$ value of the model to the $\chi 2$ of the null mode considering the null model as the model where all measured variables are uncorrelated. Generally recommended values for a good fit model should be NFI ≥ .9 as discussed in previous section (5.3.2.4.2).

iii) Tucker-Lewis index (TLI): If the model fit has problems the non-normed, Tucker-Lewis index values may fall outside the 0-1 range. In a case of good model fit values ranges from .08 to 0.95 as discussed in previous section (5.3.2.4.2). CFI, NFI and TLI values for operational performance measurement model were calculated using Amos16 and the output of lean manufacturing constructed is depicted in below table.

Table 5.33: Operational performance measurement model CFI and NFI test (Baseline Comparisons)

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.917	.905	.957	.951	.957
Saturated model	1.000		1.000		1.000

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Independence model	.000	.000	.000	.000	.000

In the give study the value of CFI, NFI and TLI are observed as 0.957, 0.917and 0.951 respectively. These values are in line with the requirement of incremental model fit; the construct is validated for incremental model fit and qualifies for fitment for further analysis.

5.3.3.4.3 Parsimonious Fit

Parsimonious Normed fit Index (PNFI) are the key indices for verification of Parsimony fit within the 0.50 to 0.90 region for a good model fit as discussed in previous section (5.3.2.4.3). The output of operational performance measurement model values were calculated through Amos 16 is depicted in table below.

Table 5.34: PCFI and PNFI test (Parsimony-Adjusted Measures)

Model	PRATIO	PNFI	PCFI
Default model	.877	.805	.840
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

The value of PCFI and PNFI and 0.840 and 0.805 respectively against the model fit requirements of the range from 0.5 to 0.9 hence parsimonious fit is validated for the operational performance measurement model. Below table summarizing the model fit statistics for operational performance measurement model.

5.3.3.5 Summary of Model Fit for Operational Performance Measurement Model

The model of operational performance measurement complies and conforms to the all three types of model fit. The convergent validity was tested using stat tool package and results observed were in line with the threshold limit of CR> 0.7, CR> AVE and AVE >0.5. For discriminant validity the results were as per requirement i.e. MSV< AVE and ASV<AVE. Hence this can be considered as valid model for further analysis and interpretation of results. Table below depicts the summary of model fit requirement verses observation of fit index for the operational performance measurement model.

Table 5.35: Operational performance- Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.97
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.055
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.899
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.957
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.917
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.951
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.840

5.3.4 Testing the Validity of the Financial Performance Measurement Constructs

The validity of the financial performance measurement model was tested with CFA using the Amos16 software. The measurement variances are decomposed into its element components. Validity of the constructs is to verify whether various measures of the model and the variation and co-variances in the measurement are in compliance with the model fit and that would be tested for validity. If the validity is observed as model fit the model may be used for further study.

5.3.4.1 Analysis of Financial Performance Measurement Data

The data collected on the way to the measurement of financial performance measurement within the Indian industries. This measurement comprised of four factors and 16 items to be answered by the respondents on 5 point scale Likert scale from 1 to 5 from "no gain" to "full gain" based on respondent's opinion on financial performance displayed the company. Analysis starts with estimating the reliability of the collected data.

5.3.4.2 Reliability

'Reliability' is measured for the consistency among the scales used to gauge a latent variable. Strong correlation among the scales indicates high level of reliability of scales signifying that they are measuring the same latent variable construct as discussed in previous section (5.3.2.2). In this study, statistical analyses are used to ascertain the reliability of the scales. Cronbach's alpha and factor analysis were used to determine the validity and reliability of the scales. Reliability scores are calculated using SPSS 16.0 software and output from SPSS is shown in table below.

Table 5.36: Cronbach's Alpha test result for financial performance measurement

Case Processing Summary

		N	%
Cases	Valid	323	100.0
	Excluded[a]	0	.0
	Total	323	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.942	.943	16

Here in this case the value of Cronbach's Alpha is 0.943. As discussed in the section (5.3.2.2), any value more than 0.65 is considered as fit for further analysis of the data so financial performance measurement data complies with validity test with cronbach's alpha value.

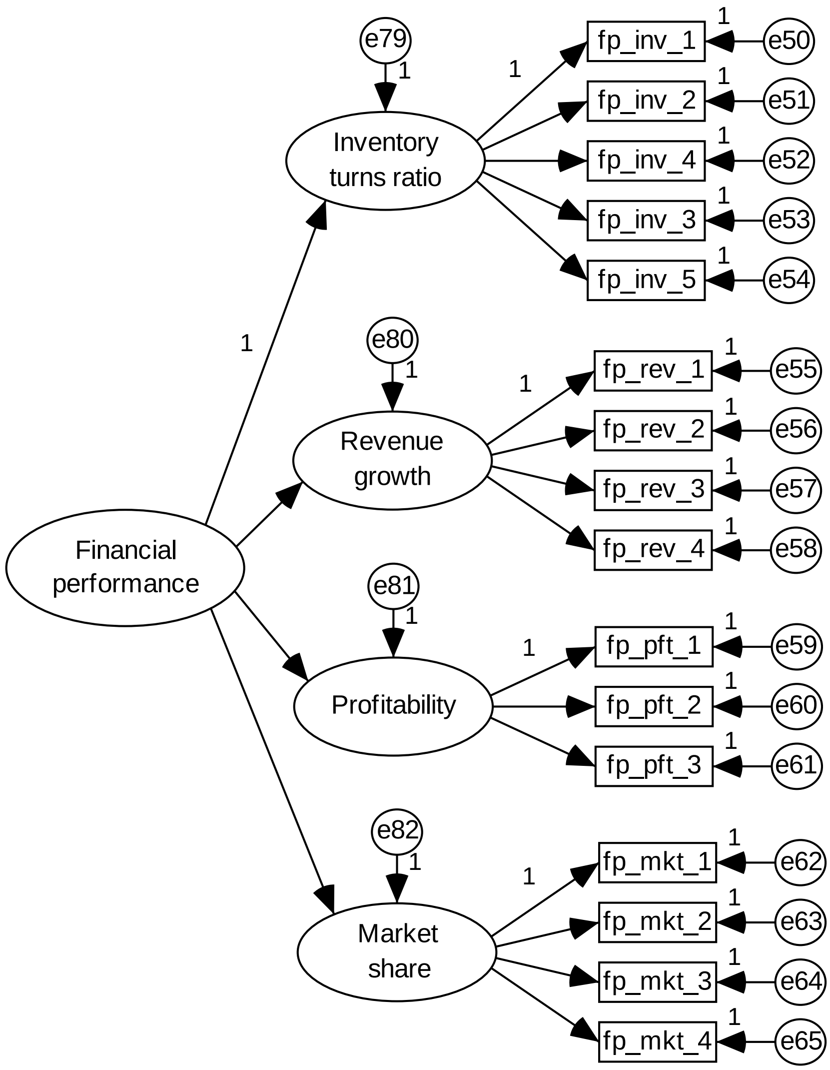


Figure5.7: Measurement model for measurement of financial performance

5.3.4.3 Exploratory Factor Analysis

To assess the suitability of the factor analysis by performing exploratory factor analysis (EFA) with the use of Kaiser-Meyer-Olkin Measure of Sampling Adequacy or KMO and Bartlett's test. The value of KMO above 0.6 is considered as satisfactory for appropriateness of factor analysis as discussed in the section (5.3.2.3). Bartlett's test of sphercity provides the statistical probability that the correlation matrix has significant correlation among at least some of the variables. In data statistics, Bartlett's test is used to test if the data is collected from adequate populations. The Bartlett test is used to verify the adequacy of the population from data is collected. The SPSS output for financial performance measurement and the result is shown in table below.

Table 5.37: Lean manufacturing practices – EFA results –KMO and Bartlett's test

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.918
Bartlett's Test of Sphericity	Approx. Chi-Square	5.092E3
	df	120
	Sig.	.000

In this case KMO value and Bartlett's test score is 0.918 which qualifies the requirements and verifies the adequacy of the sampling data as discussed in the section (5.3.2.3). Significance value is zero against 0.05 as specified determines the suitability of the data for further analysis.

Table 5.38: Total variance explained by financial performance measures

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	8.644	54.027	54.027	8.644	54.027	54.027	6.479
2	1.698	10.610	64.636	1.698	10.610	64.636	6.229
3	1.169	7.307	71.944	1.169	7.307	71.944	5.475
4	.931	5.821	77.765	.931	5.821	77.765	5.833
5	.562	3.514	81.279				
6	.481	3.003	84.283				
7	.448	2.800	87.083				
8	.390	2.439	89.522				
9	.350	2.190	91.712				
10	.305	1.906	93.618				
11	.275	1.716	95.334				
12	.250	1.564	96.898				
13	.221	1.379	98.277				
14	.165	1.031	99.308				
15	.106	.663	99.971				
16	.005	.029	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

In order to gain a more understanding, all the 16 items were subjected to a factor analysis utilizing the Principal Component Analysis with Oblimin rotation procedure extracting all the items under the four factors of financial performance measurement. The objective of this analysis is to sum up the information contained in 16 items in a smaller set of factors that represents the construct for measurement of financial performance measures.

In this study we have considered factors up to eigenvalue up to 0.931 to accommodate all the four factors used to measure the lean manufacturing practices. The resulted in the extraction of four factors explaining 77.765 percent of the total variance which means this set of factor explains reasonably amount of the total variance which is adequate. Table below depicts the SPSS output for the items related to lean manufacturing practices.

Figure5.39: Pattern Matrix of financial performance measure factors

Pattern Matrix[a]

	Component			
	1	2	3	4
fp_inv_4	.802			
fp_inv_3	.796			
fp_inv_2	.753			
fp_inv_1	.681			
fp_inv_5	.665			
fp_rev_3		.932		
fp_rev_2		.922		
fp_rev_4		.914		
fp_rev_1		.874		
fp_mkt_3			.880	
fp_mkt_4			.855	
fp_mkt_1			.785	
fp_mkt_2			.728	
fp_pft_1				.949
fp_pft_3				.941
fp_pft_2				.672

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 8 iterations.

In the next step of exploratory factor analysis, the analysis is performed through rotated factor solution using pattern matrix table. The purpose of presenting the items via pattern matrix is to test the item wise loadings and arrangement of the items under the various components or factors under study. In the case under study it was observed that all items are highly related with the factors under with they are measured. Below table depicts the SPSS output of the data analysis.

No random stretch of the same items under more than one factor signifies the articulateness of the data towards factors. In this study all the 16 items has loading more than 0.4 of the minimum threshold limit as discussed in the section (5.3.2.3). For all the factors magnitude is considered despite of loading sign positive or negative. All the factors are grouped and do not have random spread so only which signifies that the loadings and arrangement of the items under the various components is adequate and data may be considered for further analysis.

Component correlation matrix represents the relationship of factor with each other. Higher the value shows better relationship. Below table depicts the SPSS output of the financial performance measurement data analysis.

Table 5.40: Correlation Matrix financial performance measurement factors

Component Correlation Matrix

Co...	1	2	3	4
1	1.000	.565	.535	.595
2	.565	1.000	.419	.548
3	.535	.419	1.000	.455
4	.595	.548	.455	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

In this study, the correlation matrix table containing the values is greater than the threshold of 0.3 which may be acceptable for confirmation of data collected for further analysis and hence qualifying for data adequacy.

5.3.4.4 Confirmatory Factor Analysis of Financial Performance Measurement Model

The financial performance measurement model is to be validated through CFA for the verification of model fit. Structure model require to be recognized for identification of model as discussed in the section (5.3.2.4). The condition for identified model is that degree of freedom must be more than one. If the model is recognized as identified it is observed fit for further test to verify adequacy of model fit. To perform measurement of model fit it is essential to consider three important fit of model i.e. absolute model fit, incremental model fit and parsimonious model fit.

5.3.4.4.1 Absolute Model Fit

Absolute fit is an indicator which determines how well a model fits the sample data and provides some direction for the proposed fitment requirement for the model as discussed in the section (5.3.2.4.1). This measure provides the fundamental indication on how data fits into the proposed theory. It evaluates of how well the model fits to the constraints. This category utilizes the assumption of measuring of Chi-Squared analysis, RMSEA, GFI, and AGFI. Absolute model fit necessitates following fundamentals condition for a balanced model fit.

i) Chi-square Value and Probability: After model is confirmed for identification it is required to check measure of chi square test to know how well the various factors are affecting the final output of the model. The Chi-Square value is the established measure for assessing overall model fit which evaluates the degree of discrepancy among the samples and integral co-variances matrices'. Chi-Squared test maintains its popularity as a measure of fit value with recommendation of range varies from as high as 5.0 to as low as 2.0 as discussed in the section (5.3.2.4.1). Computation of degrees of freedom, Chi- square test and probability test is performed through Amos 16.0 software and below is the output from Amos for financial performance measurement model under analysis.

Table 5.41: Degree of freedom financial performance measurement model

Number of distinct sample moments:	136
Number of distinct parameters to be estimated:	37
Degrees of freedom(136-39):	97

Table 5.42: Chi-square and Probability test for financial performance measurement model.

Chi-square	240.687
Degrees of freedom	97
Probability level	.000

In the given model degree of freedom is 97and Chi-square value is 240.687 which indicates a fit ratio of Chi square to degree of freedom = 240.687/97= 2.481 against the specified range from 1 to 5. This construct may be considered as a fit for analysis. Second check is probability level which is equal to zero up to three digits against minimum requirement of less than 0.05 validating the significance of the construct.

ii) Root Mean Square Error of Approximation (RMSEA): The next fit measure is the value of RMSEA. The recommended the values of RMSEA between the ranges of 0.05 to 0.10 to be as fair-fit and values stating that value above 0.10 signify poor fit. RMSEA value from 0.08 to 0.10 signifies an adequate fit and value mainly below 0.08 indicates a good fit. Calculation of RMSEA is performed through Amos 16.0 software and below is the output.

Table 5.43: RMSEA for financial performance measurement model

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.068	.057	.079	.004
Independence model	.362	.354	.371	.000

In this case RMSEA value is 0.068 against the specified limit of 0.08 maximum and is within the specified limit so the model is adequate for further analysis.

iii) Goodness of Fit Index (GFI): The value of GFI generally ranges from 0 to 1 with increasing the value with bigger samples. As discussed in the section (5.4.3.1), an general acceptance is usually a cut-off point of 0.90 for the GFI value however, some researchers suggests that when factor loadings and sample sizes are low a higher cut-off of 0.95 is more appropriate. Further, AGFI is related to the GFI which normalize the GFI on the basis of degrees of freedom, which reduces the model fit in more saturated models. In general, AGFI increases with the increased size of samples. As in the case of the value of GFI, the AGFI measure also range between 0 and 1 and it is commonly acknowledged that values of 0.90 or greater indicates a good model fit. GFI and AGFI were calculated for financial performance measurement model using Amos 16 and below is the output of lean manufacturing constructed.

Table 5.44: GFI and AGFI test results for financial performance measurement model

Model	RMR	GFI	AGFI	PGFI
Default model	.055	.917	.884	.654
Saturated model	.000	1.000		
Independence model	.486	.197	.090	.174

As discussed, ideal value for a perfect model fir it should be more than 0.9. In this study the model output value of .91 for GFI and 0.884 for AFGI may be considered adequate for analysis of the structural model.

5.3.4.4.2 Incremental Model Fit:

Incremental fit is called as a comparative model fit which do not make use of the chi-square value but compares the chi-square value to a baseline model as discussed in the section (5.3.2.4.2). While examination for incremental model fit this model need the following requirement.

i) Comparative Fit Index (CFI): The Comparative Fit Index (CFI) was first introduced by Bentler and it takes sample size into consideration that carry out the results even if the sample size is small A cut-off criterion of CFI ≥ 0.90 is generally accepted still, some researchers argues that the value greater than 0.90 is essential in order to ensure that not good models are not accepted (Hu and Bentler, 1999). It can be concluded that a value of CFI ≥ 0.95 is acknowledged as indicative of good fit (Hu and Bentler, 1999).

ii) Normed-fit Index (NFI): The primary indices are the Normed Fit Index or NFI (Bentler and Bonnet, 1980). This statistic evaluates the model by comparing the $\chi 2$ value of the model to the $\chi 2$ of the null mode considering the null model as the model where all measured variables are uncorrelated. Generally recommended values for a good fit model should be NFI ≥ .9 (Hu and Bentler, 1999).

iii) Tucker-Lewis Index (TLI): If the model fit has problems the Non-normed, Tucker-Lewis index values may fall outside the 0-1 range. In a case of good model fit values ranges from .08 to 0.95 (Sharma et al., 2005). CFI, NFI and TLI values were calculated using Amos 16 and the output of lean manufacturing constructed is depicted in below table.

Table 5.45: CFI and NFI test (Baseline Comparisons) for financial performance measurement

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.954	.943	.972	.965	.972
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

In the give study the value of CFI, NFI and TLI are observed as 0.972, 0.954 and 0.965 respectively. These values are in line with the requirement of incremental model fit; the construct is validated for fitment for analysis.

5.3.4.4.3 Parsimonious Fit:

PCFI and Parsimonious Normed fit Index (PNFI) are the key indices for verification of Parsimony fit. To obtain parsimony fit indices should be within the 0.50 to 0.90 region for a good model fit as discussed in the section (5.3.2.4.3). The output values calculated for financial performance measurement model through Amos 16 are depicted in table below.

Table 5.46: PCFI and PNFI test for financial performance measurement model

Model	PRATIO	PNFI	PCFI
Default model	.808	.771	.785
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

In this study the value of PCFI and PNFI test are observed as 0.785 and 0.771 respectively. These values are in line with the requirement of incremental model fit; the construct is validated for fitment for analysis

5.3.4.5 Summary of Model Fit for Financial Performance Measurement Model

The model of financial performance measurement model complies and conforms to the all three types of model fit. The convergent validity was tested using stat tool package and results observed were in line with the threshold limit of CR> 0.7, CR> AVE and AVE >0.5. For discriminant validity the results were as per requirement i.e. MSV< AVE and ASV<AVE. Hence this can be considered as valid model for further analysis and interpretation of results. Table below depicts the summary of model fit requirement verses observation of fit index for the measurement model of lean manufacturing practices.

Table 5.47: Financial performance- Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	2.481
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.068
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.917
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.972
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.954
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.965
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.785

5.3.5 Comparing Lean manufacturing practices with operational performance model

The objective of the research is to study the impact of lean manufacturing practices on organisational performance of the Indian industries. Operational performance being the integral part of organisational performance as discussed in previous chapter, it is imperative to evaluate the status of lean manufacturing practices and operational performance by connecting the measurement models to form a structural equation model for measuring the impact of lean manufacturing on operational performance of Indian industries.

5.3.5.1 Model Fit Analysis of Theoretical Model of Lean Manufacturing Versus Operational Performance Construct

The validate measurement models of lean manufacturing and operational performance model are connected together to establish the relation of lean manufacturing with operational performance. Though, both the individual measurement models have been validated in the previous section still the newly formed structural model needs the verification for model fit. To perform the model fit model is tested using Amos 16. The chi-square of the model was observed 1943 with degree of freedom 1147 indicating the identified status of the model and ratio 1.70 indicating a good model fit. The overall fit of the model was found adequate with the Goodness of Fit Index (GFI) as 0.815 and Adjusted the Goodness of Fit Index (AGFI) as 0.794 which is acceptable. RMSEA is 0.046 which is below the threshold limit of 0.08 for a reasonable model fit (Browne and Cudeck, 1992)

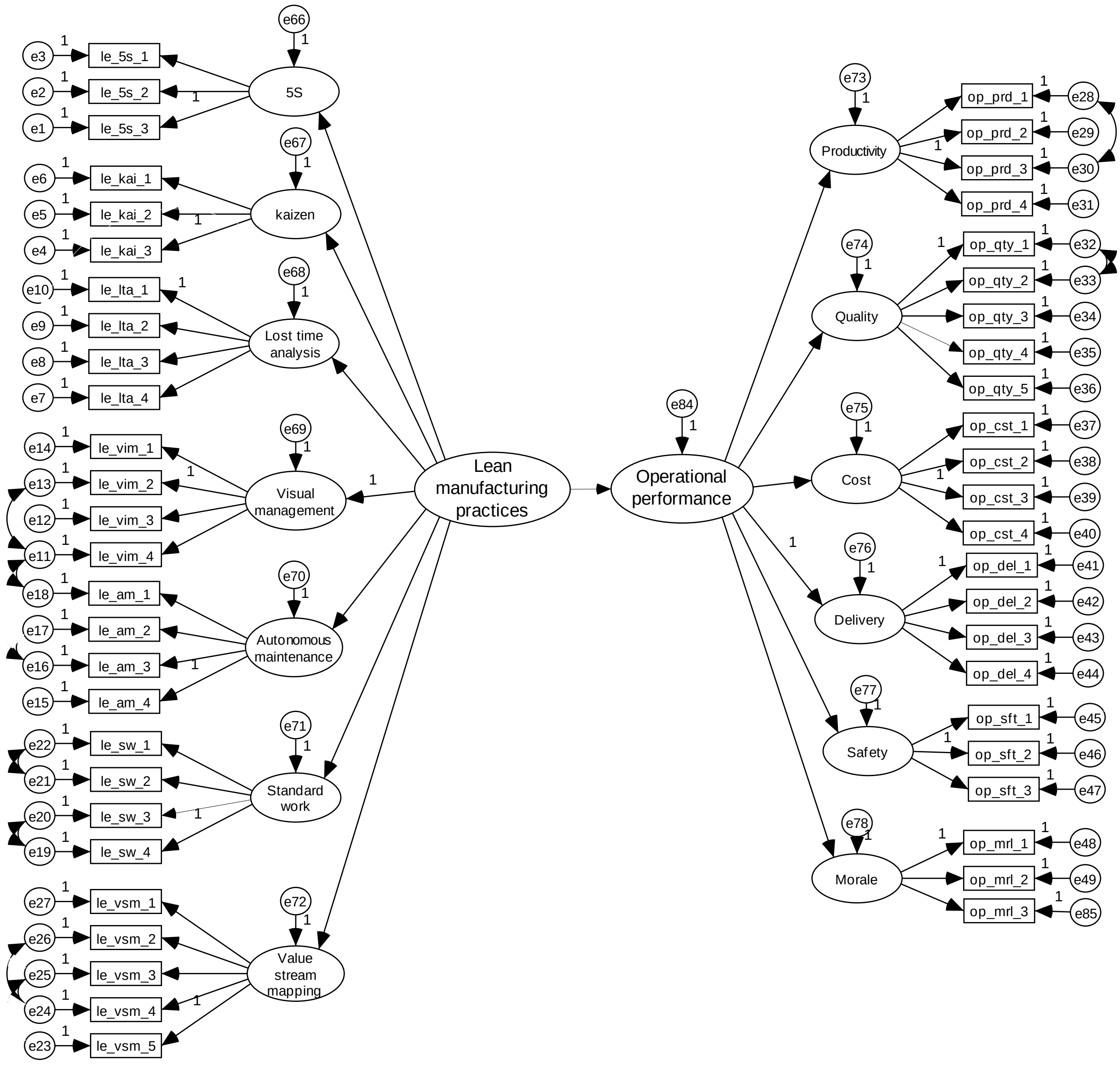


Figure 5.8: Theoretical model --- Lean manufacturing practices versus operational performance

A comparison of fitness of goodness statistics is indicated in table below.

Table 5.48: lean manufacturing versus operational performance model - Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.70
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.046
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.815
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.935
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.855
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.930
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.800

5.3.6 Comparing Lean manufacturing practices with financial performance model

The objective of the research is to study the impact of lean manufacturing practices on organisational performance of the Indian industries. Financial performance being the integral part of organisational performance as discussed in previous chapter, it is imperative to evaluate the status of lean manufacturing practices and financial performance by connecting the measurement models to form a structural equation model for measuring the impact of lean manufacturing on financial performance of Indian industries.

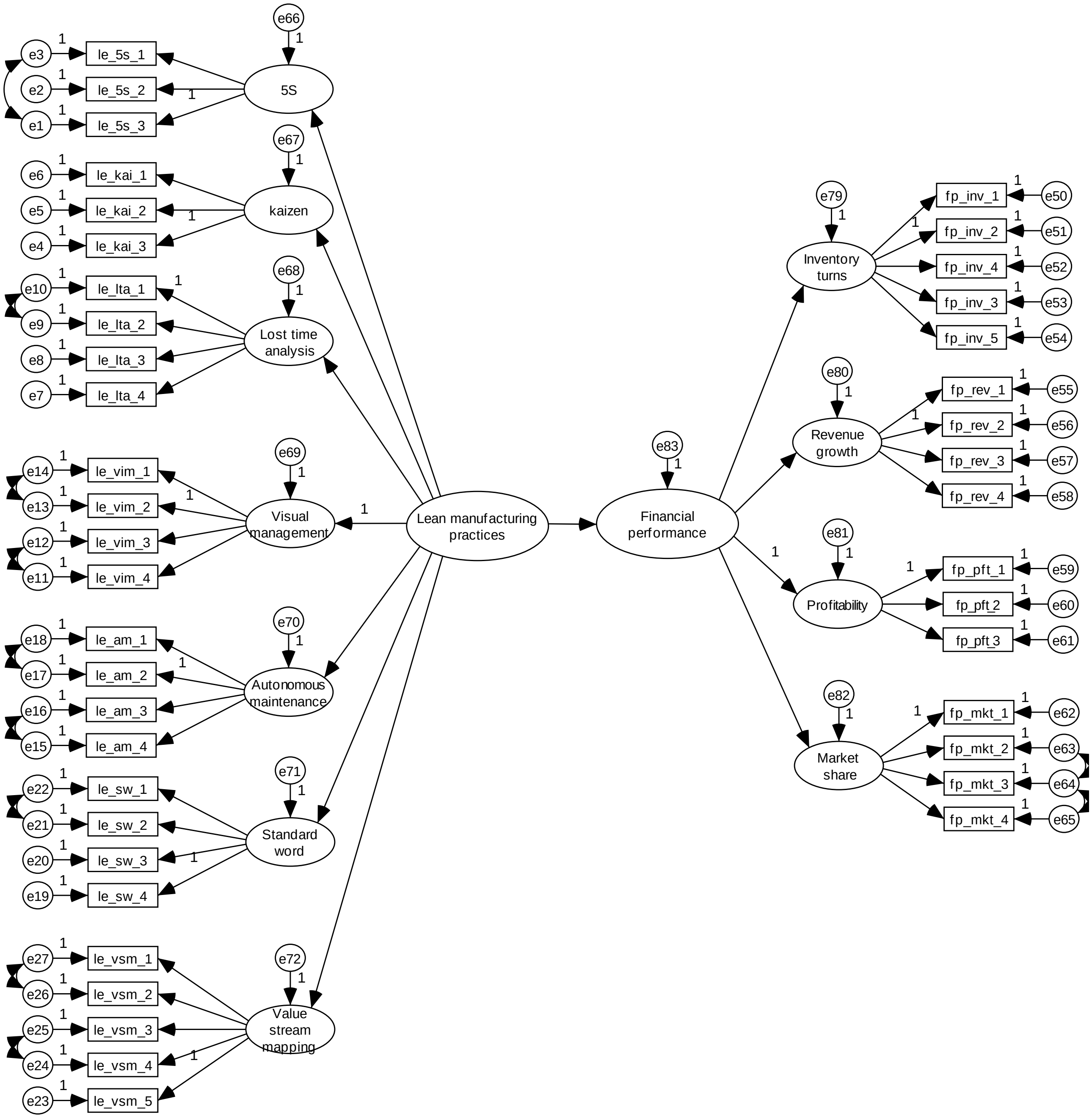


Figure5.9: Theoretical model --- Lean manufacturing practices versus financial performance

5.3.6.1 Model Fit Analysis of Theoretical Model of Lean Manufacturing Versus Financial Performance Construct

The validated measurement models of lean manufacturing and operational performance model are connected together to establish the relation of lean manufacturing with operational performance. To perform the model fit, the model is tested using Amos 16. The Chi-square of the model was observed 1492 with degree of freedom 837 indicating the identified status of the model and ratio 1.8 indicating a good model fit. The overall fit of the model was found adequate with the Goodness of Fit Index (GFI) as 0.830 and Adjusted the Goodness of Fit Index (AGFI) as 0.808 which is acceptable. RMSEA is 0.049 which is within specified limit hence the model is considered as compliance with the parameters of model fit. A comparison of fitness of goodness statistics is indicated in table below.

Table 5.49: lean manufacturing versus financial performance model - Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.782
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.049
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.830
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.946
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.885
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.941
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.820

5.3.7 Comparing operational performance with financial performance model

The purpose this research is to measure the impact of lean manufacturing on operational performance and financial performance is that in several cases it is observed that lean does not directly improves the financial results rather improves the operational efficiencies and improved operational results impacts the financial performance. Now it becomes imperative to validate this hypothesis with comparing the level of operational performance with the status of financial results by connecting the measurement models of operational performance and financial performance.

5.3.7.1 Model Fit Analysis of Operational Performance versus Financial Performance Model

The factor structure of the operational performance versus financial performance model is to be validated through Confirmatory Factor Analysis (CFA) for the verification of model fit. To perform the model fit model is tested using Amos 16. The Chi-square of the model was observed 1312 with degree of freedom 683 indicating the identified status of the model and ratio 1.9 indicating a good model fit. The overall fit of the model was found adequate with the Goodness of Fit Index (GFI) as 0.837 and Adjusted the Goodness of Fit Index (AGFI) as 0.814 which is acceptable. RMSEA is 0.054 which is as per the specified limit of 0.08 hence model is considered as fit.

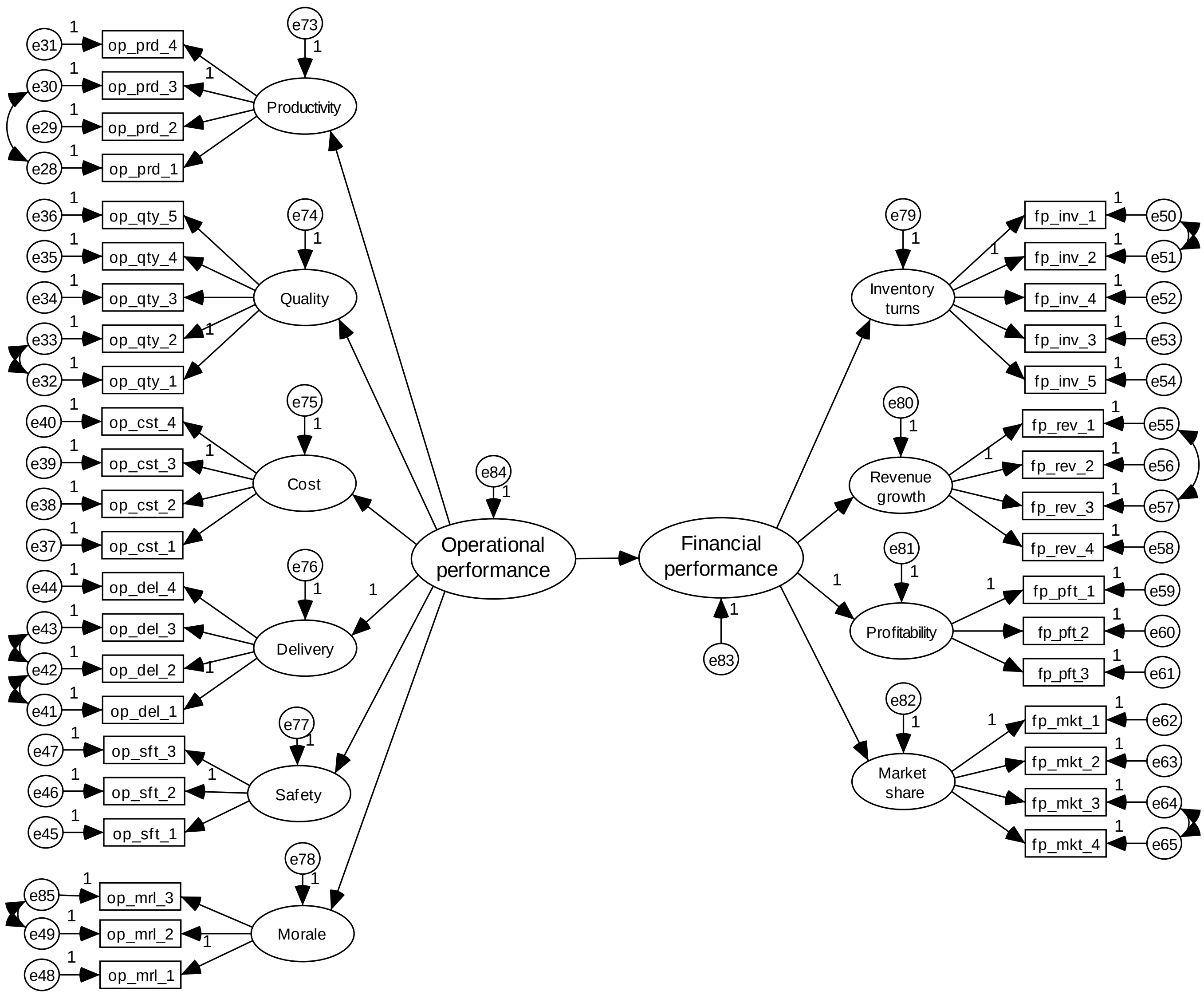


Figure 5.10: Theoretical model --- Lean manufacturing practices versus financial performance

A comparison of fitness of goodness statistics is indicated in table below.

Table 5.50: operational performance versus financial performance model - Fit statistics validation

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.920
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.054
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.837
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.940
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.884
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.935
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.815

5.3.8 Development of Final Structural Equation Model for measuring the impact of lean manufacturing implementation on organisational performance

The purpose of this research study is to measure the impact of lean manufacturing on organisational performance (operational performance and financial performance) . Hence it imperative to validate this hypothesis with comparing the level of lean manufacturing implementation with the organisational performance by connecting the three measurement models viz. lean manufacturing, operational performance and financial performance measurement model to form final structural model as shown in figure 5.11.

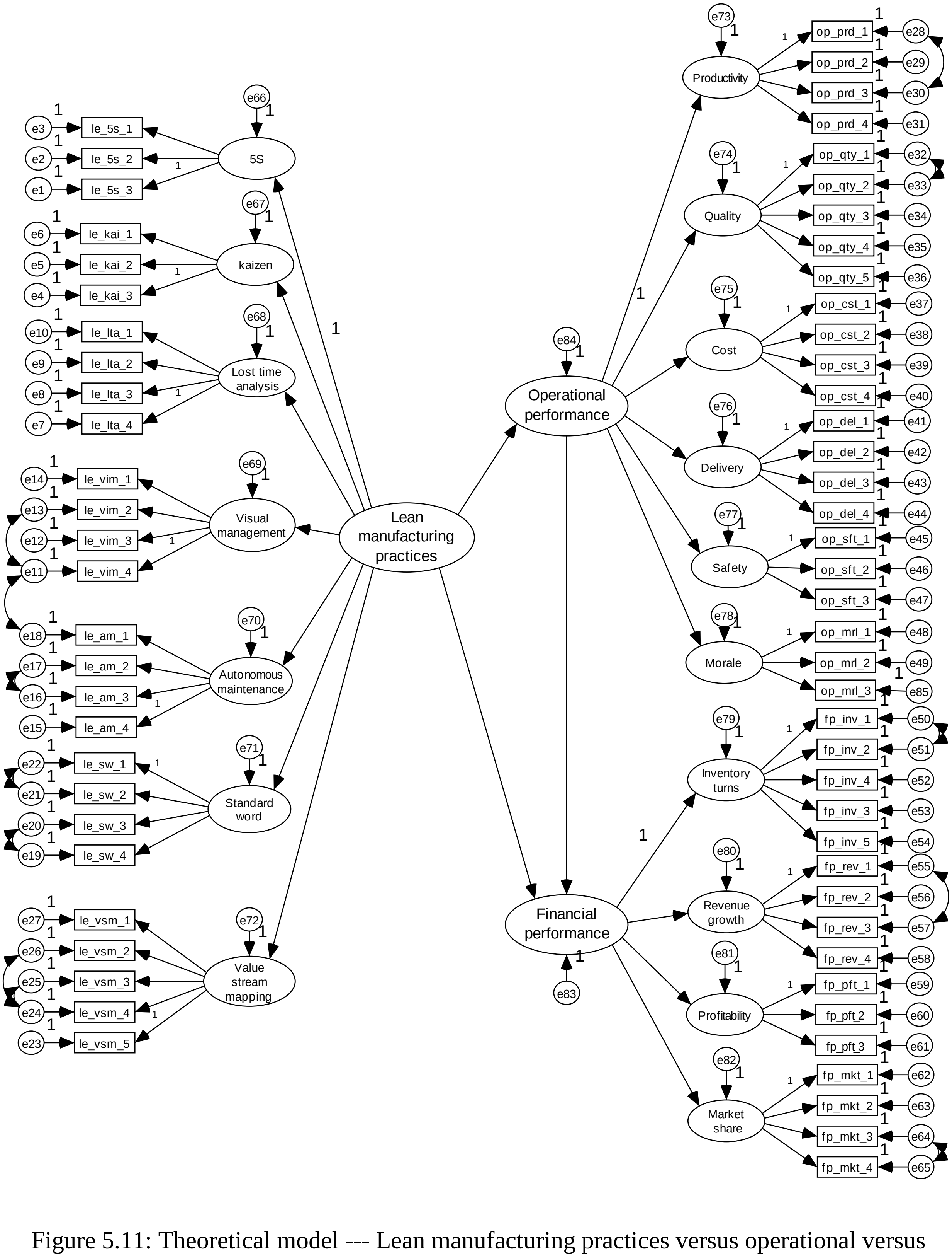


Figure 5.11: Theoretical model --- Lean manufacturing practices versus operational versus financial performance.

5.3.8.1 Confirmatory Factor Analysis of Lean Manufacturing Practice Performance Model

For determining the correlation between lean manufacturing practices, operational performance and financial performance all the three measure model were joined to form a structural equation model. Subsequent to completing the structure of full lean practice – performance model it is was required to check the goodness of model fit through Confirmatory Factor Analysis (CFA). To perform the model fit model is tested using Amos 16 and the model output is analyzed. The chi-square of the model was observed 3529 with degree of freedom 2047 indicating the identified status of the model and ratio 1.72 indicating a good model fit. The overall fit of the model was found adequate with the Goodness of Fit Index (GFI) as 0.766 and Adjusted the Goodness of Fit Index (AGFI) as 0.747 which is acceptable. RMSEA is 0.047 which is well below the threshold limit of 0.08 indicating fair model fit. A comparison of fitness of goodness statistics is indicated in table below.

Table5.51: Fit statistics of Lean manufacturing practices performance - structural equation model

S. No.	Statistic measure for model fit	Specified values for model fit	Observations from the model
1	Chi-square test statistic (df)	df>1 for identified model, Chi-square/df between from1 to 5(Hu and Bentler, 1999)	1.723
2	RMSEA	0.08 to 0.10 signifies a adequate fit and below 0.08 indicates a good fit (MacCallum et al., 1996)	0.047
3	Goodness of fit index (GFI)	Varies from 0 to 1 with sample size higher with cut-off of 0.95 (Shevlin and Miles, 1998)	0.766
4	Comparative Fit Index(CFI)	CFI ≥ 0.95 is indicative of good fit (Hu and Bentler, 1999)	0.918
5	Normed Fit index (NFI)	NFI ≥ .9 (Hu and Bentler, 1999)	0.825
6	Tucker Lewis Index (TLI)	Good model fit values falls from .08 to 0.95 (Sharma et al., 2005)	0.914
7	Parsimonious Fit index (PFI)	0.5 to 0.9 (Mulaik et al., 1989)	0.788

5.4 CHAPTER SUMMARY

This chapter has covered two aspects of lean practice and performance parameters via modeling. First aspect has covered whether there is any inter-relationship between lean practices and performance parameters. Second aspect covers the exactness of correlation and measures the impact of lean practice and performance parameters on each other. In first portion, the inter relationship between the lean practices and performance parameters is identified and they are ranked based on their driving powers and dependence powers as determined through ISM. The practice and performance parameters discussed in previous chapter are considered for validation of the interrelationships. The implication of ISM is to validate whether the lean practices and performance parameters are interconnected or not. A factual correlation is established with MICMAC analysis and construct of ISM model. The understanding of the relationship developed in this chapter about different practice and performance parameters is relevant for professional, researchers and Indian industry for further work on the subject. The results of the study indicate that organisational performance in the form of operational and financial performance is driven by various factors of lean manufacturing practices. Performance parameters variables can only be improved when lean manufacturing parameters as bottom level variables are achieved showing strong dependency of performance parameters on dependent parameters as variables related to lean manufacturing implementation. The development of ISM model is based on opinion of few researchers and professionals and may have and has some element of bias, so the ISM model may be statically validated on wide base with collecting larger size data and employing SEM technique (Agarwal et al., 2006).

In the second aspect, the methodology for model building, data collection via various items and inter connecting the models is discussed. Detailed analysis of the data is performed related to implementation of lean manufacturing practices, operational performance and financial performance is covered viz. reliability test of the observed data, exploratory factor analysis and confirmatory factor analysis. A series of validation procedures was followed for each model for performing the validity test for the content, convergent discriminant and nomological validity tests. Consequently a valid structure is proposed for each construct viz. lean manufacturing practices, operational performance and financial performance measurement. Lean manufacturing practices construct covered seven factors covering 27 items, operational performance construct covered six factors covering 23 items and financial performance construct covered four factors 16 covering items. These measurement scales developed in this chapter can be helpful to professional and researchers for measuring the level of implementation of lean manufacturing, measuring the operational performance and financial performance with the help of allocated items under each factor. Individual score of each factor can also be measured to know that which particular aspect may cause trouble hence signifying plan for improvement. This may be helpful to monitor the performance periodically by comparing the results across the various time periods. Relative performance can also be measured among various factors indicating suggestions for improvements and finally these scales may be used for benchmarking which may be helpful in formulating the precise policy for further improvements.

CHAPTER VI

RESEARCH FINDINGS FROM SURVEY AND MODELS

6.1 INTRODUCTION

Research hypothesis was discussed in the chapter IV 'Survey of Indian industries' with various research propositions to measure the impact of lean manufacturing on organizational performance of Indian industries. Once hypothesis were developed, the accomplishment plan was prepared for identification of latent variables and sub-variables followed by items which may be specific to represent the latent variables by discussing with academia and professionals. The measurement models were developed for each major latent variables viz. lean manufacturing practices, operational performance and financial performance. The conceptual measurement models were designed to connect the variables in various combinations to measure the impact of variables on each other. In this research, ISM technique was used to observe the significance of each variable of lean manufacturing practices and organizational performance. Further, SEM technique was used for observing measurable impact of lean manufacturing on organizational performance in the context of Indian industries. The research advanced towards data collection instrument and survey administration. All the measurement models and structural equation models were tested for exploratory and confirmatory factory analysis to validate the data and model fitment.

6.2 INTERPERTATION OF RESULTS FROM ISM MODELS

In the literature review (section 2.10), one of the research gap was identified pertaining to the absence of established correlation between the factors responsible for lean manufacturing implementation and factors responsible for measurement of organizational performances factors in the context of Indian industries. It was observed that understanding and quantifying the correlation between individual practice and performance parameters is significantly important but is a complex challenge. ISM methodology was deployed for identifying the relationships among practice and performance parameters individually.

In this process the groups of people from academia, industries and consulting agencies were employed for structuring their collective knowledge to develop a logical map of the composite relationships between all the variables under study in the Indian industry context.

6.2.1 Out come from the ISM Model of lean manufacturing Practices

The ISM model of lean manufacturing Practices (figure 5.2) reveals that 5s and kaizen are the drivers of lean manufacturing practices.5s support kaizen, visual management, lost time analysis and autonomous maintenance for their implementation. Kaizen supports 5s, visual management, autonomous maintenance and value stream mapping. Visual management and autonomous maintenance are supported by 5s and kaizen simultaneously they facilitate lost time analysis, standard work and value stream mapping to get implemented. This reveals that 5s and kaizen are the starting point of lean implementation. This study suggests that 5s and kaizen should be practices at the initial phase followed by visual management and autonomous maintenance. After attaining reasonable level of mentioned parameters; lean practices of higher order i.e. lost time analysis, standard work and value stream mapping should be initiated for successful and uncomplicated implementation of lean manufacturing.

6.2.2 Out come from the ISM Model of Organizational Performance

The ISM model of organizational performance (figure 5.4) reveals that the productivity, quality and safety are the primary outcome of the improved efficiency of the manufacturing system. These three variables may further exaggerate the improvement in cost, delivery and morale of the employees. Quality drives productivity, cost, delivery and finally profitability. Productivity directly impacts cost, delivery, morale and profitability of the organization. Safety enhances the productivity by improving morale of the employees. It is revealed that to achieve improvement in delivery, morale and cost; organizations will have to make sure of the improvement in quality, productivity and safety. Hence Indian industries should keep monitoring the progress of the organizational performance through productivity, quality and safe working environment.

The model suggests that with the improved results in terms of morale, cost and delivery; higher order organizational performance may be achieved in the form of improved inventory turns ration, revenue growth, market share and finally profitability in the Indian industries context.

6.3 RESULTS FROM THE STRUCTURAL EQUATION MODELING OF LEAN MANUFACTURING PRACTICES, OPERATION PERFORMANCE AND FINANCIAL PERFORMANCE MODELS

In this section analysis of the measurement model and structural equation models has been done to establish the correlation between lean manufacturing and organizational performance. Three best possible scenarios have been modeled through SEM whose analysis have been presented in the following section.

6.3.1 Analysis of Measurement Model of Lean Manufacturing Practices

The model for measuring the lean manufacturing is discussed in section (4.6.4), consisting of seven dimensional factor structure. The questions developed in the section (4.6.5) emphasis on the pattern of the lean manufacturing implementation. More precisely, this construct is supposed to determine whether all the factors of lean manufacturing are implemented in a systematic manner or only a few factors are selected for implementation of lean manufacturing in Indian industry.

The validated model represents the level of lean manufacturing implementation in Indian industry as shown in figure 6.1. This construct measures the level of implementation of lean manufacturing in the organisation based on all the seven factors viz. 5s, kaizen, lost time analysis, visual management; autonomous maintenance, standard work and value stream mapping comprehensively represent the lean manufacturing practices. Regression analysis of path coefficient was done using Amos16. Where ever path coefficient is more than 0.5 it is significantly different than zero hence indicates the direct and strong relation. The lean manufacturing measurement model with standardized results is depicted below.

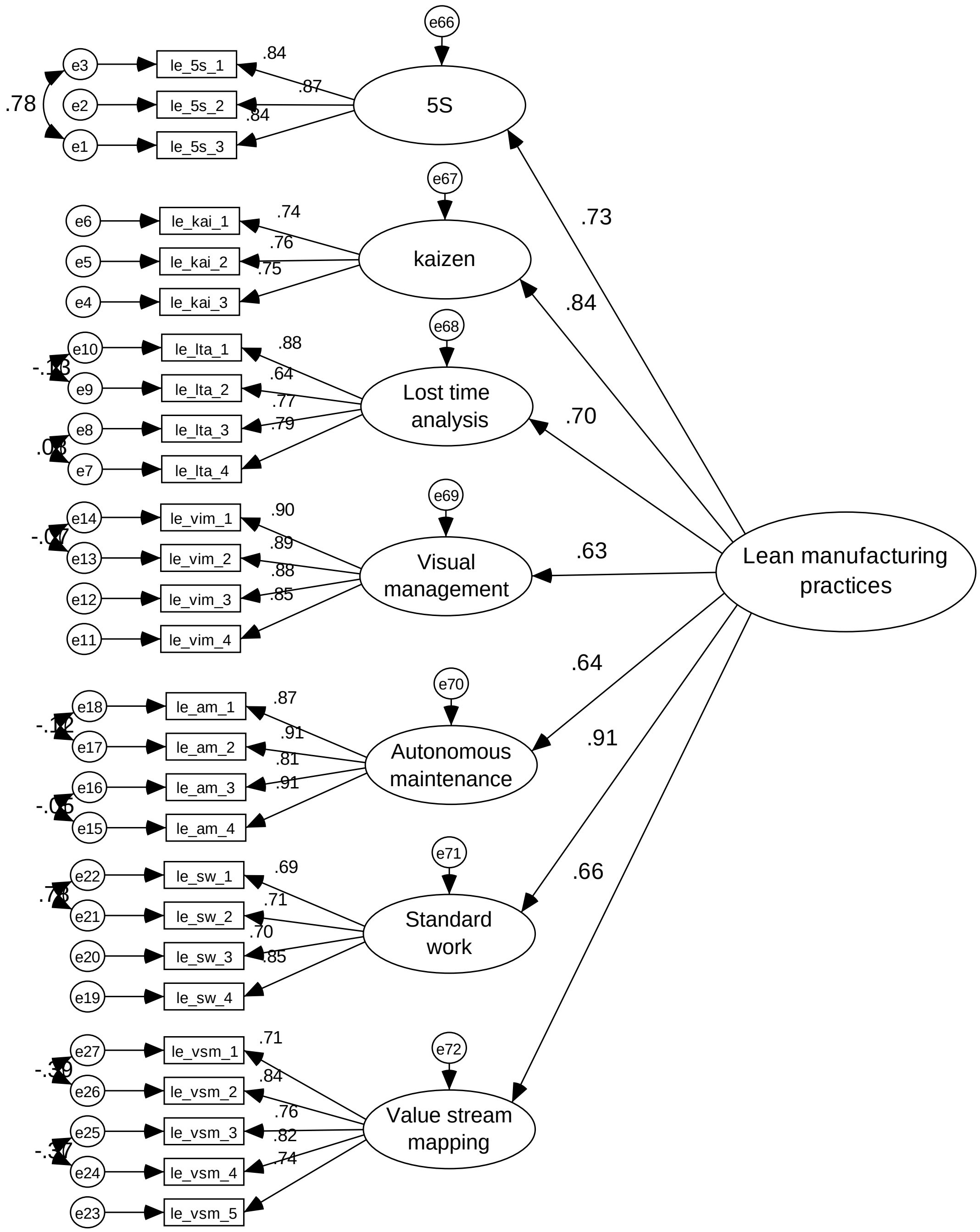


Figure 6.1: Result of Lean manufacturing practices Measurement model

5s is considerably associated with lean manufacturing practices with significance value of 0.73, kaizen with significance value of 0.84, lost time analysis with significance value of 0.70, visual management with significance value of 0.63, autonomous maintenance with significance value of 0.64, standard work with significance value of 0.91 and value stream mapping with significance value of 0.66.

Table 6.1: Results of regression analysis of individual items on lean manufacturing factors.

			Estimate
5S	<---	Lean	.730
kaizen	<---	Lean	.836
Lost time_ analysis	<---	Lean	.702
Visual_management	<---	Lean	.634
Autonomous_maintenance	<---	Lean	.644
Standard_work	<---	Lean	.911
Value stream_mapping	<---	Lean	.659
le_5s_3	<---	5S	.844
le_5s_2	<---	5S	.868
le_5s_1	<---	5S	.840
le_kai_3	<---	kaizen	.751
le_kai_2	<---	kaizen	.764
le_kai_1	<---	kaizen	.742
le_lta_4	<---	Lost time_ analysis	.793
le_lta_3	<---	Lost time_ analysis	.774
le_lta_1	<---	Lost time_ analysis	.877
le_vim_4	<---	Visual_management	.852
le_vim_3	<---	Visual_management	.875
le_vim_2	<---	Visual_management	.887
le_vim_1	<---	Visual_management	.895
le_am_4	<---	Autonomous_maintenance	.914
le_am_3	<---	Autonomous_maintenance	.807
le_am_2	<---	Autonomous_maintenance	.910
le_am_1	<---	Autonomous_maintenance	.872
le_sw_4	<---	Standard_work	.846
le_sw_3	<---	Standard_work	.705
le_sw_2	<---	Standard_work	.713
le_vsm_4	<---	Value stream_mapping	.824
le_vsm_3	<---	Value stream_mapping	.764
le_vsm_2	<---	Value stream_mapping	.844
le_vsm_5	<---	Value stream_mapping	.736
le_vsm_1	<---	Value stream_mapping	.706
le_lta_2	<---	Lost time_ analysis	.641
le_sw_1	<---	Standard_work	.695

Results of regression analysis are depicted in table 6.1 verifying the standard estimates of individual items on lean manufacturing factors shows that Individual items are quite well connected with the factors having path coefficients to the tune of 0.634 to 0.914 validating the suitability of the construct.

6.3.1.1 Analysis of Lean Manufacturing Factor Structure

The mean score and standard deviation of each item is calculated using SPSS 16.0 software. The mean score of factors were calculated taking average of mean scores of the items under each factor which were recorded on a five point Likert scale. Score 1 indicated 'no implementation' and 5 for 'full implementation' of lean manufacturing practices. The factor analysis revealed seven factors (5s, kaizen, lost time analysis, visual management, autonomous maintenance, standard work and value stream mapping) structure to measure implementation level of lean manufacturing practices in Indian industries. The key statistics of the seven factors is depicted in the table 6.2. The outcome of the results is summarized below:

[1] The first factor is 5S consisting of responses related to training, practice and monitoring. The factor contributes significantly to lean manufacturing practice with a factor mean value of 3.331. The respondents believe that practicing 5S is important to lean manufacturing. This dimension is in line with the researchers. (Chen and Hua Tan, 2011; Gurumurthy and Kodali, 2011; Rahman et al., 2010; Silva, 2012; Singh et al., 2009).

[2] Kaizen is the second factor of lean manufacturing practices which was measured on availability of kaizen scheme in the plant, practicing Kaizens and regular monitoring of kaizens through periodical meetings. Kaizen is strongly associated with lean manufacturing practices with a factor mean score of 3.334. Respondents has indicated the importance of kaizen for the implementation of lean manufacturing in line with the reports from research studies (Ahuja and Khamba 2008; Rahman et al 2010; Saraswat et al 2014; Chen and Hua Tan, 2011; Singh et al 2009; Singh et al., 2010;

Mohanty et al., 2006; Nordin et al., 2010; (Mohanraj et al., 2015)Mohanraj et al., 2015).

Table 6.2: Summary statistics of Lean Manufacturing factors

S. No.	Factor Name	Item	Item name	Mean	Std. Deviation	Factor mean
1	5 S	le_5s_ 1	5S training is delivered to each employee	3.381	0.823	3.331
		le_5s_ 2	5S is practiced throughout the plant.	3.257	0.901	
		le_5s_ 3	5S is monitored periodically and improvement actions are initiated	3.356	0.812	
2	Kaizen	le_kai_1	Suggestion scheme is in place and working.	3.424	0.907	3.334
		le_kai_2	Kaizen process is practiced by shop floor person.	3.285	0.870	
		le_kai_3	Kaizen meeting is held periodically	3.294	0.883	
3	Lost Time Analysis	le_lta_1	Lost time is monitored on bottle neck machines	3.310	0.832	3.325
		le_lta_2	Lost time data is anaysed and actions are initiated	3.375	0.852	
		le_lta_3	Setup time reduction is practiced on machine .	3.307	0.872	
		le_lta_4	Periodical review of bottleneck process or equipment is in place	3.310	0.847	
4	Visual management	le_vim_1	Equipments are identified with sinages	2.926	0.831	2.938
		le_vim_2	Process parameters are displayed on shop floor	2.929	0.855	
		le_vim_3	Andons are connected to equipments interventions	2.929	0.891	
		le_vim_4	Manufacturing performance is displayed on shop floor	2.969	0.856	
5	Autonomous maintenance	le_atm_1	Operators are involved in improving equipment conditions.	3.359	0.875	3.326
		le_atm_2	Equipment operational efficiency improvement projects	3.313	0.877	
		le_atm_3	Shop floor teams works for basic condition improvement of machines.	3.316	0.877	
		le_atm_4	There is a chase for reduction of cycle time	3.316	0.863	
6	Standard Work	le_sw_1	Cell balancing is evaluated periodically and actions are initiated	3.433	0.918	3.443
		le_sw_2	Standardised work instructions are available on work centers	3.464	0.882	
		le_sw_3	Work sequence and content are same even the operator changes	3.409	0.834	
		le_sw_4	Cellular manufacturing concept is employed in equipment layouting.	3.464	0.930	
7	Value stream mapping	le_vsm_1	Rate of production is controlled by customer requirement.	3.322	0.889	3.266
		le_vsm_2	Cycle time and operating efficiency is monitored periodically	3.195	0.960	
		le_vsm_3	Value stream mapping is performed periodically	3.254	0.825	
		le_vsm_4	FIFO is followed between production stations where ever designated.	3.130	0.927	
		le_vsm_5	Production lot formation is controlled by Heijunka system.	3.430	0.865	

[3] Third factor of lean manufacturing is lost time analysis which is measured on monitoring of bottleneck machines, lost time data analysis, setup time reduction and periodic review of bottleneck machines. The respondents have rated lost time analysis as the most significant factor in the implementation of lean manufacturing with a mean score value of 3.325. The results are in line with the researchers (Bekar et al., 2012; Chen and Ronald, 2012; Dombrowski et al., 2012; Wong et al 2009; Nordin et

al., 2011; Antony and Desai, 2009; Ferdousi and Ahmed, 2009; Narain et al., 2004; Kengar et al., 2013; Deif, 2012; Joshi and Naik, 2012).

[4] Visual management is the fourth factor which is assessed for its implementation with the identification of equipments, visually displaying of the process parameters, availability of equipments and display of manufacturing performance on the shop floor. The factor has been assessed by respondents for the implementation of lean manufacturing with the mean score of 2.938.

[5] Autonomous maintenance is measured on involvement of operators in improving basic condition of the equipments, improving equipment efficiencies and sensing the urgency of cycle time reduction. The factor score is observed as 3.326 signifying the significance of the factor in lean manufacturing implementation in line with the researchers (Ahuja and Khamba, 2008; Wong et al., 2009; Nordin et al., 2011; Antony and Desai, 2009; Ferdousi and Ahmed, 2009).

[6] Standard work is measured on cell balancing, work standardization, work content sequencing and implementation of cellular manufacturing. The factor score is observed 3.443 indicating relevance of standard work factor in the implementation of lean manufacturing. (Singh et al., 2010; Vikas et al., 2004; Joshi and Naik, 2012).

[7] Seventh factor of lean manufacturing is value stream mapping which is observed on customer driven manufacturing, monitoring of processing time, and periodical review of value stream, implementation of FIFO lines and implementation of Heijunka for batch formation. The factor mean is scored to the tune of mean value of 3.266 representing the importance of the factor in lean manufacturing implementation as discussed by researchers (Ahuja and Khamba, 2008;Silva, 2012;Singh et al., 2010; Vikas, 2010; Mohanty et al., 2006; A, Kumar et al., 2013).

6.3.2 Analysis of Conceptual Measurement Model of Operational Performance

The validated measurement model (as discussed in earlier section 5.3.2) of operational performance consisting six dimensional factor structures represents the level of operational performance of Indian industry in figure 6.2. The construct is aimed to measure the status of operational performance in Indian industry. The six factors viz. productivity, quality, cost, delivery, safety and morale are closely associated with representation of operational performance. Regression analysis of path coefficient was calculated using Amos 16. The operational performance measurement model with standardized results is depicted below.

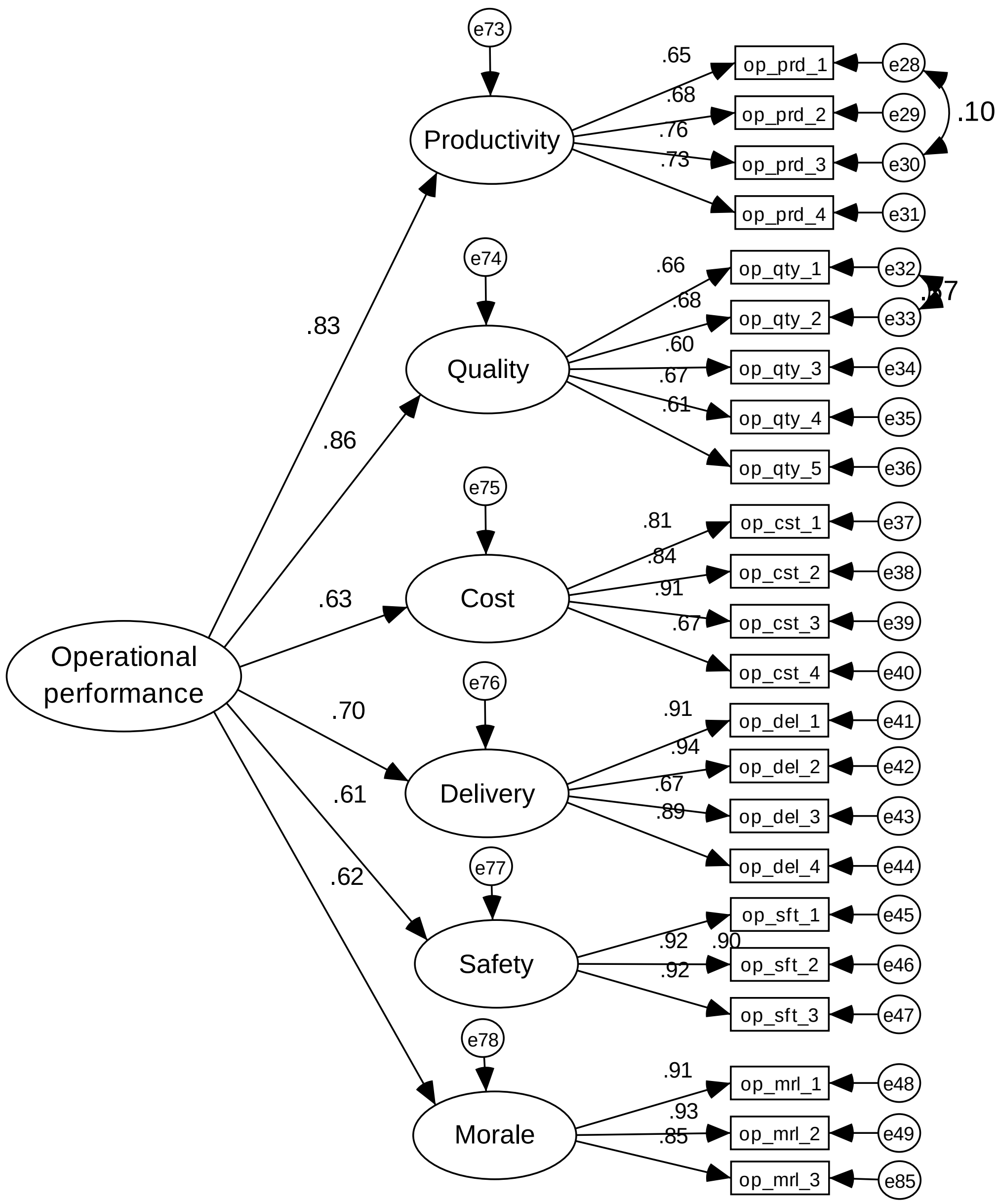


Figure 6.2: Results of operational performance Measurement model

Productivity is considerably associated with operational performance with significance value of 0.83, quality with significance value of 0.86, cost with significance value of 0.63, delivery with significance value of 0.70, safety with significance value of 0.61, morale with significance value of 0.62. Table 6.3 shows that Individual items are quite well connected with the factors having path coefficients to the tune of 0.599 to 0.933 validating the direct and strong correlation.

Table 6.3: Results of regression analysis for individual items on operational performance factors.

			Estimate
Productivity	<---	Operational_performance	.827
Quality	<---	Operational_performance	.858
Cost	<---	Operational_performance	.630
Delivery	<---	Operational_performance	.701
Safety	<---	Operational_performance	.610
Morale	<---	Operational_performance	.615
op_prd_1	<---	Productivity	.646
op_prd_2	<---	Productivity	.685
op_prd_3	<---	Productivity	.760
op_prd_4	<---	Productivity	.731
op_qty_1	<---	Quality	.658
op_qty_2	<---	Quality	.678
op_qty_3	<---	Quality	.599
op_qty_4	<---	Quality	.667
op_qty_5	<---	Quality	.613
op_cst_1	<---	Cost	.813
op_cst_2	<---	Cost	.839
op_cst_3	<---	Cost	.910
op_cst_4	<---	Cost	.669
op_del_1	<---	Delivery	.911
op_del_2	<---	Delivery	.936
op_del_3	<---	Delivery	.669
op_del_4	<---	Delivery	.886
op_sft_1	<---	Safety	.896
op_sft_2	<---	Safety	.925
op_sft_3	<---	Safety	.922
op_mrl_1	<---	Morale	.906
op_mrl_2	<---	Morale	.933
op_mrl_3	<---	Morale	.851

6.3.2.1 Analysis of Operational Performance Factor Structure

The mean score and standard deviation of each item is calculated using SPSS 16.0 software. The mean score of Factors were calculated taking average of mean scores of the items under each factor which were recorded on a five point Likert scale. Score I indicated ‘no gain’ and 5 for ‘full gain’ of the operation performance. The results are depicted in Table 6.4. The factor analysis revealed six factors (productivity, quality, cost, delivery, safety and morale) structure to measure operation performance of the Indian industries. The key statistics of the six factors are summarized in the table.

Table 6.4: Summary statistics of Operational Performance factors

S. No.	Factor name	Item	Item name	Mean	Std. Deviation	Factor mean
1	Productivity	op_prd 1	Changeover time reduction	3.230	0.805	3.220
		op_prd 2	Increase in productivity	3.270	0.859	
		op_prd 3	Reduction in unplanned breakdown	3.240	0.912	
		op_prd 4	Improvement in OEE	3.140	0.975	
2	Quality	op_qlt 1	Reduced inspection,	3.240	0.849	3.288
		op_qlt 2	Reduced rework,	3.240	0.864	
		op_qlt 3	Reduced scrap	3.450	0.884	
		op_qlt 4	Reduced numers of customer complaints	3.210	0.869	
		op_qlt 5	Reduced cost of poor quality (COPQ)	3.300	0.896	
3	Cost	op_cst 1	Reduction in inventory cost	3.200	0.872	3.190
		op_cst 2	Reduction in distribution expenses	3.140	0.885	
		op_cst 3	Raw material yield improvement	3.150	0.871	
		op_cst 4	Reduction in utility cost	3.270	0.916	
4	Delivery	op_dly 1	Improved delivery rating of supplier	3.150	0.833	3.143
		op_dly 2	Improved delivery rating to customer	3.130	0.820	
		op_dly 3	Reduced throughput time	3.110	0.805	
		op_dly 4	Improved flexibility	3.180	0.803	
5	Safety	op_sty 1	Reduced numbers of first aid cases	3.240	0.810	3.240
		op_sty 2	Reduced numbers of accidents	3.240	0.821	
		op_sty 3	Improved actions on safety improvement	3.240	0.841	
6	Morale	op_mrl 1	Improved core competencies of employee	3.330	0.869	3.337
		op_mrl 2	Increse in no. of kaizens per head	3.300	0.848	
		op_mrl 3	Employees participation in trainings	3.380	0.849	

[1] The first factor is productivity which is measured on the basis of the responses related to improvement in changeover time reduction, increase in productivity, reduction of unplanned breakdown and improvement of OEE. The factor is observed as improved operational performance with a factor mean value 3.220. The respondents indicated

the importance of productivity in measuring operational performance in line with the researchers (Narain et al., 2004; Kumar et al., 2013; Oehmen et al., 2012).

[2] Second factor of operational performance is quality which is measured with measuring the reduction of inspection, rework, scrap, customer complaints and cost of poor quality. The respondents have indicated the quality as the most significant factor in the operational performance with a mean score value of 3.288. The results are in line with the researchers (Rahman et al., 2010; Saraswat et al., 2014; Kumar et al., 2013, Oehmen et al., 2012)

[3] The third factor of operational performance measurement is the cost measured through the reduction of inventory cost, reduction of distribution cost, reduction of raw material cost and improved utility cost. Cost has strong relation with operational performance measures with mean score of 3.190. Respondents have indicated the importance of cost for the measurement of operational performance in line with the researchers (Chen and Ronald, 2012; Rahman et al., 2010; Anand and Kodali, 2008; Saraswat et al., 2014; Joshi and Naik, 2012).

[4] Delivery to customer is the fourth factor which is assessed for operational performance. The delivery is measured with the deliver rating improvement with the customer and improvement of delivery rating of the supplier, reduced through put time and improved flexibility. The delivery has been assessed by respondents for the operational performance with the mean score of 3.143. In line with the researchers (Bekar et al., 2012; Chen and Ronald, 2012; and Silva, 2012).

[5] Safety as a factor of operational performance is measured on reduced numbers of first aid cases, reduction in number of accidents and actions implemented for the improvement of safety. The factor score is observed as 3.240 notifying the significance of this factor in operational performance as discussed by researchers (Bekar et al., 2012; Anand and Kodali, 2008; Oehmen et al., 2012).

[6] Morale is the sixth factor of operational performance measured for improvement of core competencies of the employees increased number of Kaizens per head and increased involvement of employees in trainings. The factor score is observed 3.337 indicating relevance of morale as factor of operational performance as discussed by

researchers (Dombrowski et al., 2012; Anand and Kodali, 2009;Upadhye et al., 2010; Ferdousi and Ahmed, 2009).

6.3.3 Analysis of Conceptual Measurement Model of Financial Performance

The validated measurement model (as discussed in earlier section 5.3.2) of financial performance consisting four dimensional factor structures represents the level of operational performance of Indian industry in figure 6.3. The construct is aimed to measure the status of financial performance in Indian industry. The six factors viz. inventory turns, revenue growth, profitability and share of business are closely associated with representation of financial performance. Regression analysis of path coefficient was calculated using Amos16. The financial performance measurement model with standardized results is depicted below.

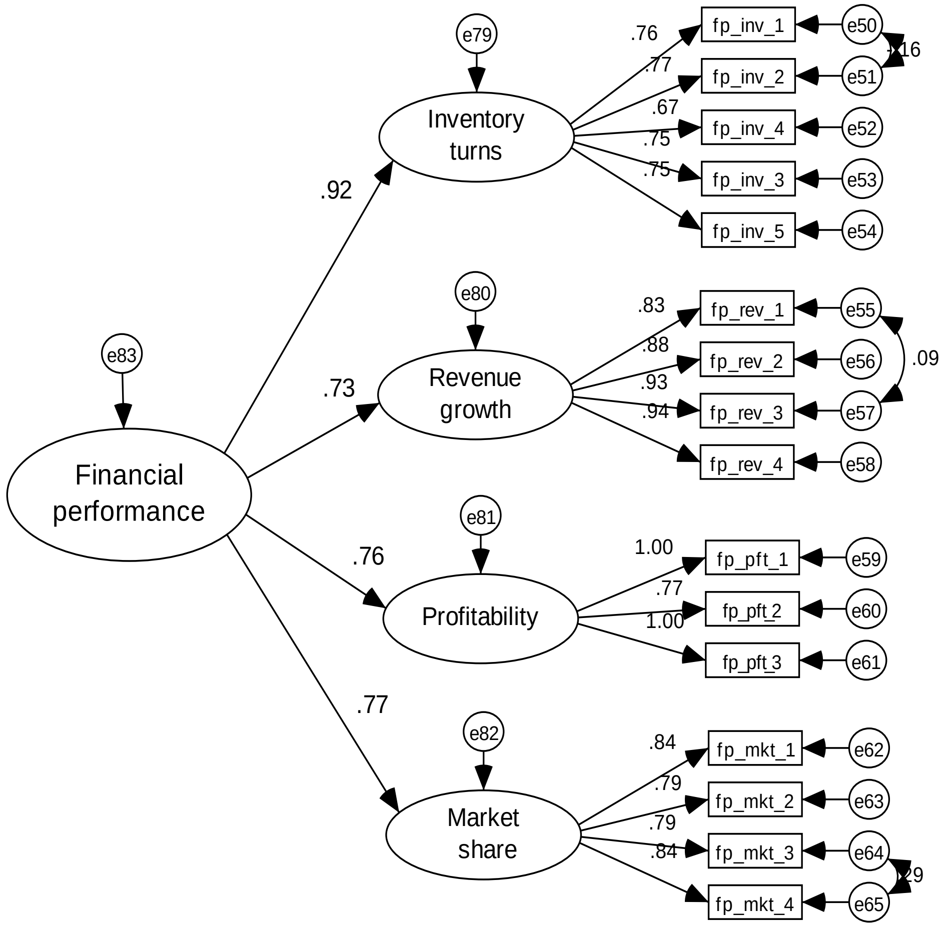


Figure 6.3: Results of financial performance Measurement model

Inventory turns is considerably associated with financial performance with significance value of 0.92, revenue growth with significance value of 0.73, profitability with significance value of 0.76, share of business with a significance value of 0.77. Table 7.5 shows that Individual items are quite well connected with the factors having path coefficients to the tune of 0.672 to .996 validating the suitability of the construct.

Table 6.5: Results of regression analysis to verify the standard estimates of individual items on financial performance factors.

			Estimate
Inventory_turns	<---	Financial_performance	.922
Revenue_growth	<---	Financial_performance	.733
Profitability	<---	Financial_performance	.757
Market_ share	<---	Financial_performance	.771
fp_inv_1	<---	Inventory_turns	.757
fp_inv_2	<---	Inventory_turns	.770
fp_inv_4	<---	Inventory_turns	.672
fp_inv_3	<---	Inventory_turns	.750
fp_inv_5	<---	Inventory_turns	.747
fp_rev_1	<---	Revenue_growth	.828
fp_rev_2	<---	Revenue_growth	.885
fp_rev_3	<---	Revenue_growth	.932
fp_rev_4	<---	Revenue_growth	.943
fp_pft_1	<---	Profitability	.998
fp_pft_2	<---	Profitability	.772
fp_pft_3	<---	Profitability	.996
fp_mkt_1	<---	Market_ share	.837
fp_mkt_2	<---	Market_ share	.792
fp_mkt_3	<---	Market_ share	.791
fp_mkt_4	<---	Market_ share	.842

6.3.3.1 Analysis of Financial Performance Factor Structure

The mean score and standard deviation of each item is calculated using SPSS 16.0 software. The mean score of factors were calculated taking average of mean scores of the items under each factor which were recorded on a five point Likert scale. Score 1 indicated ‘no gain’ and 5 for ‘full gain’ of financial results. The results are depicted in Table 6.6. The factor analysis revealed four factors (inventory turns, revenue growth, profitability and share of business) structure to measure financial performance of the Indian industries. The key statistics of the four factors are summarized in the table.

Table 6.6: Summary statistics of Financial Performance factors

S. No.	Factor name	Item	Item name	Mean	Std. Deviation	Factor mean
1	Inventory turns	fp_inv 1	Inventory analysis is performed periodically	2.901	0.927	2.939
		fp_inv 2	Product follows unidirectional flow while manufacturing.	2.966	0.976	
		fp_inv 3	Production order is generated by next station through pull system.	2.985	0.967	
		fp_inv 4	Inventory turns is improving year over year	2.845	0.978	
		fp_inv 5	Overall reduction in inventory cost year over year	2.997	0.980	
2	Revenue growth	fp_rev 1	Increase in revenue per customer	2.898	0.990	2.829
		fp_rev 2	Increase in revenue year over year	2.783	1.035	
		fp_rev 3	Increase in product price with value addition	2.827	1.016	
		fp_rev 4	Adding of revenue source	2.808	0.978	
3	Profitability	fp_pft 1	Increase in profitability of plant	2.941	0.942	2.925
		fp_pft 2	Return on working asset (ROWA)	2.889	0.939	
		fp_pft 3	Improved cash flow	2.944	0.941	
4	Market share	fp_msa 1	Existing customer are retained	2.882	1.083	2.858
		fp_msa 2	Increase in demand from customers	2.789	1.030	
		fp_msa 3	Increase in share of business per customer	2.845	1.115	
		fp_msa 4	Added new customers	2.913	1.086	

[1] The first factor is inventory turns consisting of periodical inventory analysis, unidirectional flow of value stream, ordering via pull system, improvement in inventory turns over the years and overall reduction of inventory cost. The factor is observed contributing to financial performance with a factor mean value 2.939. The respondents believe that inventory turns is important to financial performance . This dimension is in line with the researchers (Chen and Tan 2011; Upadhye et al., 2010; Ferdousi and Ahmed, 2009).

[2] Second factor of financial performance measure is revenue growth which is measured with increase of revenue per customer, increase of revenue year over year, increase in product price and adding the new source of revenue. Inventory turns is strongly associated with financial performance with a factor mean score of 2.829. Respondents have indicated the importance of revenue turns in the financial performance in line with the researchers (Singh et al., 2009; Chowdary and George, 2011; Upadhye et al., 2010; and Oehmen et al., 2012).

[3] Third factor of financial performance is profitability which is measured on improvement in profitability of the plant, return on working asset, overall increase in profits and improved cash flow. The respondents have indicated the profitability as the most significant factor in the implementation of financial performance with a mean score value of 2.925. The results are in line with the researchers (Anand and Kodali, 2009; Antony and Desai, 2009).

[4] Market share is the fourth factor which is assessed for measurement of financial performance with the measure of customer retention rate, increase share of business per customer and addition of new customer. The factor has been evaluated significant by respondents for the financial performance with the mean score of 2.858. The results are in line with the researchers (Anand and Kodali, 2009; Antony and Desai, 2009).

6.4 ANALYSIS OF THE STRUCTURAL EQUATION MODEL OF LEAN MANUFACTURING PRACTICES VERSUS FINANCIAL PERFORMANCE

Originally Lean Manufacturing was developed with the intention to improve operational efficiencies by keeping lower inventories and improving productivity, cost, deliveries and product quality (Chowdary and George, 2011). In fact, industries are always looking for innovative ways to get competitive edge over their competitors. Nowadays, increasing global competition has further increased the intensity of the search for innovative ways of cost reduction by eliminating non value adding activities to stay alive in the competitive world (Kumar V, 2010). Lean Manufacturing is the system industries are looking for reducing product cost and increasing quality (Dombrowski et al., 2012). Indian industries are looking for improving operational efficiencies with innovative manufacturing methods to keep themselves competitive in their market segment (Ahuja & Khamba, 2008). Indian industries have started adopting lean manufacturing, derived from extensive benefits gained by companies who have implemented lean manufacturing and enhanced their manufacturing operational performance (Upadhyay et al., 2010). Lean Manufacturing is illustrated from two viewpoints, one from a theoretical viewpoint associated to philosophical guidelines and second a practical viewpoint describing lean manufacturing practices and finally the outcomes (Li et al., 2005; Shah and Ward, 2003) . This research has validated the individual importance of each factor in the lean manufacturing implementation and each factor contributing to the organizational performance of the organization in the previous section. The impact of lean manufacturing practices on operational performance was tested using Amos 16.0 software.

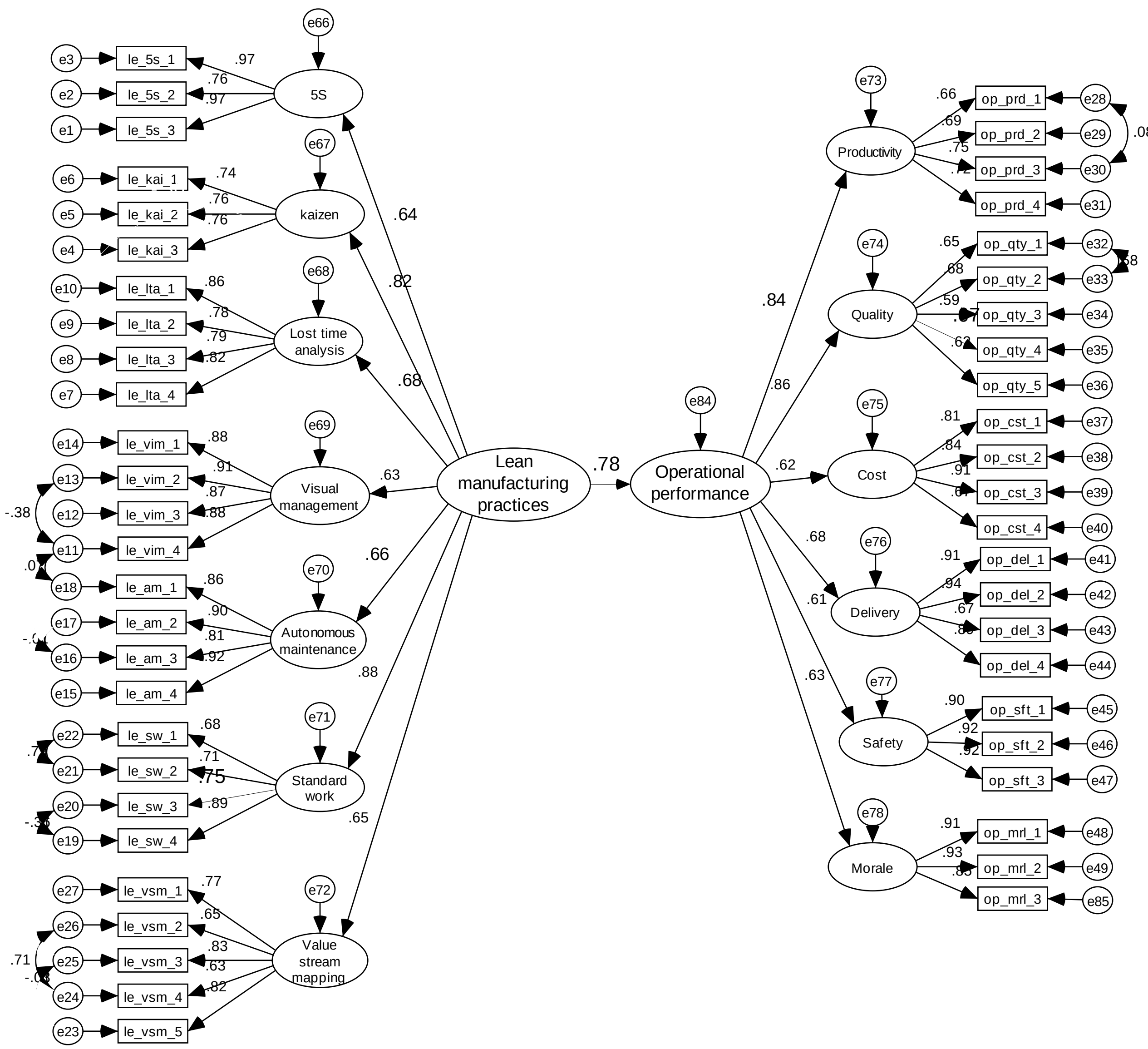


Figure 6.4: Structural equation modeling output of Amos 16 -- measuring impact of Lean manufacturing practices comparing on operational performance

The Amos was run to obtain the results. Confirmatory factor analysis was performed to measure the validity of the model fit and results have been discussed in previous section. Key findings from structural equation model are discussed below:

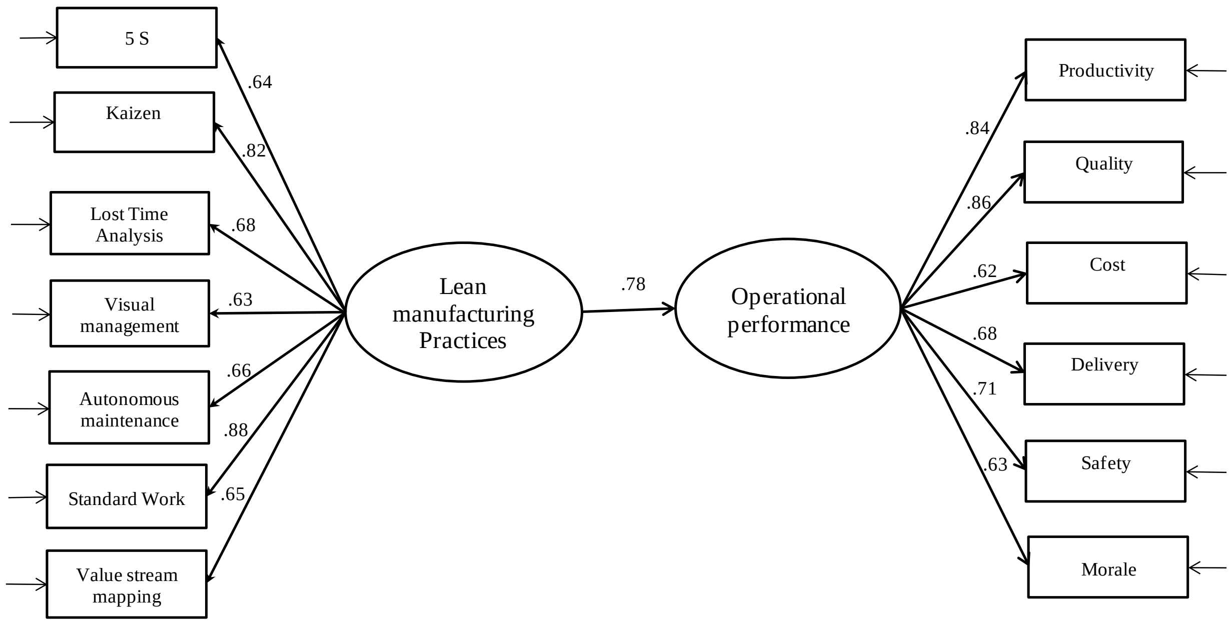


Figure 6.5: Results of conceptual model for examining relation between lean manufacturing practices and operational performance.

6.4.1 Major Research Findings from the Model

1. Overall impact of lean manufacturing implementation on operational performance is denoted by path coefficient value of 0.78 which is significant. The results revealed that there is a major change in operational performance in Indian industry with the implementation of lean manufacturing in line with the researchers (Boppana V. Chowdary and Damian George, 2011; Upadhye et al., 2010). Hypothesis was tested with the development of structural equation modeling for measuring the impact of lean manufacturing practices on operational performance of Indian industry. The results are summarized below:

S. No.	Hypothesis	Results
H1	Lean manufacturing practices implementation has significant impact on operational performance of manufacturing organizations in Indian context	Alternate hypothesis accepted

2. Lean manufacturing practices is well supported with the implementation of all the seven factors viz. 5S, kaizen, visual management, lost time analysis, standard work,

autonomous maintenance and value stream mapping. The strength of correlation between lean factors and lean manufacturing is validated with estimated regression weight values from 0.63 as low and 0.88 as high. This is significant and signifies that lost time analysis and implementation of standard work plays significant role in lean manufacturing implementation among the Indian industry. Still 5s and value stream mapping has been implemented with lesser effectiveness. Results of hypothesis measuring the contribution of individual enabler in establishing the level of lean manufacturing implementation is depicted below:

S. No.	Hypothesis	Results
$H1a_1$	'**5S**' enables lean manufacturing practices significantly	Alternate hypothesis accepted
$H1a_2$	'**Kaizen**' enables lean manufacturing practices significantly.	Alternate hypothesis accepted
$H1a_3$	**Lost time analysis**' enables lean manufacturing practices significantly.	Alternate hypothesis accepted
$H1a_4$	'**Visual management**' enables lean manufacturing practices significantly	Alternate hypothesis accepted
$H1a_5$	'**Autonomous maintenance**' enables lean manufacturing practices significantly.	Alternate hypothesis accepted
$H1a_6$	'**Standard work**' enables lean manufacturing practices significantly.	Alternate hypothesis accepted
$H1a_7$	**Value stream mapping**' enables lean manufacturing practices significantly.	Alternate hypothesis accepted

3. Operational performance is well measured with contribution of all six factors effectively and is validated with the estimated regression weight from 0.62 as minimum and 0.86 as maximum. Quality, productivity and deliveries has been observed as high gainer with the estimated regression weight of 0.86, 0.84 and 0.68

signifying that the Indian industry has gained to a large extent on quality and productivity front after implementation of lean manufacturing practices. Cost, safety and morale are also gained significantly with the lean manufacturing implementation with the estimated regression weight of 0.62, 0.71 and 0.63. Results of hypothesis measuring the contribution of individual performance parameter in establishing the operational performance of the industry, the following are results of hypothesis.

S. No.	Hypothesis	Results
H1b$_1$	**'Productivity**' significantly impacts the operational performance of the organization.	Alternate hypothesis accepted
H1b$_2$	'**Quality**' significantly impacts the operational performance of the organization.	Alternate hypothesis accepted
H1b$_3$	'**Cost** 'significantly impacts the operational performance of the organization.	Alternate hypothesis accepted
H1b$_4$	'**Delivery**' significantly impacts the operational performance of the organization	Alternate hypothesis accepted
H1b$_5$	'**Safety**' significantly impacts the operational performance of the organization.	Alternate hypothesis accepted
H1b$_6$	**Morale**' significantly impacts the operational performance of the organization	Alternate hypothesis accepted

6.5 ANALYSIS OF THE RESULTS OF STRUCTURAL EQUATION MODEL FOR MEASURING IMPACT OF LEAN MANUFACTURING PRACTICES ON FINANCIAL PERFORMANCE

Originally Lean Manufacturing was developed with the intention to improve business financial performance through improved inventory turn ratio, improved profitability, retaining share of business and revenue growth (Kumar and Kumar, 2015). The impact of lean manufacturing on overall business performance has been validated globally and found to be having a significant relationship(Easton and Jarrell, 1998; Fullerton and Wempe, 2009; Kinney and Wempe, 2002). With the observed results from the study it is indicated that there is a strong empirical and logical and direct causal relationship between lean manufacturing practices and financial performance measures. This research has validated the individual importance of each factor contributing to represent the financial performance of the organization in the previous section. The impact of lean manufacturing practices on financial performance was tested using Amos 16.0 software.

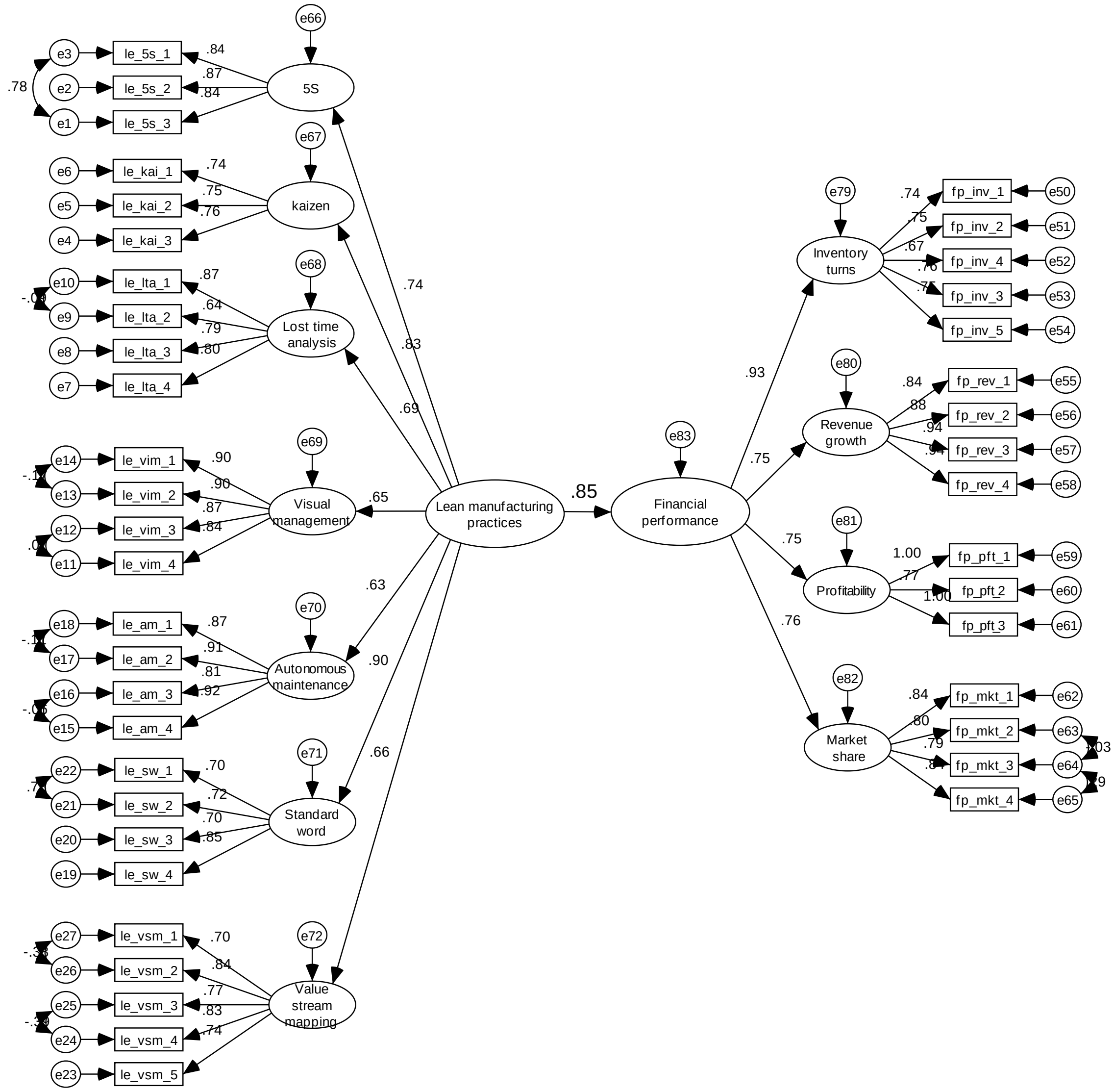


Figure 6.6: Structural equation modeling output of Amos 16 -- measuring impact of Lean manufacturing practices

The Amos was run to obtain the results. Confirmatory factor analysis was performed to measure the validity of the model fit and results has been discussed in previous section. Key findings from structural equation model of lean manufacturing practices on financial performance are discussed below:

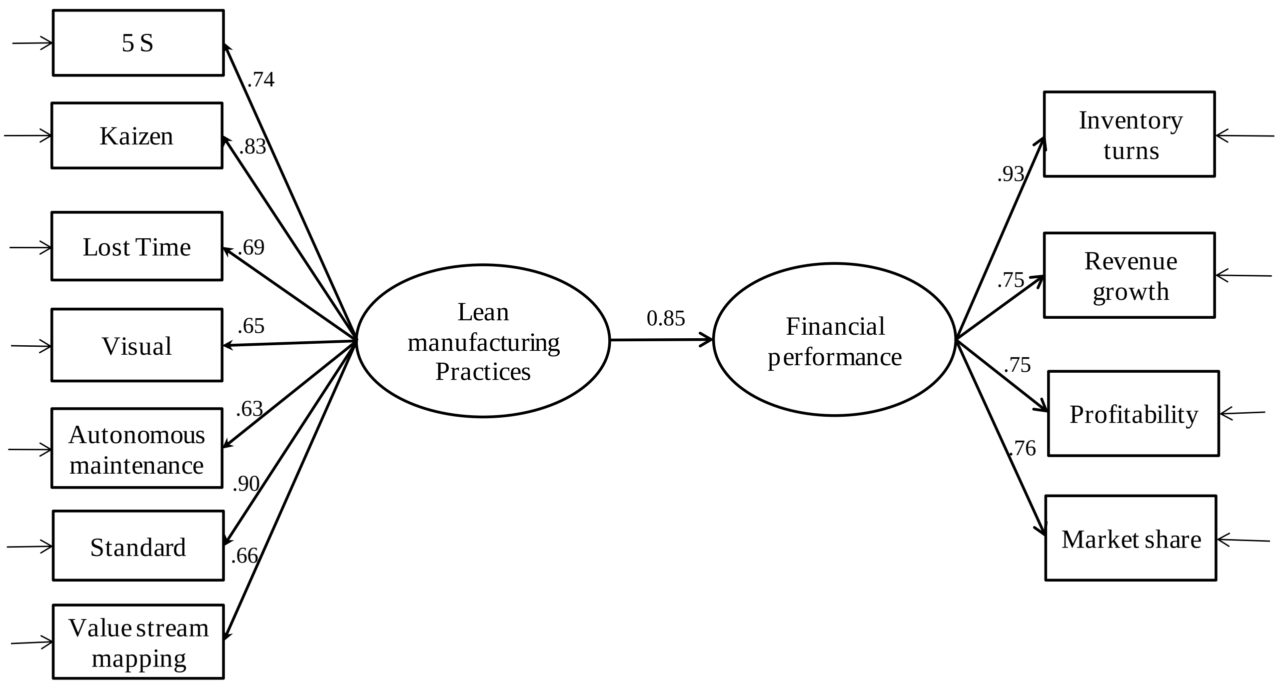


Figure 6.7: Results of conceptual model for examining relation between lean manufacturing practices and financial performance.

6.5.1 Major Research Findings from the Model

[1] Lean manufacturing practices is well supported with the implementation of all the seven factors viz. 5S, kaizen, visual management, lost time analysis, standard work, autonomous maintenance and value stream mapping as discussed in previous section . The strength of correlation between lean factors and lean manufacturing is validated with estimated regression weight values from 0.63 as low and 0.90 as high. This is significant and signifies that lost time analysis and implementation of standard work plays significant role in lean manufacturing implementation among the Indian industry. Still 5S and value stream mapping has been implemented with lesser effectiveness.

[2] Overall impact of lean manufacturing implementation on financial performance is denoted by path coefficient value of 0.85 indicating significance of the influence. The results revealed that there is major change in financial performance in Indian industry and has observed result in line with the earlier researches (Boyd, 1991; Easton and Jarrell, 1998; Huson and Nanda, 1995) indicating a significant relationship with financial performance.

S. No.	Hypothesis	Results
H2	Lean manufacturing practices implementation has significant impact on financial performance of manufacturing organizations in Indian context	Alternate hypothesis accepted

[3] Financial performance is measured with contribution of all four factors effectively and is validated with the estimated regression weight from 0.75 as revenue growth and profitability as minimum to 0.93 for gain in inventory turn ratio improvement and market share as maximum with gain in market share to the tune of 0.76.

S. No.	Hypothesis	Results
H2c$_1$	'**Inventory turns ratio**' significantly impacts the financial performance of the organization.	Alternate hypothesis accepted
H2c$_2$	'**Revenue growth**' significantly impacts the financial performance of the organization.	Alternate hypothesis accepted
H2c$_3$	'**Profitability**' significantly impacts the financial performance of the organization.	Alternate hypothesis accepted
H2c$_4$	'**Share of businesses'** significantly impacts the financial performance of the organization.	Alternate hypothesis accepted

6.6 ANALYSIS OF THE RESULTS OF STRUCTURAL EQUATION MODEL FOR MEASURING IMPACT OF OPERATIONAL PERFORMANCE ON FINANCIAL PERFORMANCE

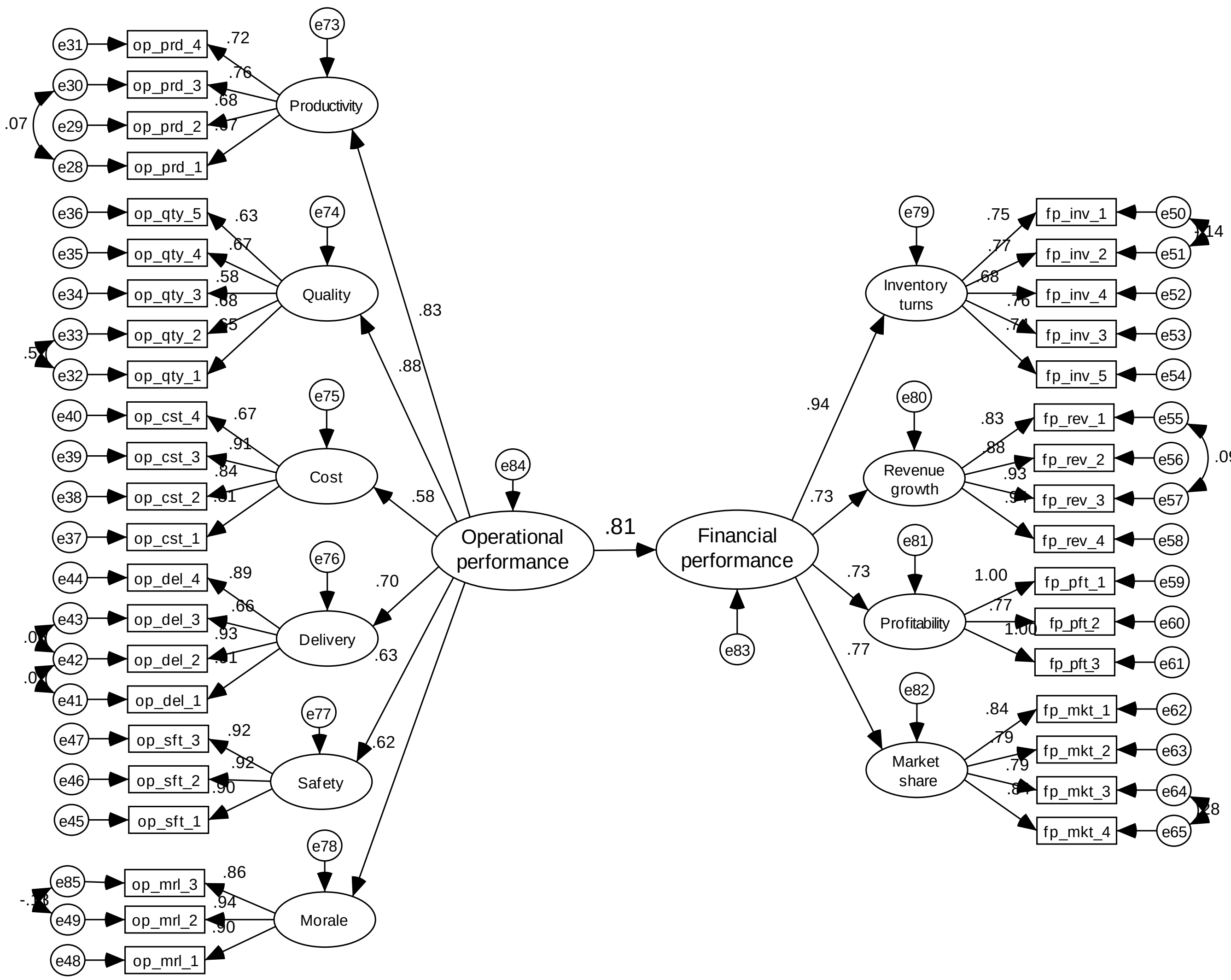


Figure 6.8: Structural equation modeling output of Amos 16 -- measuring impact of operational performance on financial performance

Implementation of lean manufacturing is supposed to improve business financial performance through improved operational efficiencies. Improved operational may not be the only factor in improved financial performance but plays a significant role in improved financial performance. Based on literature review and exploratory interviews this research proposed the proposition that operational performance has significant impact on financial performance of manufacturing organizations in Indian context. To validate the hypothesis the measurement models were connected to form the structural equation to gauge the impact of operational on financial performance using Amos 16.0 software. The result of model is depicted in figure 7.8

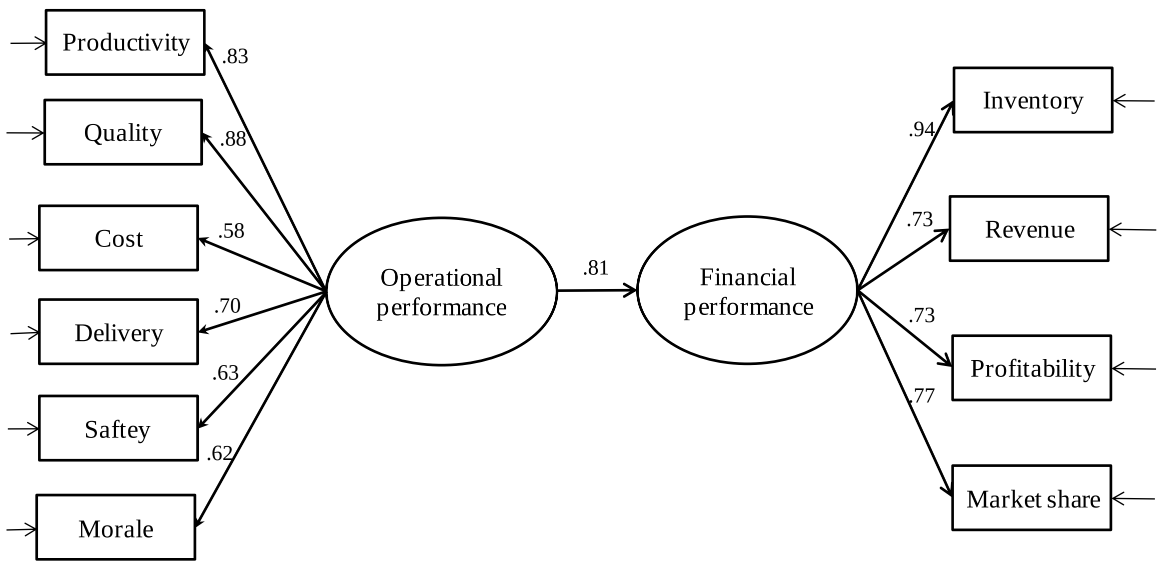


Figure 6.9: Results of conceptual model for examining relation between operational performance and financial performance model for the Indian manufacturing organizations.

6.6.1 Major Research Findings from the Model

[1] As discussed in previous sections about the significance of role of factors of operational performance and factors of financial performance. All the factors has contribution with the regression weight from 0.58 to 0.88 in operation factors and from 0.73 to 0.94 in the factors of financial performance measurement indicating strong connect between latent variables and measured variables.

[2] The path coefficient between operational performance and financial performance is 0.81 indicating the strong relation between operational performance and financial performance. Results of hypothesis measuring the impact of operational performance on financial performance of the industry, the following are results of hypothesis.

S. No.	Hypothesis	Results
H3	Operational performance has significant impact on financial performance of manufacturing organizations in Indian context.	Alternate hypothesis accepted

6.7 INTEGRATING LEAN MANUFACTURING PRACTICES, OPERATION PERFORMANCE AND FINANCIAL PERFORMANCE

Three measurement models were developed in the chapter number IV. These models were lean manufacturing practice model, operational [performance model and financial performance model.

This chapter examines the relationships between each of these measurement models. Figure 6.10 represents the relationships observed between the lean manufacturing practice models to operational performance model, manufacturing practice model to financial performance model operational performance model to financial performance model. The SEM model in Figure 6.10 to examine the relation between lean manufacturing practice, operational performance and financial performance is developed through the result output using Amos 16.

The validated results of conceptual model represents the seven factors of lean manufacturing implementation, six factors representing operational performance and four factors representing financial performance. Lean manufacturing has impact on operational performance with a path coefficient of 0.78 which is significantly different than zero hence indicating direct and strong impact, lean manufacturing practices having path coefficient of 0.53 with financial performance direct and positive relationship and operational performance having path coefficient with financial performance to the tune of 0.40 presenting significant impact in the context of Indian industries.

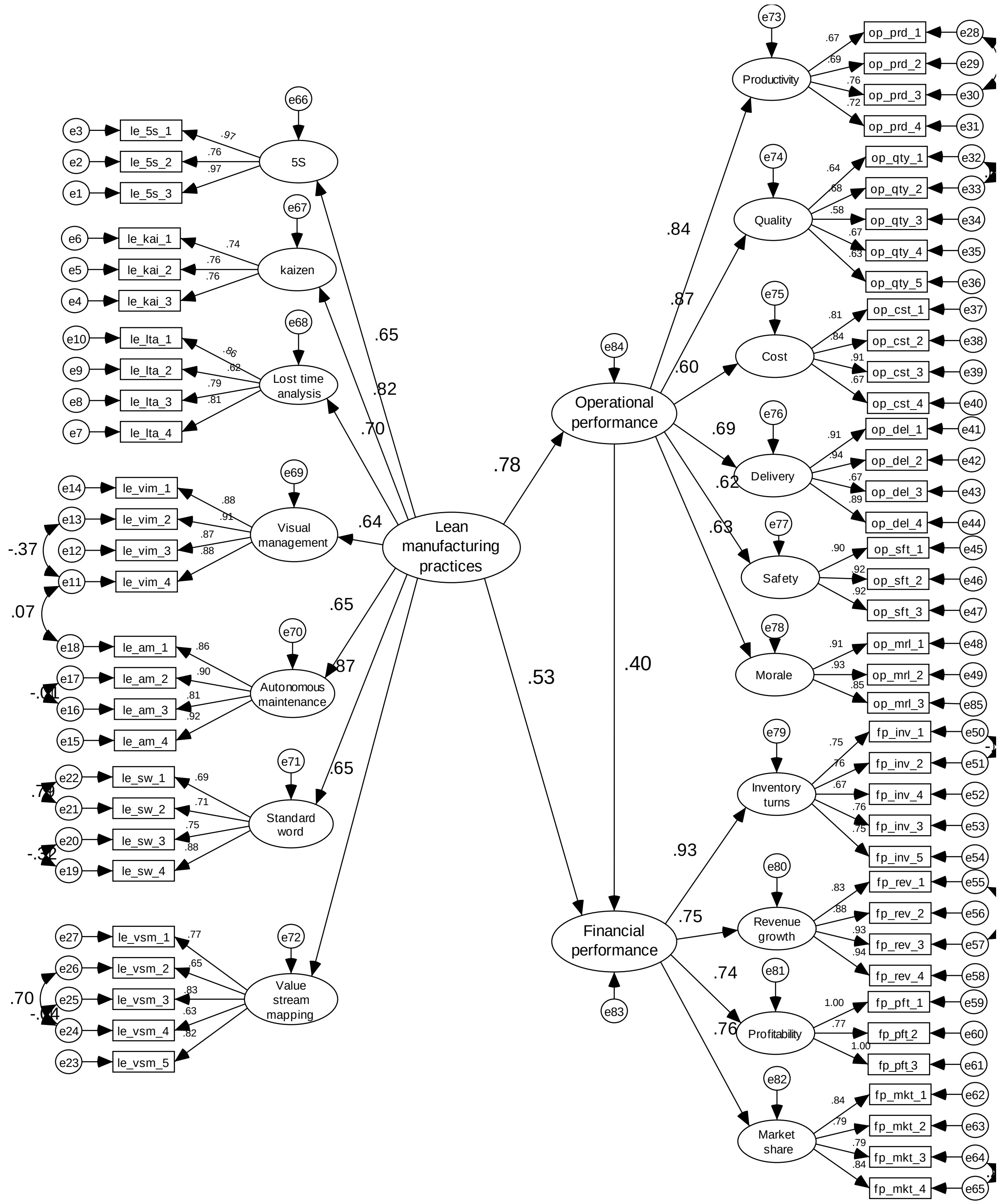


Figure 6.10: Structural equation modeling output of Amos 16 – measuring impact of lean manufacturing practices on operational performance and financial performance

For ease of understanding; an conceptual model (Figure 6.11) is derived from the SEM model for examining relation between implementation of lean manufacturing and its impact on organizational performance in both the measures i.e. operational and financial performance.

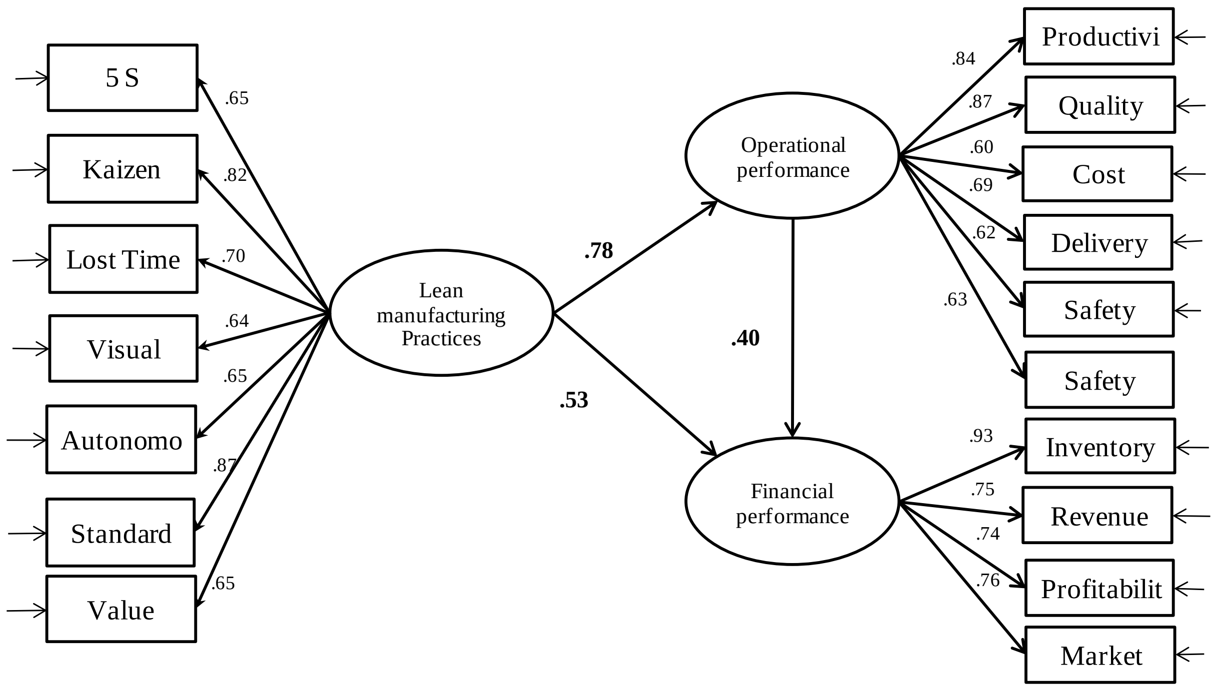


Figure 6.11: Conceptual model for examining relation between lean manufacturing practice, operational performance and financial performance.

6.8 CONCLUSION

In the literature review chapter (section 2.10) research gaps were identified. The first gap was pertaining to the identification of elements of lean manufacturing and establishing the level of lean manufacturing implementation consolidating all the elements. This research identifies 29 elements which are unique to lean manufacturing and a mechanism is presented to measure the status of lean manufacturing The level of lean implementation in Indian industries is observed and it is revealed that lean elements such as inventory reduction, total employee's involvement, wastage identification, quality at source, small lot size, continuous improvement, heijunka, cycle time reduction, quick changeover, lead time reduction, standardization, Just-In-Time deliveries, flexible manufacturing and pull system are identified as most significant elements in the context of Indian industries.

Cellular manufacturing, standardization, line balancing, cycle time reduction, overall equipment efficiency is commonly practiced in lean manufacturing environment among the Indian industry as discussed in previous section (6.3.1.1). In this research implementation level of lean manufacturing is measured through seven enablers as discussed in design of research methodology (section 4.6). It is observed that implementation of work standardization, 5s, kaizen, autonomous maintenance and lost time analysis are practiced aggressively whereas visual management and value stream mapping are still lagging in the context of Indian industries. The obstacles of lean manufacturing are also discussed in the section 3.7. The major obstacles are observed as lack of management focus, inadequate consultancy, lack of funds and lack of sense of urgency for the lean practices.

Organizational performance is measured considering ten factors of operational performance consisting of six factors of operational and four factors of financial performance. The operational performances factors are productivity, quality, cost, delivery, safety and morale. The financial performance factors are considered as inventor turns ratio, revenue growth, profitability and market share. The results of operational performance are discussed in section 6.3.2.1. Impact of lean manufacturing is observed on operational performance factors. Employee's morale is improved along with significant improvement in productivity and quality to the tune of 3.33, 3.29 and 3.22. Cost and delivery is improved with 3.19 and 3.14. Safety is improved to the tune of 3.24 on a scale of 1 to 5. It is revealed that there is a significant improvement in all the operational performance parameters after implementation of lean manufacturing.

The results of financial performance are discussed in section 6.3.3.1. It is observed that there is significant improvement in financial performance of Indian industries in terms of profitability and improved inventory turns ration is to the tune of 2.93 and 2.94. The improvement in market share and revenue growth is to the tune of 2.86 and 2.83. The observed mean value of financial performance factor is 2.88 on a scale of 1 to 5 indicating enhanced financial performance. It is also revealed that implementation of lean manufacturing has positively impacted both operational performance and financial performance. But impact on financial performance is lesser as compared with the impact on the operational performance.

Lean manufacturing practices and operational performance are considered as latent variables and are measured through measurable variables as discussed in section 4.2. The correlation between the factors responsible for lean manufacturing implementation and factors responsible for measurement of organizational performances considering all the practice and performance factors in the context of Indian industry are discussed in section 6.2. The correlation between measurement models of lean manufacturing practices and operational performance is observed through the structural equation model (Figure 6.4). The path coefficient is observed as 0.78 which is significant; indicating direct and strong correlation between two lean manufacturing practices and operational performance. The correlation between lean manufacturing practices and financial performance is observed through the structural equation model (Figure 6.6). The path coefficient is observed as 0.85 which is significantly other than zero, indicating direct and strong correlation between the lean manufacturing practices and financial performance. The correlation between operational performance and financial performance is observed through the structural equation model (Figure 6.8). The path coefficient is observed as 0.81 which is significant; indicating direct and strong correlation between operational performance and financial performance.

The interrelationship among lean manufacturing Practice factors and organizational performance factors is depicted in figure 6.10. The results of structural equation model reveals that lean manufacturing has impact on operational performance with a path coefficient of 0.78, lean manufacturing practices has path coefficient 0.53 with financial performance and operational performance has path coefficient with financial performance to the tune of 0.40 presenting significant impact validating the direct and positive impact of lean manufacturing implementation on organizational performance of Indian industries.

CHAPTER VII

IMPACT OF LEAN MANUFACTURING: A CASE STUDY

7.1 BRIEF INTRODUCTION OF THE COMPANY

The ABC Ltd started its first plant in 1996 in national capital region Delhi as a supply source to major two wheeler and four wheeler manufacturing companies for supplying precision machined engine & transmission parts through technical tie up with renowned Japanese company.

Major customers of the company are the automotive Original Equipment Manufacturers, at both national and international level for two-wheeler and four-wheeler in passenger cars and light commercial vehicles. Product of the company can be classified into two categories as precision machined power transmission parts and engine parts. It employs around 275 workers, 110 executive staff and 35 managerial and above positions. It has annual turnover of 3200 million rupees. The management has inclination towards having systems in place hence company is ISO 14001, TS 16949 and OHSAS 18001 certified organization.

7.1.1 Need for Lean Implementation

The company was committed for expansion but due to regular issues in manufacturing and delivery, it lost its share of business to the competitors. Major issues in the production system were related to higher lead times for manufactured parts, higher work in process (WIP) inventories, High setup time, changeover time and lack of work standardization; all these issues were causing lower productivity for the unit. Lack of communication, human attitude, low skill level, low reliability of the machines caused issues in customer deliveries. Despite of sufficient capacity, manufacturing cells were not efficient hence downstream processes kept on waiting for the parts. Higher scrap rates and frequent customer complaints were major hurdle in new product development and getting new business. These issues all together were responsible for higher manufacturing cost and delivery issues resulting into lower morale of the employees and unpleasant customers. Company had tried a lot of initiatives in bits and pieces but was not able to achieve comprehensive improvement.

7.2 COURSE OF LEAN MANUFACTURING IMPLEMENTATION

In order to improve upon its weaknesses, the company tried to go for lean manufacturing implementation. To come out of the current issues, prime objective was to bring back the morale of the employees by human development, improve the basic condition of equipments, cell balancing, work standardization and making road map for full scale implementation of lean manufacturing. Understanding the importance of the system and the fact that lean manufacturing implementation cannot be a part time job and someone need to be deployed for full time with some external support and mentor the responsible manager. In 2006, company decided to implement lean manufacturing under the consultation of a professor from Utah University, USA who inaugurated lean manufacturing system by addressing each employee that now organisation is committed to improve the overall performance through implementation of lean manufacturing system. The Lean manufacturing implementation strategy focused on followings two areas:

- People development and
- Manufacturing process improvement

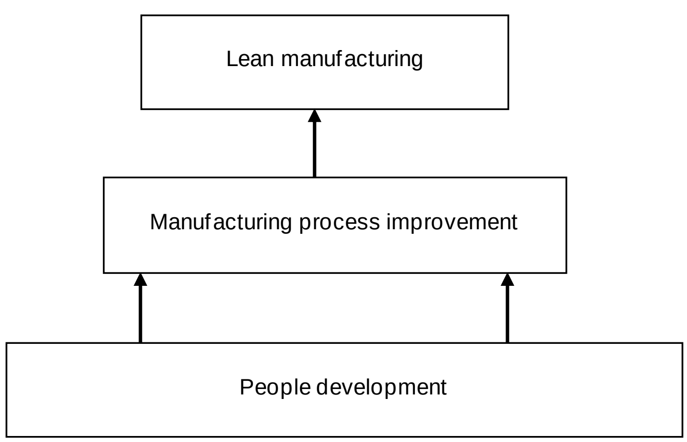


Figure 7.1: Lean manufacturing implementation model

Realizing the fact that lean manufacturing can be implemented and sustained through employee's involvement, development of the people was kept on priority with practicing lean manufacturing system.

7.2.1 People Development

The company focused on improving employee involvement for continuous improvement cycles by breaking the old moulds & creating the way for new heights. For accomplishing this, the management was supposed to play vital role and portray this attitude to develop leaders and not just 'Managers'. A vision statement symbolized the spirit of the company as well as the future. People development consisted of following actions.

7.2.1.1 Education &Training

Company adopted employee oriented training methodology. The purpose was to enhance the skill of the employees with a structured program which was held annually for them. The training plan was linked with the training need identification of the employees which was done by their seniors in the organizational hierarchy. Later actions were planned to bridge the gaps. To achieve the main objective of multi skilling the employees, a skill monitoring matrix for each employees was put into practice. Operators were classified as per four defined levels. These four levels were as trainee, beginner, operator, and trainer. Each level was clearly defined which acted as a guideline for skill assessment. Likewise, operators were also evaluated on similar guidelines. In addition to this some specific behavioral training were conducted, classroom as well as on job, which enabled them to perform the task more effectively & efficiently. Training is conducted over a wide range of the topics ranging from 5s, identification & elimination of waste, structured problem solving methodology, kanban system, small group improvement activity, change over time reduction technique, standardized work practice kaizen and various lean tools like value stream mapping but at the same time to make use of them in daily work management.

7.2.1.2 Empowerment & Involvement

The company emphasized upon improvement of employee involvement through following ways.

Kaizen System: Main purpose of the kaizen scheme was to increase the involvement of the employees and minimization of waste and consequently productivity improvement. Plant 'kaizen-committee' was responsible for conducting training, providing awareness, mentoring and evaluating the implemented kaizen. Good kaizens were promoted with rewards for recognitions.

TPM Initiatives: Company started TPM as a practice to achieve manufacturing excellence through lean manufacturing initiatives. Effective involvement of employees was ensured through engagement in TPM initiative. Operators were involved in this TPM initiative through cleaning and taking care of their machines. Autonomous maintenance activities were carried out as per different steps involved in TPM initiative. During the TPM initiative, operators used to perform initial cleaning, identifying sources of contamination and difficult to access area and other abnormalities in the equipments. The effort put by the team responsible for keeping the machine clean & dry was acknowledged and appreciated by management in various meetings.

Quality Circles: The main objective of these quality circles was to resolve quality related issues within the company. These quality circles participated in various competitions outside the company and helped employees gain in confidence and soft skills.

5S Initiative: A structured approach to maintain & improve 5s was essential for the shop floor, offices & surroundings. Plant was divided into various zones for 5s and each zone was having a leader who was responsible for maintaining, improving 5s of that zone. Zone leader was responsible to facilitate team members in 5S activities, participate in layered 5s audits, promotes & encourages team member's participation.

Project Management: All the employees were committed to waste reduction through continuous improvement and for this reason they were engaged in various project management activities. Different projects were taken up in different departments. Each individual was engaged in the execution of the strategy decided by the top management to achieve the organization mission & vision through project management activities.

Involvement through Various Meetings: Performing kaizens and projects management activities may require a cross functional team. In order to monitor and perform the same a daily meeting was held in each of the department or sub functions. Each Line supervisor had a daily meeting with the operators of his manufacturing line on shop floor with a well decided agenda for the discussion. For instance, cost cutting or quality improvement was the need of the hour. Therefore, a special drive was launched wherein cost cutting and quality improvement were taken as a kaizen theme. Such drives not only help to identify and eliminate waste by bring the issue to the focus but also improves employees involvement more effectively.

Special Drives: On some occasions, special drives are performed to maximize the involvement of the employees. One of the examples of special drive is slogan competition on the occasion of safety week, quality week or month celebration. All the entries of the competition were considered by a board and best entries are rewarded. This motivates the employees for more participation in fulfilling the common goal of the company.

7.3 MANUFACTURING PROCESS IMPROVEMENT

Under the umbrella of lean manufacturing, different tools and techniques of process improvement and measurement were put into practice. All the lean elements must be properly understood, implemented and measured for successful implementation. Following are the major lean manufacturing elements practiced at the company under study.

- Inventory reduction
- Total Employee Involvement.
- Error proofing (poka-Yoke)
- Set up reduction.
- Improve OEE.
- De-bottlenecking
- Pace maker process
- Wastage identification
- Equipment uptime
- Quality at source
- Takt Time working
- Small lot size
- Continuous improvement
- Good Housekeeping
- Manpower reduction

- Load leveling (Heijunka)
- Reduced information barriers
- Cycle time reduction
- Quick changeovers
- Process control.
- Lead time reduction
- Safe working
- Standardization.
- Reduce variability.
- JIT deliveries
- Flexible manufacturing.
- Layout improvement.
- Line Balancing
- Pull System

It was very complex to take care each of these elements individually without any structured approach. The approach adopted here was to divide all the elements into major components or enablers of lean manufacturing. Each enabler gave concrete recommendation on how to implement the enabler. Each enabler contained a number of lean elements and some of elements were covered by more than one enabler. To understand the perspective and applicability of each enabler they were mapped with performance measures.

Lean element is illustrated as the requirement of lean manufacturing to be implemented to achieve the improved results whereas lean enablers are known as the tool to achieve the implementation of desired element. It was observed that value stream mapping covered 19 elements of lean manufacturing, standard work covered 16, visual management and kaizen 11, autonomous maintenance covered 10, lost time analysis and 5S covered 9 each out of total 29 elements of lean manufacturing.

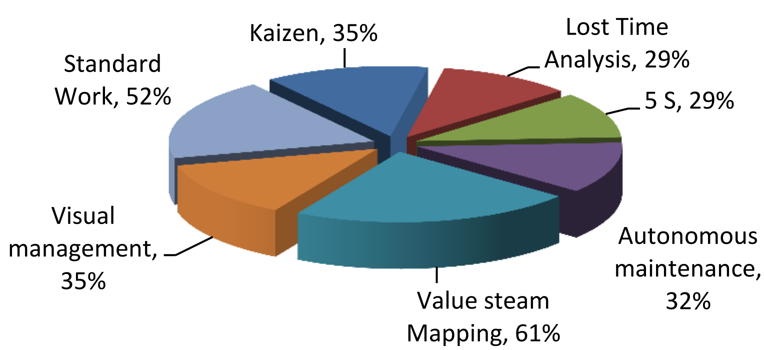


Figure 7.2: Coverage of lean elements by lean manufacturing enabler

Following is the detailed implementation strategy and case study of each enablers implemented in the company under study.

7.3.1 Lean enabler: value stream mapping

Value stream mapping is an effective tool for identifying the non-value-adding activities in manufacturing process for any company. The objective of value stream mapping is to enable everybody to see the waste simply and easily, identify the current operating philosophy and to provide a roadmap for change that yields bottom line results.

7.3.1.1 Case Study of Value Stream Mapping Implementation

In this case study value stream mapping was applied on gear manufacturing line to identify and eliminate waste from the manufacturing processes. First of all one value stream was selected for improvement. Data collection and data analysis were performed for macro and micro level activity. Complete study was performed to identify the wasteful activity and root cause. Future state value stream map was prepared. Action plan was prepared to implement the changes. Plan-Do-Check-Adopt (PDCA) cycle was adopted till waste was removed from the process.

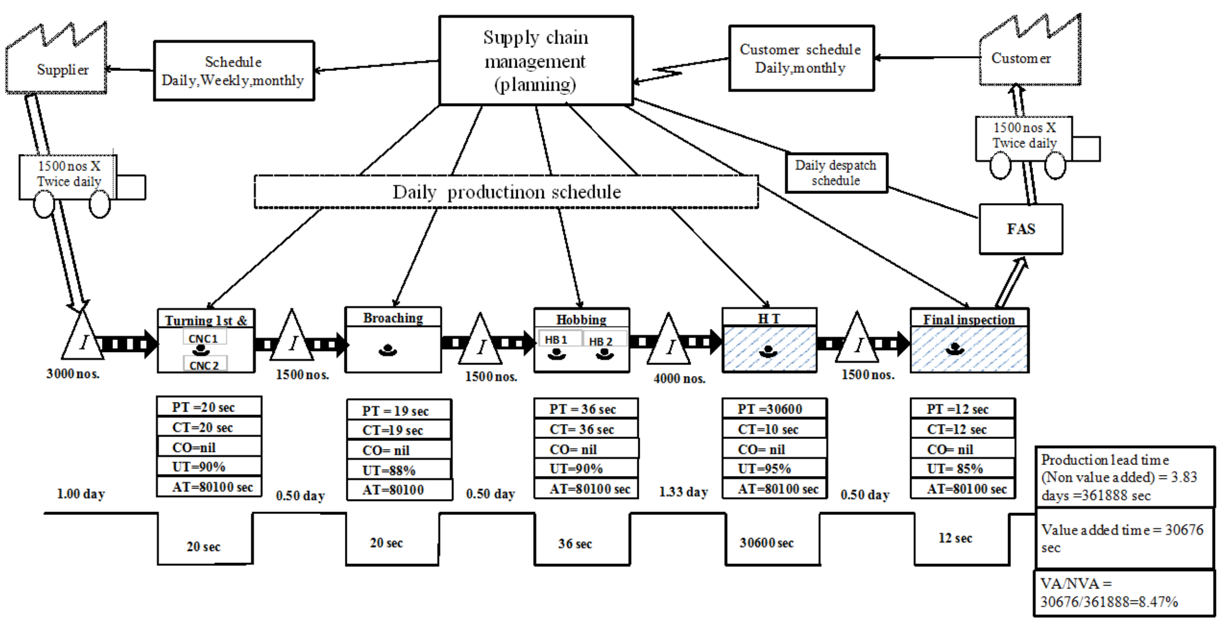


Figure 7.3: “Current State Map” of Value Stream mapping

All the information required for this map was gathered from the manufacturing processes by conversation with workers, supervisors and managers of the shop floor of the of the selected product value stream. From the past data and based on current month schedule customer demand was 78000 nos. gears per month. Effective nos. of working days was

26 days in month. Hence per day customer demand was 3000 nos. per day. Shop was running in three shifts of eight hours each.

In morning and evening shifts there was a lunch break of 30 minutes in addition to two tea breaks of 7.5 minutes each in night shift there was no lunch break and tea breaks were as in morning and evening shifts. So available time in morning and evening shifts was= (8 hours* 60)-(30 minutes*1 lunch break)-(7.5 minutes* 2 tea breaks)=435 minutes each. Available time in night shift was= (8 hours* 60)-(7.5 minutes* 2 tea breaks)=465 minutes. Total available time =435+435+465=1335 minutes=80100 seconds.

$$\text{Takt Time} = \frac{\text{Total available time per day(80100 sec)}}{\text{Total demand per day (3000 nos.)}} = 26.7 \text{ seconds per part}$$

As shown in the current state map demand was received by supply chain management department and it was broken down into monthly, weekly and daily requirements. The customer demand was then communicated via electronic media and in hard copies to suppliers and manufacturing each of processes in the form of daily production schedule. WIP inventory is kept between the stations to keep production flow smooth in case of any interruption of supplies form supplier or breakdown of equipments. WIP inventory norms at CNC Turning are 3000 nos., broaching 1500 nos., hobbing 1500 nos., heat treatment 4000 nos. and final inspection1500 nos. Thus total inventory at any point of time was 11500 nos. Manpower deployment at CNC turning was 1, at broaching 1, hobbing 2, at heat treatment 1 and in final Inspection was 1 in number. Thus total manpower deployment was 6 number. Process time, cycle time, changeover time and uptime of each station was plotted in current state of value stream map. Production lead time was 3.83 days which is equivalent to 361888 seconds. Total process time was 30676 seconds. So Value addition in percentage of time was =VA/NVA = 30676/361888=7.81%.

Analysis of current state of value stream map was performed to identify the improvements opportunities available. It was observed that the manufacturing lines are dedicated to product and there was no need to plan for each process separately rather one pace maker process can be identified to maintain the line pace. Final inspection being the downstream process was identified for the scheduling purpose. Kanban was implemented to serve as scheduling tool for upstream processes. Two loops were identified and both were joined with supermarket. The location of supermarket was decided before heat treatment process as single piece flow cannot take place at heat treatment because batch size of lot is 4000 nos. for heat treatment.

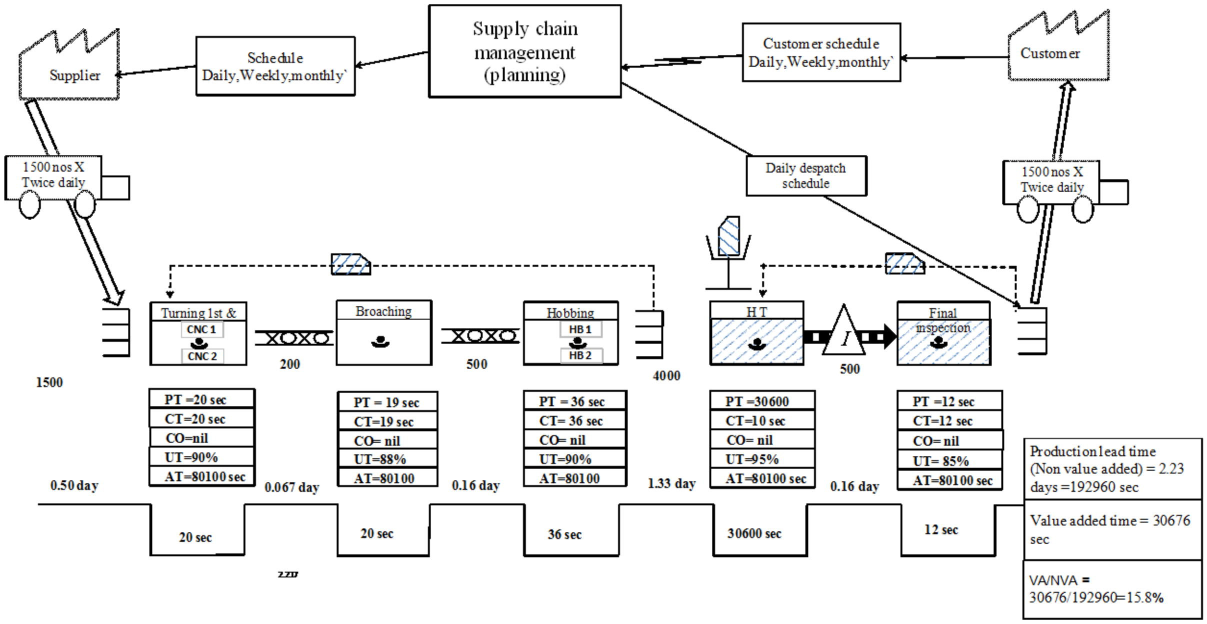


Figure 7.4: "Future State Map" of Value Stream mapping

Modified WIP inventory norms at CNC turning were 1500 nos. broaching 200 nos., hobbing 500 nos., heat treatment 4000 nos. and final inspection 500 nos. Thus total inventory at any point of time was 6700 nos. With the reduction of inventory in the system lead time was reduced to 2.23 days equal to 192960 seconds.

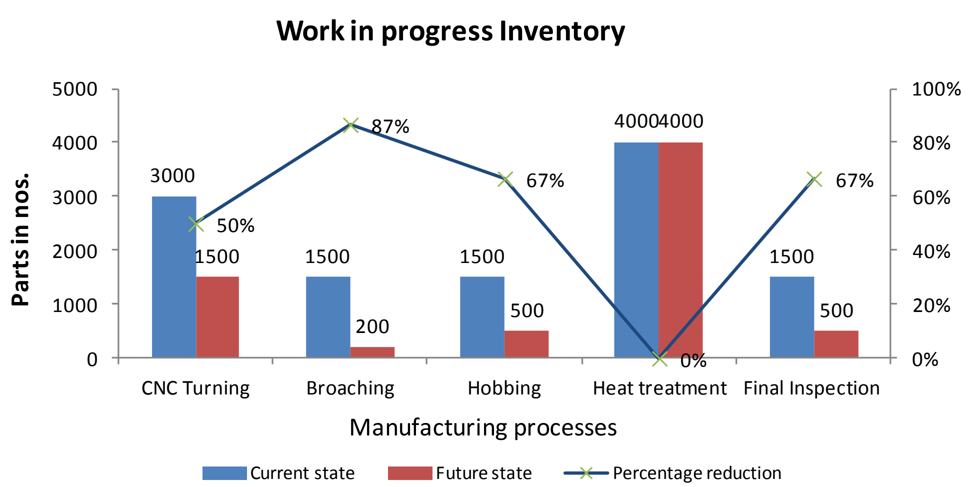


Figure 7.5: Comparisons of WIP inventory before and after

So improved value addition in percentage of time was =VA/NVA = 30676/192960=13.7%. Hence reduction in non value adding activities was observed by 43.1%.

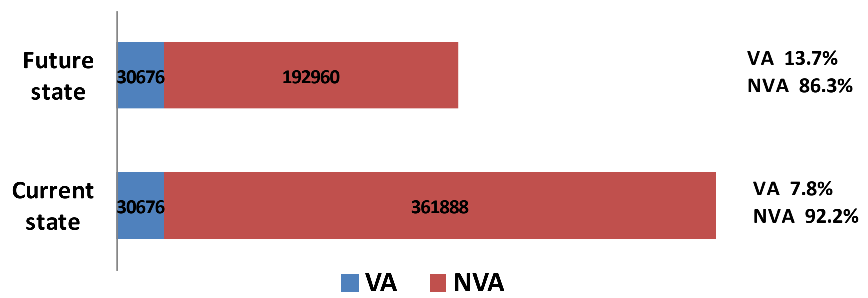


Figure 7.6: Comparisons of VA and NVA before and after

Layout change of hobbing machine resulted in saving of one man power as one operator was found enough to run two machines simultaneously. So new manpower deployment at CNC turning was 1 no., broaching 1 no., hobbing 1 nos., heat treatment 1 no. and final inspection was 1 number. Thus total manpower deployment was 5 nos. saving of one per shift and total three operators per day were observed.

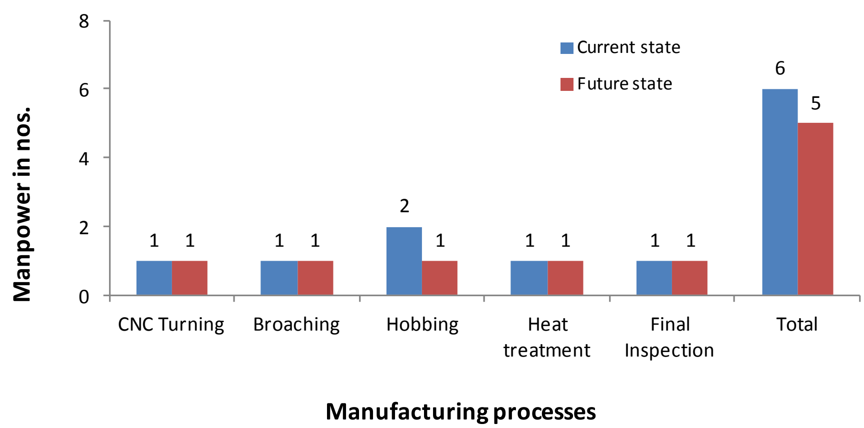


Figure 7.7: Comparisons of manpower deployment before and after

Material was pulled from turning process through broaching and hobbing by kanban card. FIFO lines were installed between turning to broaching and broaching to hobbing. Operator need not to wait for daily schedule rather he needs to follow the kanban system. Once supermarket achieves maximum level of defined inventory no Kanban card was released from supermarket and hence overproduction waste was reduced. Material is pulled by customer demand from finished article store supermarket. Once there is pull from finished article store supermarket; kanban card creates order for heat treatment and material is pulled from final inspection and from heat treatment to final inspection via FIFO lines. Hence scheduling is at one point i.e. finished article supermarket and rest all processes are driven by demand created from finished article supermarket via kanban cards system.

7.3.1.2 Benefits Gained from Value Stream Mapping

In this case impact of lean enabler value stream mapping was observed. Smaller PDCA cycles has enable team to understand the root cause of the waste and alternates has been developed resulting in reduction of in process inventory from 11500 nos. to 6700 nos. to the tune of 41%. Process lead time has been reduced from 3.83 days to 2.23 days. "Push production" where need arise to schedule for each process individually has been change to "pull production" where only finished article store supermarket needs to plan. The case study reveals the effectiveness of value stream mapping tool in identifying and eliminating of a variety of wastes into the manufacturing system. The decrease in work in process inventory, product lead time reduction, and manpower reduction indicates the usefulness of value stream mapping into manufacturing system.

7.3.2 Lean Enabler:5S

5S (Sort, Shine, Simplify, Standardize and Sustain) is a lean manufacturing enabler that is used in company to deliver the improvements. The aim of 5s is to create systematic, standard, efficient and effective workplace for all the employees. There are five steps in the implementation of lean manufacturing enabler 5S

- Sort (Clear out all unnecessary items)
- Shine (Keep it clean, visible and safe)
- Simplify (Organise – A place for everything and everything in place)
- Standardize (Establish standards for Sort, Shine & Simplify)
- Sustain (Seek further improvements)

The first three (Sort, Shine and Simplify) are normally completed during a focused and supported kaizen event to improve a specific area. The improvements from such an event are only sustained through the fourth and fifth S's. Only strong and envisioned leadership will allow level four to be reached, and only an exceptional understanding and commitment to improvement will achieve the status of level 5 – a world class achievement. The following is the detail of procedures to complete the five steps of 5S, and begin the journey to real improvement via lean manufacturing.

Sort: The aim of 1s is to have the object in the area what is required for the process. Because if unnecessary items are not removed from work place they will occupy the space and it is difficult to progress with even the most basic workplace improvements. . Sorting through the work area and removal of any non-essential item was done. The objective was to clear out everything from the workplace area first and then sort out the required items and put them back into the work area and then identify the non-essential items for review before disposal. After implementation of 1s the workplace that contains only the needed items is easier and more efficient to work in. Employees have made the first essential step to improve their workplace.

Shine: The aim of 2nd S is to prevent dirt and contamination from reoccurring by eliminating the sources of dirt and by making cleaning an everyday work activity. Implementation of 2nd S results in improved safety like oily walkways cause slipping etc. There are less chances of affecting product quality by contamination. Cleaning is a form of visual inspection. The general condition of equipment can be inspected and concerns can be addressed, creating more satisfying working environment. Dirty machines have a tendency to break down more often and produce defective work. The workspace, all essential items and all machines need to be cleaned and fixed for all issues.. Each essential items is cleaned as it is replaced, clean each machine, from the top down. These issues must be revisited to find and eliminate the root cause by investigation and assigning corrective action.

After implementation of 2nd S, the intense shining of a 5S activity will deliver a clean, pleasant and efficient working area. It will also identify maintenance issues and will identify and action opportunities for small, continuous improvements. After a shine activity the workplace is easier to clean because sources of dirt will be eliminated.

Simplify: The aim of 3rd S is to simplify the process of using items or completing tasks. It is an activity for simplifying processes minimizing waste, makes everything easy to find, use and return, simplifying is the first step towards visual control, make simpler work area aims to make things easier to complete, and therefore will increase productivity. Many tasks require the use of items such as tools or materials. Simplifying the use of all necessary items will increase the efficiency of the workplace. Items should be arranged so that they are at hand, easy to use, and labeled to make their storage sites easily and simply understood by everyone. If an item is essential then its use must be simplified as much as possible.

After implementation of 2nd S the workplace is easier and more efficient to work within. Any needed item has a place and is in its place. Now it is easier to assess the condition of the workplace, as abnormalities are visual.

Standardize: The aim of 4th S is to ensure that the current standards achieved for Sort, Shine and Simplify are monitored and maintained. To gain the immediate benefits from an event will quickly be lost if the improved condition is not maintained. Completing the Sort, Shine and Simplify steps delivers the improved workplace, but the benefits can only be captured if the improvements are sustained in the long term. 5S daily checklists are created to ensure that the 5S condition is monitored and maintained.

After implementation of 2nd S the improved state from the Sort, Shine and Simplify steps is maintained to allow the benefits to be gained on a long-term basis. 5S becomes part of everyone's day-to-day practices.

Sustain: The aim of 4th S is to involve every employee contributes to sustaining the rate of improvement. By using employee energy and innovation to continuously improve the 5s condition will lead to a cycle of improvement and reward. Time and effort used to Sort, Shine and Simplify pays back by introducing a safer, organized, productive and efficient workplace. Self-discipline by everybody to adhere to the 5s rules is the key. 5S practices creates a continuous improvement culture depends on everyone being involved and understanding the benefits. Monthly 5s progress report is communicated and achievements are recognized. Sorting, Shining and Simplifying have to become part of everyone's daily work habits. After implementation of 5^{th} S; continuous improvement has become part of 'the way we do things'.

7.3.3 Lean Enabler: Lost Time Analysis

The purpose of lost time analysis is to decrease the losses occurring during manufacturing and improve productivity and quality by reducing all types of losses as waste.. First of all focus must be given on elimination of these losses but if it is not possible to eliminate, they must be targeted for reduction because they consume costly resources like increased working hours or additional spending on capital equipments. Implementation of Lost time analysis starts with identification of the bottleneck equipment or process. The data observation must be performed on the workplace to maintain exactness of collected data. Improvements performed in particular one process may not improve the overall production capacity of the manufacturing lines so improvements must be performed on whole value stream till line is balanced in terms of actual manufacturing capacity. Manufacturing Efficiency is measured as a ratio of value added time and total time.

$$\textit{Manufacturing Efficiency} = \frac{\textit{Value Added Time}}{\textit{Total Time}}$$

Equipment Efficiency is measured as a ratio between actual output and standard output based on installed capacity considering no loss of time in non value adding activities.

$$\textit{Equipment Efficiency} = \frac{\textit{Actual output}}{\textit{Standard output (installed capacity)}}$$

All the processes and equipments must be analyzed to identify bottleneck in the value stream. Standard manufacturing capacity level must be established for every process in the manufacturing line. Equipment efficiency must be calculated by collecting data for a certain period to gauge the actual efficiencies of equipments.

Actual output capacity= Installed capacity Equipment Efficiency*

The actual output capacity will help in identification of bottleneck process in the manufacturing cell. The equipment with lowest output will regulate the complete manufacturing line output. Standard output norms must be established depending upon type of process and relative benchmarking with best practices assume. Equipments or processes that do not achieve preset norms level are subjected to be investigated and considered as area for improvement under lost time analysis enabler. Such Equipments or processes must be tracked continuously to make sure that the real life data is continuously collected and efficiency is sustained. Once the requirement for lost time analysis is recognized for any Equipments or processes, a five step series of actions must be pursued and iteration must be continual till the acceptable levels of performance is achieved.

Collection of Data: Data must be collected for the equipments or processes under observation and must be displayed. The traceability of every minute of lost time must be recorded in the time log. The time study must also contain the production target based on time period divided by cycle time, statement of the time period and shifts timings, planned maintenance activities and time allotted based on past time studies. The output must be noted for each time period against target for that period including quantity of rejected parts. Based on the above data overall manufacturing line efficiency must be calculated on shift basis.

Analysis of the Data: The data collected through lost time logs should be thoroughly analyzed by breaking it down into main types of problem to select the focus on problem and area of improvements required. Data is analyzed with the use of different tools for creating first level of understanding. This will provide a bigger picture of bifurcation between value adding time and non value adding time. In the next level non value adding data must be represented with pareto chart to understand the contribution of different non value adding activities. Thumb rule is to tackle biggest problem first so that focus on one bigger non value adding activity may result in bigger positive contribution in reduction of waste from the system.

Recognition of Root Cause: The recognition of root cause is very important in continuous improvement process and problem solving techniques. The team responsible for root cause investigation and identification must look ahead for the result. There are many tools that can be used to support root-cause analysis is and is generally supported by why-whys analysis, Ishikawa diagram (fish bone diagrams) and brainstorming.

Formation of Action Plan: After recognition of the root causes an action plan is formed containing the clear objectives, problems faced in the equipments or processes, the proposed solution, anticipated benefits, responsible person for execution of decided solution and measurement indicators to monitor the improvement. It must contain the constraints, required resources and estimated time. The plan must be communicated to all participants of improvement team. Open discussions must be preferred to avoid individual thoughts and to create synergies between team members for the common goal of improvement. This improves the cohesiveness in the team and will improve ownership of the action plan.

Running Plan-Do-Check-Adopt (PDCA) Cycle: Action plan are implemented to recognize the benefits of lost time analysis. Effectiveness of action plan implementation must reflect in performance improvement of manufacturing equipments or processes. Permanent solution on removal of the root cause determines the benefits to sustain for an indefinite period of time. Targets are set for improve the effectiveness of bottleneck process or equipment with a structured approach shown in figure below.

The process flow diagram mentioned in Fig 7.9 is used as a tool to understand if any equipment or process is required to be improved or just need monitoring. This process has two cycles observation cycle and improvement cycle .In observation cycle data is collected to measure the lost time and evaluated for identification of bottleneck. During analysis if it is observed that the process or equipment is bottle-neck, improvement cycle steps are followed to improve the process. Once improvement cycle is completed, the observation cycle must be performed to gauge the effectiveness of the improvement cycle. The process is constantly repeated till target performance level is achieved.

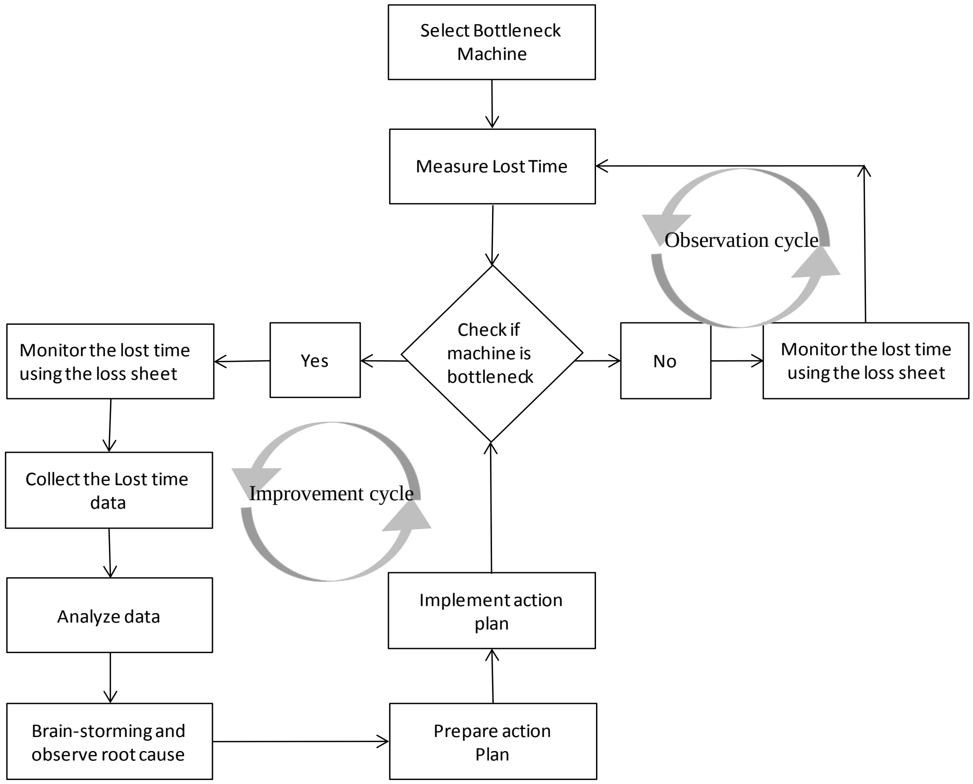


Figure 7.8: Process flow diagram for improving effectiveness of bottleneck equipment

7.3.3.1 Case study of Lost Time Analysis Implementation

Lean manufacturing implementation in the company under study was at very advance stage and significant enhancement in operational performance had taken place on account of lean manufacturing implementation. Below is a case study of lost time analysis enabler implementation in a manufacturing cell.

Collection of Data: Data collection comprised of some important steps like design of lost time monitoring sheets, providing training to workmen for proper filling of loss monitoring sheets and following up for recording of data in the monitoring sheets. Specific loss time monitoring sheets were designed as per the requirement of process carry out on the equipment to obtain the data related to amount and type of loss. Once design of loss monitoring sheet is finalized, loss sheets were deployed on all the machines within the manufacturing cell for collection of lost time data. Since cell capacity is decided by the equipment having lowest actual manufacturing output capacity so this is called bottleneck machine or process. The manufacturing line under observation was planned for running round the clock in three shifts of eight hours each. Monitoring was performed for whole 7810 minutes of working time in a week. Working schedule of observed manufacturing line is given below.

Available work Time in a shift of 8 hours = 480 min

Lunch breaks of @ 30 min. = 30 min

Tea breaks of @ 7.5 min. each (twice) = 15 min

Total Available Time per shift = 435 min

Nos. of shifts planned per day = 3 shifts

Total Available Time per day = 1305 min

Weekly quality communication meeting = 20 minutes

Total Available working time per week = 7810 min

Collected lost time data with the help of loss monitoring sheet was analyzed based on installed capacity and actual manufacturing output capacity for each of the equipment. Data is tabulate in the below form to calculate efficiency for each equipment and to find out the bottleneck machine.

Table 7.1.: Table showing machine wise capacity of manufacturing cell

Machines Name	Available time (minutes/shift)	Cycle time in seconds	Installed capacity	Actual output	Efficiency
CNC Turn 1	435	35	746	604	81%
CNC Turn 2	435	38	687	591	86%
Rough milling	435	34	768	614	80%
Finish Milling	435	34	768	660	86%
Cylindrical	435	37	705	459	65%
Inducto- heat	435	32	816	620	76%
Track grinder 1	435	34	768	606	79%

In the above table it is observed that in the given manufacturing cell cylindrical grinder machine with a lowest actual output of 459 parts average per shift is a bottleneck machine and process is grinding.

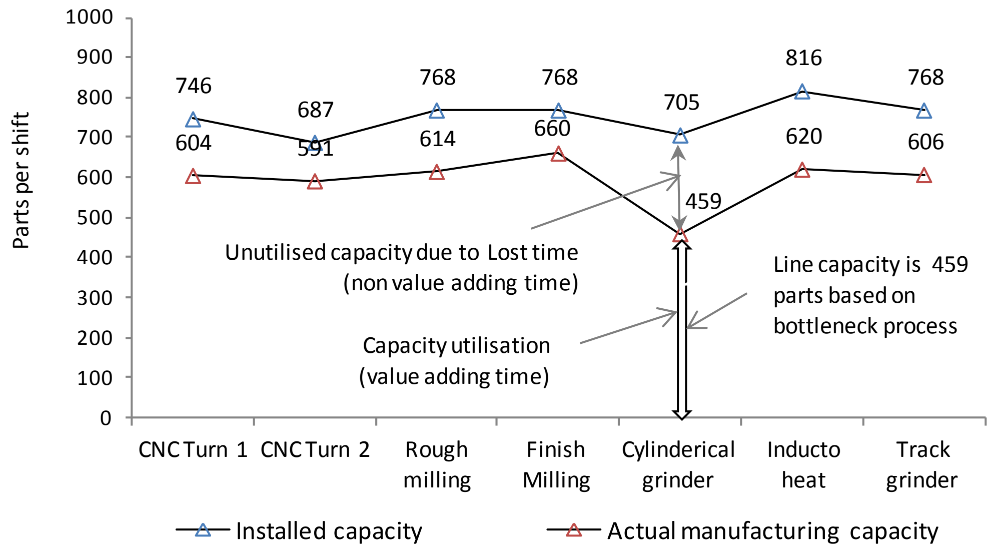


Figure 7.9: Bottleneck process/machines identification in the manufacturing line

Impact of bottleneck machine on cell manufacturing capacity was calculated by subtracting bottleneck machine actual capacity from actual manufacturing capacity of second lowest machine. Bottleneck impact of cylindrical grinding machine on overall cell manufacturing capacity was observed (591-459) = 132 parts per shift. This means that this machine is restricting cell manufacturing capacity. This way bottleneck impact if multiplied because bottleneck machine is causing negative utilization impact on other six machines by keeping them idle for 132 parts per shift.

Analysis of the Data and Recognition of Root Cause: After recognition of bottleneck machine, three step lost time analysis was performed to investigate the real root cause responsible for the loss of productive time. Series of investigation step followed to recognize the root cause of the problem starting with current condition monitoring including equipment name process details etc. Details of bottleneck process are given below:

Operation time = 25 seconds

Wheel dressing time =12 seconds

Frequency of dressing = after every part

Actual manufacturing capacity based on collected data = 459 parts / shift

Efficiency (actual output/standard output) = 65%

Data showed that during observed period machine was non-operational for 2734 minutes out of total of 7810 minutes. Unutilized time of machine was (2734/7810) =35% of total time. It was decided to further investigate the lost time into different elements.

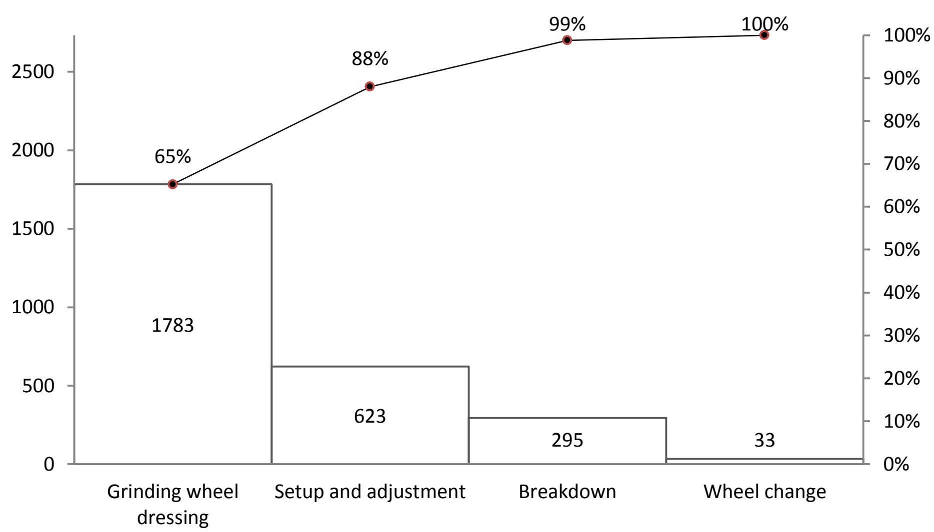


Figure 7.10: Analysis of total time

Non productive or non-functional time of 2734 minutes was broken into four singular elements and it was establish that out of total lost time of 2734 minutes, 1783 minutes were attributed to grinding wheel dressing time and 623 minutes were lost in set up and adjustment, for 295 minutes machine remained breakdown and 33 minutes were lost in grinding wheel change. Two major losses grinding wheel dressing and set up and adjustment time contributed to 88% of total lost time or non-productive time.

Formation of Action Plan: After analyzing the lost time it was observed that the bottleneck machine (cylindrical grinder) was having machining time of 25 second. Interval between two parts was 37 seconds out of which 12 seconds were for non productive after each part in account of grinding wheel dressing by keeping machine in unutilized condition . Though dressing of wheel is essential to keep grinding wheel ready to deliver the required quality but it keeps the machine idle. It was decided to consider 12 second dressing time to reduce first as it is obviously nonproductive time.

Action for Wheel Dressing Time Reduction: After acceptance of the root causes an action plan was created containing the objectives to eliminate the grinding process as bottleneck from the observed manufacturing line. Followed by brainstorming and considering feasibility of alteration in dressing sequence, it was agreed to perform wheel dressing during loading and un-loading of the part on the machine. Machine programming was customized to change the sequence of machine activities as decided. Total time between two cycles was reduced from 37 second to 25 seconds by changing sequence of activities such that dressing will be performed during part loading and unloading by operator hence negating the effect of dressing time.

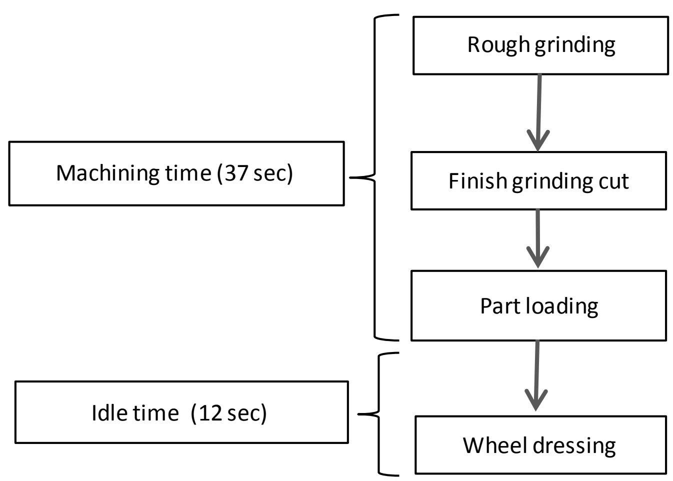


Figure 7.11: Block diagram showing sequence of activities of machine before improvement

With the implementation of this action lost time due to wheel dressing was completely eliminated because part loading and unloading time was 14 second and dressing was suppose to happen within this non productive time itself.

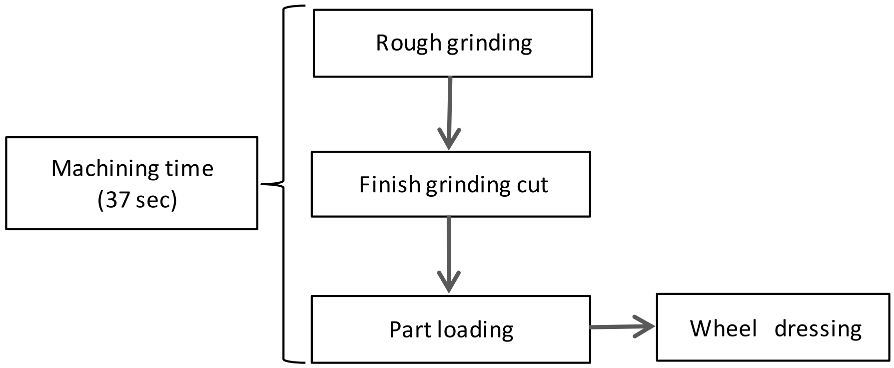


Figure 7.12: Block diagram showing sequence of activities of machine after improvement

Followed by implementation of action on eliminating grinding wheel dressing time machine was put for observation for one another full week. Time study revealed that for 1141 minutes out of 7810 minutes, equipment was non productive equal to 14.61% of total time. Machine worked at 85.3% efficiency and production rate improved from 459 to average of 601 parts per shift.

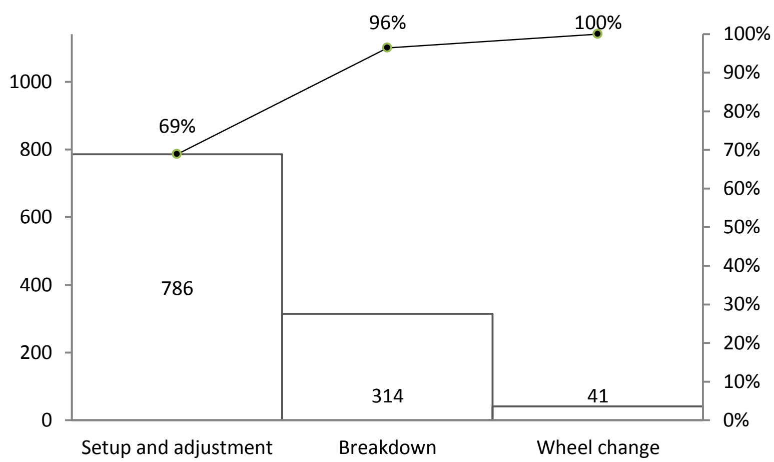


Figure 7.13: Analysis of total time after first cycle of improvement

Action for Setup and Adjustment Time Reduction: With the help of collected data for the machine it was observed that lost time in account of setup and adjustment was 786 minutes followed by breakdown loss of 314 minutes. Both these losses contributed to 96% of total loss. It was decided to consider setup and adjustment loss reduction as area for focused improvement. After critical analysis it was observed that there was no structured process for set up and adjustment of the machine. After discussion with cell engineers and operators a structured methodology was provided with series of work instructions to describe the correlation among the setting parameters and the amount of correction required to meet the product requirement. It resulted in time saving during setup and adjustment of the machine. As a result machine setup and adjustment time was condensed from 25 minutes per setup to ten minutes per setup. Improvement was noted to the tune of 60% reduction in setup and adjustment time.

Monitoring and Comparing the Results: Subsequent to completion of second PDCA cycle on lost time reduction a measurable and positive improvement was observed. Reduction in flow to flow time of the machine for one part reduced from 37 second to 25 second hence eliminating of 12 second non value addition from the bottleneck process in each cycle. Further improvement in set up and adjustment process there was additional improvement in value adding time. Machine was kept for observation cycle for one full week of 7810 minutes and it was observed that for 877 minutes out of 7810 minutes machine was non- productive.

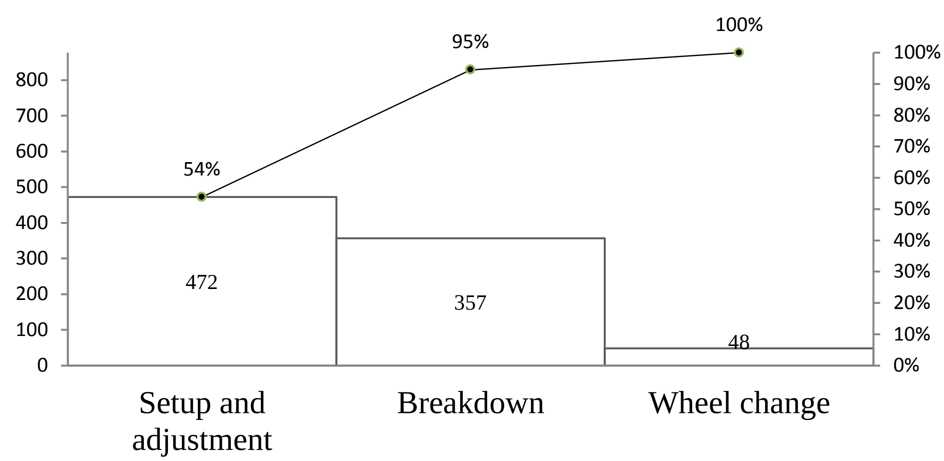


Figure 7.14: Analysis of total time after second cycle of improvement

With the discussed improvements it was experienced that there was an increase in manufacturing capacity from 459 parts per shift to 628 parts per shift. Improvement in efficiency of machine was observed from 65% to 89%. In the process of regular monitoring of efficiency of machines and comparing within the machines of a manufacturing cell it was revealed that this machine was no more a bottleneck after improvement. With this improvement bottleneck operation was shifted to CNC turn2 as shown in figure below.

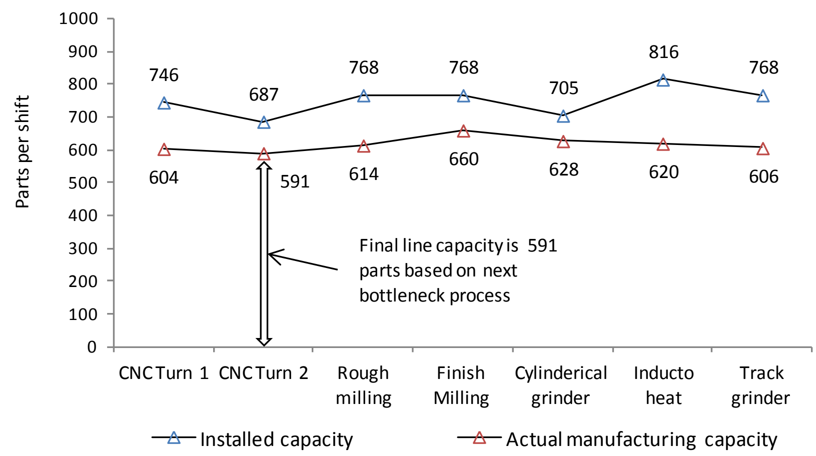


Figure 7.15: Machine wise capacity of manufacturing cell after improvement

7.3.3.2 Benefits Gained Through Implementation of Lost Time Analysis

The case study represents the impact of lean manufacturing on the manufacturing performance. In this case the lost time analysis enabler has been implemented and had direct and positive effect on operational performance in manufacturing cell by increasing line manufacturing capacity from 459 parts per shift to 591 parts per shift and to the tune of 28.7%. The improvements gained through implementation of lost time analysis enabler highlights the contributions of lean manufacturing implementation initiatives. Examined case is a small node but implementation of such cases in series might results in significant manufacturing performance improvements in the manufacturing organizations. The knowledge and motivation obtained by employees in performing such improvement cycle may support in growth of lean culture in the organisation and could result in bigger impact on manufacturing performance.

7.3.4 Lean Enabler: Visual Management

The aim of visual management is to enable everyone to immediately see deviations from the optimum state of work and working, and to enable immediate corrective action. This is achieved by designing a system of visual indicators which makes clear when a process is not operating at its optimum stage.

Implementation Steps for Visual Management: Visual management systems are used with a variety of lean manufacturing elements but the process for designing and implementing an effective visual management system contains five following steps:

Identify: It is about the parameters which need to be controlled**.** The visual management focuses on the most critical parameters and ensures that the workplace remains clear and free from unnecessary and confusing information. Once the most critical parameters have been found; the indicators that measures these parameters can be identified or established

Design: It is related to the system of visual indicators. Good design of visual systems will enable any employee to quickly review the status of a process and to immediately see where operation is non-optimum

Define: It is about describing the procedure of reaction**.** The only reason to make an indicator visible and accessible is to be proactive and tackle issues before they adversely impact the manufacturing capacity or capability. The required corrective action must be defined and verified to be effective to tackle the root cause. In some cases the reaction procedure may not need to be formal.

Implement the system: The use of a kaizen may allow a quick and effective implementation of a visual management system. During a focused event; gauges, signboards, notices or instructions should be put in place and employees who will interact with the system should be trained. Active involvement of employees will help to generate support and ownership of the system.

Improve: The involvement of employees to use and sustain a visual management system can highlight opportunities to further improve the systems, or to implement similar systems to protect against other problems. These opportunities to further improve should be captured and implemented following the same cycle as the initial system. For example, including an alarm system to alert the operator of a low oil condition could eliminate the need for an oil gauge and ensure that the operator responds only when a response is needed.

7.3.4.1 Examples of Visual Management

Followings are few examples areas of visual management in manufacturing industries.

Visual Management for Safety: Although often covered by legislation, the visual management of risk areas and incident response tools can improve the safety.

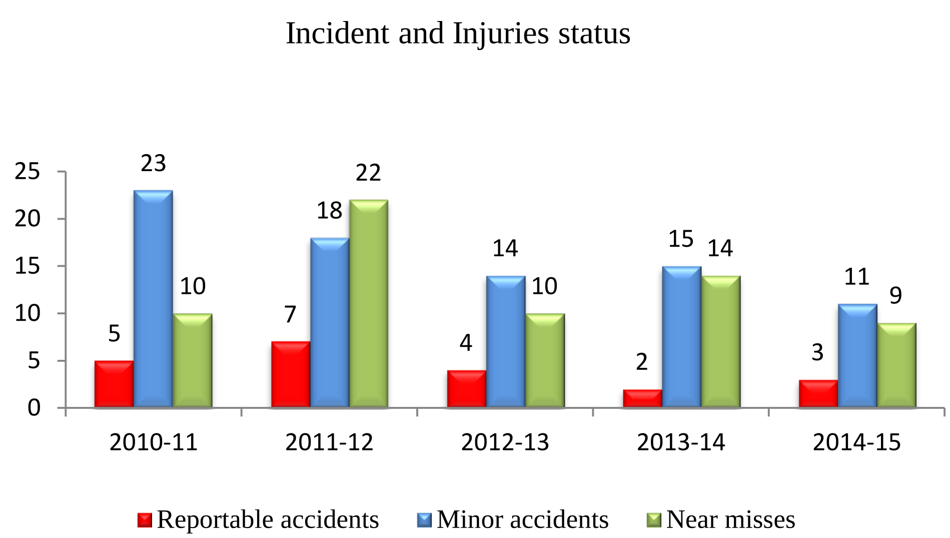


Figure 7.16: Visual management for safety parameters

Visual Management of Items: Visual management can be used to organize the workplace. Managing items such as tools and materials offers increased efficiency and quality of work. To enable efficient work within the workplace, items such as tools or materials are managed. Visually defining where an item is kept by using labels, color coding and designated locations will enable any employee to locate and replace items.

Visual Management of Production Progress: Visual management systems shows when production is not meeting planned levels and can encourage an effective reaction. Visibility of production progress allows higher focus on critical processes and increased responsiveness to the customer. An effective system to visually manage production progress provides a quick status of progress against plans and indicates the place of the problems.

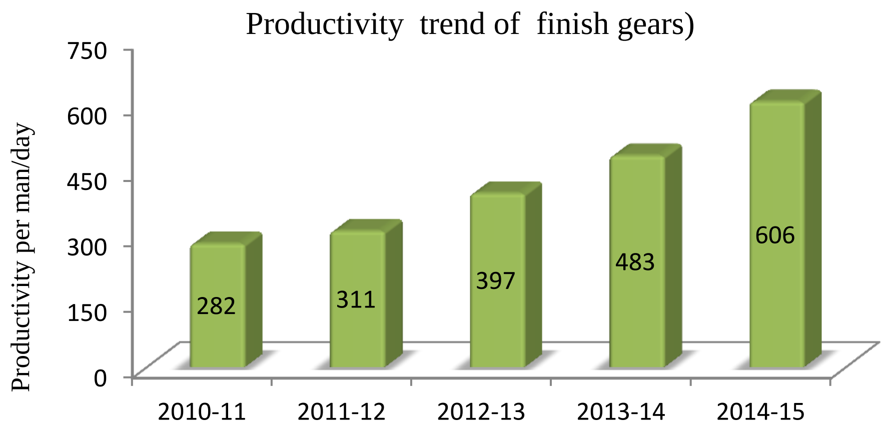


Figure 7.17: Visual management for productivity

Visual Management for Quality: Visual Management systems can highlight quality issues and solutions to improve the quality of products that are supplied to the immediate customer and end consumer. It can improve quality performance by reducing the risk of quality issues escaping, and by focusing improvement efforts. Effective visual management for quality should highlight the defect rate for each machine or process, predict a quality defect before scrap is caused and aid the use and maintenance of quality checking devices. For example, marking the tolerance range on gauge faces helps increase quality standards. Out of specification parts are easily visible and adjustments can be made to solve the arising problem. Information related quality history is displayed.

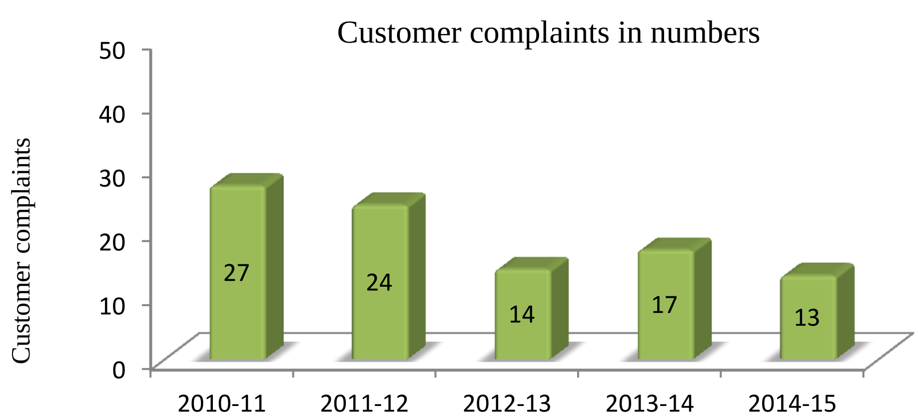


Figure 7.18: Visual management for quality parameters

Visual Management of Information: The clear and simple display of information is an important method to highlight issues. Information displays may be for the machine, the cell, or the whole production area. These displays must be clear and quick to understand, direct and encourage corrective actions, be easy to keep updated. Visual methods of displaying information include Pareto diagrams, graphs, and histograms and scatter charts. The type of information that can be displayed includes defects, standard work charts, operator skill, maintenance and safety**.**

7.3.5 Lean Enabler: Standard Work

The aim of standard work enabler is to decrease process variability by standardizing working during operations and improve productivity and quality by eliminating all types of waste. Standard work is the process of making standards of doing all activities and formalization them such a way that they are followed by the operators actually during performing his task in operating machines to manufacture a part or to inspect the part after manufacturing. There are four steps to implement Standard Work i.e. waste removal, documentation of work cycles, apply work standardization and Continuous improvements

7.3.5.1 Case Study on Implementation of Standard Work

The presented case is an example of lean enabler Standard work implementation in a manufacturing cell. Major problems in the studied cell were lower people productivity, high lead time for manufacturing parts because of batch production and High WIP inventory which resulted in around ten times waiting time than actual processing time of the parts. To cope up with the problems, focus area was to improve the operator productivity using cell balancing techniques. To implement standard work enabler following sub steps were taken for Implementation of standard work

Study of layout and material flow: Manufacturing cell under improvement was studied and equipment layout was drawn with display of material movement and operator’s location.

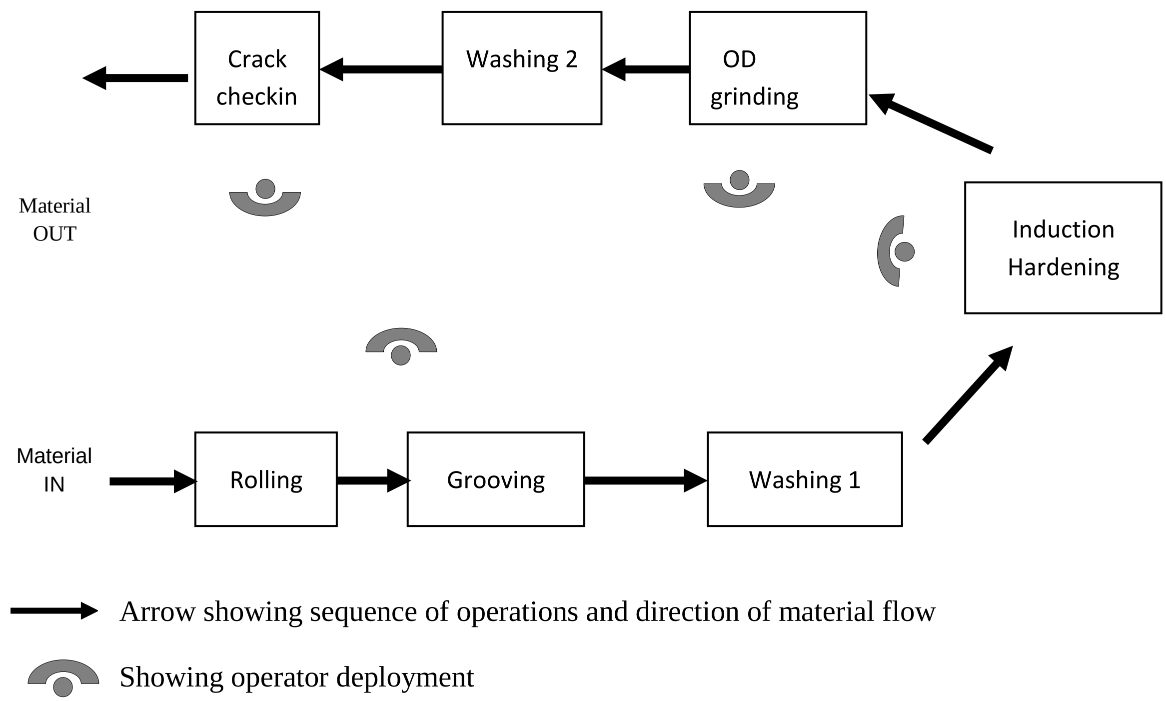


Figure 7.19: Block diagram showing layout of cell studied

Data collection: Data was collected to identify the wastage and locate the focus area of improvement.

i) Takt Time Calculation:

Customer Demand (for the month)	= 1720 / per day
Available work Time = 24 Hours	= 1440 min
Less 3 breaks of Lunch @ 30 min. each	= 90 min
Less 6 breaks of Tea @ 10 min. each	= 60 min
Total Available Time	= 1290 min/day
Takt Time = 77400 sec/1720 unit	= 45 seconds
Hence pull demand from cell	= one unit every 45 Seconds.

ii) Target Cycle Time Calculation:

Production Requirement	= 1720 / per day

Change over In the month (as per plan) = 6 nos.

Changeover time = 600 min

Total Changeover time in a month = 3600 min

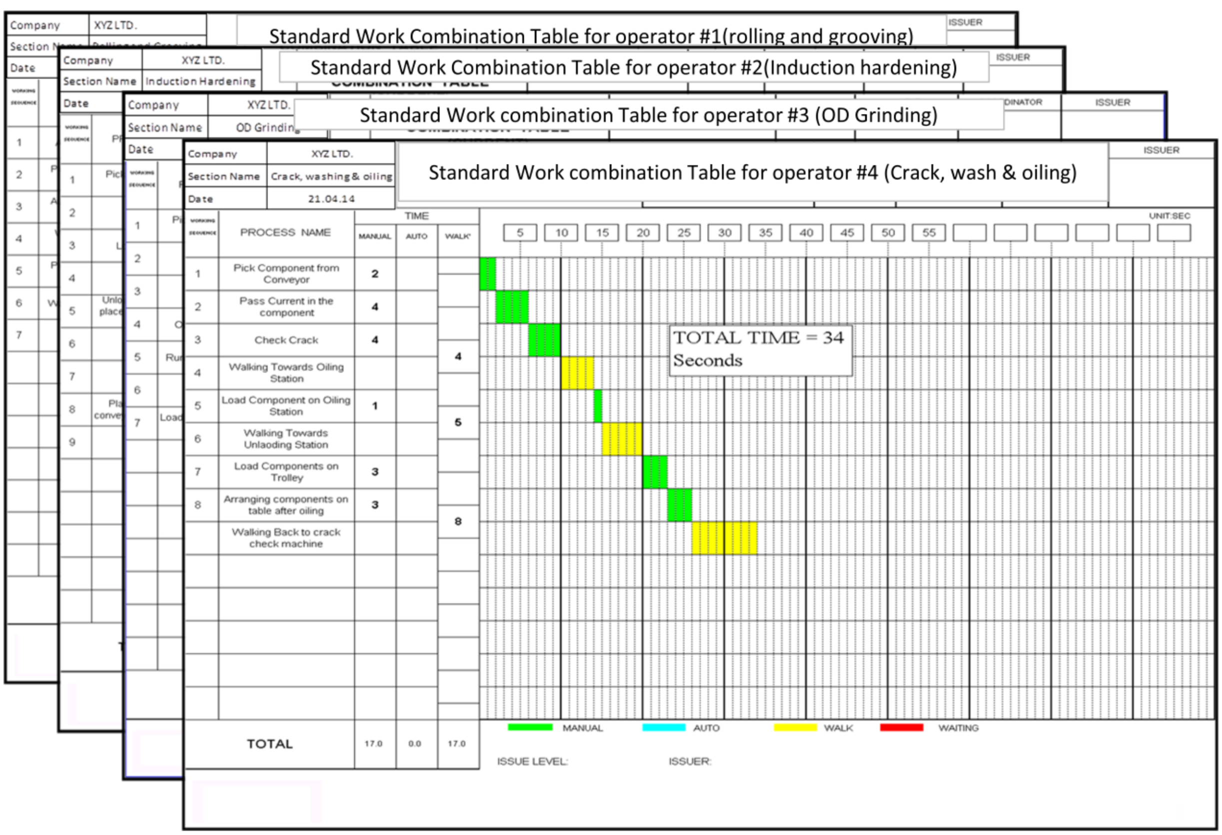
Changeover time per day = 3600 min/25 working days

= 144 mins/day or 8640 Secs/day. 8640/1720 =5.2Seconds lost to special allowance i.e. changeover time

Target Cycle time = 45(Takt) – 5.02(SPA) = 39.98 sec.

Standard work combination table (SWCT) preparation for analysis work content of each operator in the cell. SWCT is a table, which is used for data collection pertaining to operator activities with respect to time.

Table 7.2: Standard Work Combination Table for operators



WORKING SEQUENCE	PROCESS NAME	MANUAL	AUTO	WALK
1	Pick Component from Conveyor	2		
2	Pass Current in the component	4		
3	Check Crack	4		
4	Walking Towards Oiling Station			4
5	Load Component on Oiling Station	1		
6	Walking Towards Unlaoding Station			5
7	Load Components on Trolley	3		
8	Arranging components on table after oiling	3		
	Walking Back to crack check machine			8
	TOTAL	17.0	0.0	17.0

In SWCT each activity was recorded to find out the time consumed for each activity and total time by operator for doing all assigned activities. SWCT helps in examining the loading pattern of operator i.e. the time for which operator is working, moving or waiting..

Analysis of data and decision making: Once the data has been collected it was analyzed for decision making for loading pattern and making uniform loading of operators, ideal requirement of operator for doing the same job (staffing calculation), present deployment of manpower against the same. The table 7.3 gives the results of data collected by SWCTs prepared from conducting time study in the cell. This is mean value of time taken five times for the repeated activities. The table 7.3 shows that operator no1 has manual time for which he is actual working is 12 seconds while walking time is 6 seconds for next 10 seconds he is waiting for completion of machine cycle hence he is working only for 12 seconds as value addition to work contents. For next 10 seconds it may be necessary to move for operating the next machine as he is operating two machines simultaneously (grooving and rolling as shown in the cell layout). This operator is loaded for 18 seconds and he remains idle for ten second. For this time this operator can be utilized for doing another activity.

Table 7.3: Total Time Distribution for all the Four Operators

Operator	Manual time	Walking time	Waiting time	Actual cycle time	Target cycle time	Unassigned time
Rolling & Grooving	12	6	10	28	39.98	11.98
Induction hardening	22	0	14	36	39.98	3.98
OD Grinding	14	1	24	39	39.98	0.98
Crack, wash & oiling	17	17	0	34	39.98	5.98
Total	65	24	48	137	39.98	22.98

Actual work content for operator no1 is 28 seconds as compared with the target cycle time of 40 seconds, this also shows that his work content are already short by 12 seconds. This time can also be utilized for doing another job in addition of waiting time of ten seconds. After analysis it was concluded that operator no.1 can be assigned another job of 22 seconds and in present condition he is under-loaded as per pull system.

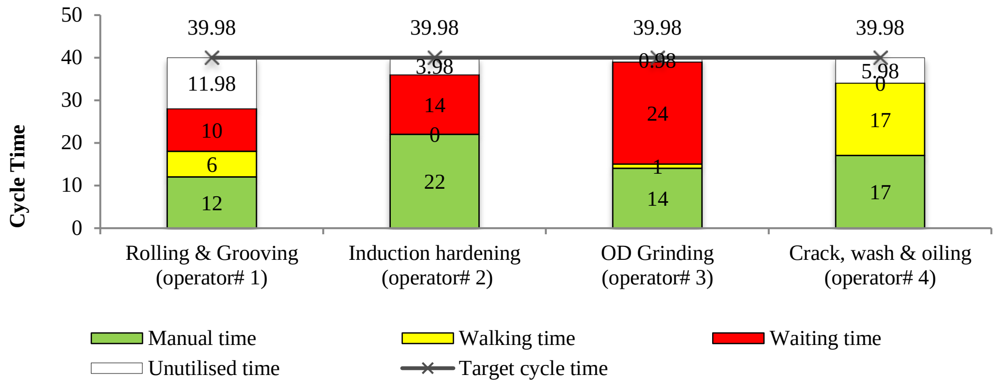


Figure 7.20: Current state of Line balancing based on Standard Work Combination Table

Summary Report:

Takt Time: = 45 Seconds

Target Cycle Time: = 39.98 Seconds

Customer Requirement = 1720 parts

Total Work Unit Manual Time: = 64 Seconds

Total Work Unit Walk Time: = 24 Seconds

Total Work Unit Wait Time: = 48 Seconds

Target work unit staffing: = 2.80

Longest Operator Actual Cycle Time: = 39 Seconds

No. of operators required

$$= \frac{\text{Total Manual Time} + \text{Total Walk Time}}{\text{Target Cycle Time}}$$

$$= \frac{(12+22+14+17) + (6+1+17)}{39.98}$$

= 2.3 Operators at one time

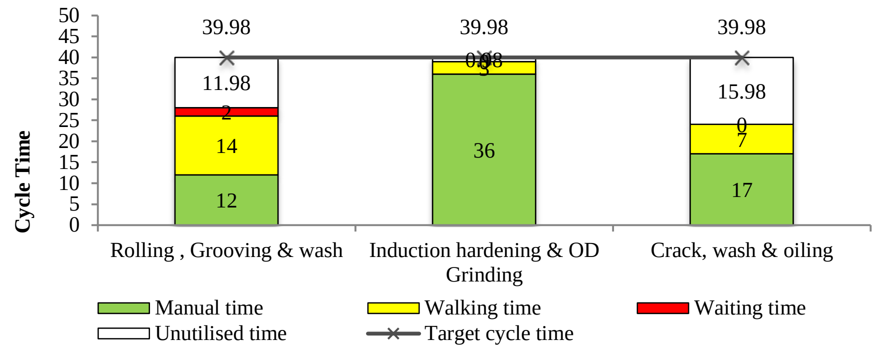


Figure 7.21: Line balancing after implementation of Standard work

Implementation of actions: Operator activities redefined: Operator activities were redefined to achieve uniform loading in the cell. Number of operators were reduced from four to three by providing equal load to each operator. Operator running induction hardening machine was deployed to run outer diameter grinding machine to reduce waiting time. Operators were trained to work in a team as per changing requirement of standardized work environment. Proper incentive scheme was also introduced for the operators working at two stations simultaneously.

Monitoring and comparison of the results: After implementation of Standard work as Lean Manufacturing enabler it was observed that the gain is reduction in manpower from four to three resulting in increase in productivity by 24.8% i.e. from 21.2 parts per man per hour to 28.2 parts per man per hour.

Table 7.4: Improvements observed after implementation of Lost Time Analysis enabler

S. No.	Measure of improvement	Before	After	% improvement
1	Waiting time	48 sec per takt	2 sec per takt	96%
2	Headcount	4	3	25%
3	Labor productivity	21.2 parts per man per hour	28.2 parts per man per hour	33%
4	Inventory	500 parts in WIP	130 parts in WIP	74%

7.3.6 Lean Enabler: Kaizen

Kaizen can be described as a focused and supported event which initiates continuous improvement by giving employees the skills, encouragement and opportunity to make positive changes Implementation of lean enabler: kaizen. There are below five steps in the implementation of kaizen.

Idea Generation: This is regarding generation of idea to improve the current condition. The current state describes the 'starting point' of the kaizen event. This includes factual information such as inventory stock levels, process steps or work practices. The methods and detail of recording the current state will depend on the nature of the event. Identifying the current state will show the effect of improvements. Improvements can be compared to the original current state to demonstrate the magnitude of the changes. It must be aiding value to the development of the future state plan. Knowledge of the facts of the current state can provide a valuable input into the idea generation for the future state and ensure that every member of the team is familiar with the area. Analysis of the current state provides an opportunity to review the procedures, safety risks and processes performed within the area. The current state should be subject to some analysis to aid development of the future state. For example, the current process may be divided into value-added / non value-added / waste or into walking time / waiting time / machine time.

Idea Capturing: Instantaneous capturing of the idea is important. An idea comes to the mind of team member in his area/ in other area, documentation is done by filling the yellow tag. This ensures participation by every individual. Team member puts the filled tag on the area layout in kaizen map placed in the manufacturing cell to communicate to the team about the idea because creativity and innovation can make a major impact without the need for significant investment.

Implementation of Kaizen: The core of the Kaizen event is implementation, where ideas and suggestions are implemented in the work area and refined before permanent integration. This portion of the event remains with high energy, focused on making positive changes, biased for action and with open to experiment. Maximum involvement of employees is ensured by the champion as no kaizen event can deliver good results without the active involvement of the people who work in the area.

Presentation of Kaizen: The team should prepare and deliver a short presentation to the champion and other representatives of senior management. This will provide an opportunity to display the achievements of the team, as well as to gain the visible support of the management team to sustain the improvements. Effective kaizen events have the potential to make massive improvements to performance. However, it is only through sustaining and building on improvements made in the initial kaizen events that this potential can be achieved. The team must ensure that the improvements realized during the kaizen event motivated everybody in the area to drive further improvements. This ability and willingness of all employees to incorporate improvements into their everyday activities is crucial to embed lean manufacturing practices within the company.

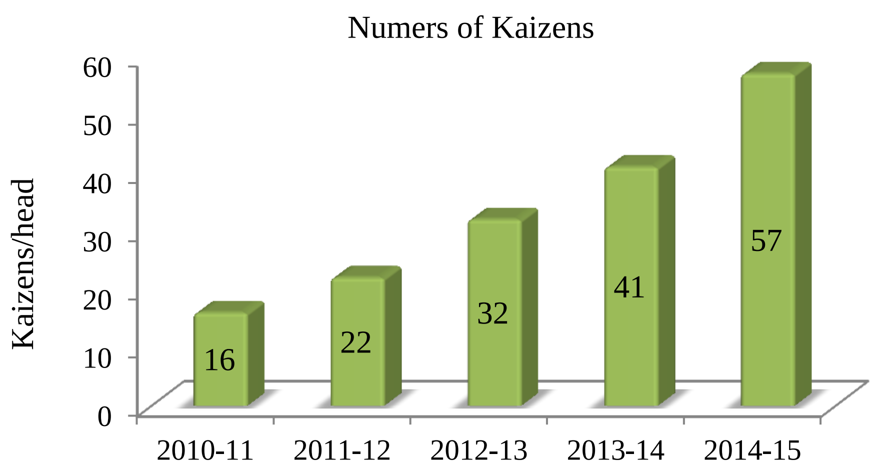


Figure 7.22: Numbers of kaizens completed by employees

Evaluation and Recognition: Evaluation of each kaizen is performed based on three factors: ingenuity of the idea, Improvements made with the kaizen and scope for horizontal deployment across the organisation. The kaizens are recognized based on their ranking to keep employees motivated and enthusiastic for further improvement. Sustaining of this process is important as a kaizen event may start the improvement process, but long-term gains can only be realized by sustaining the changes and implementing further improvements. Numbers of kaizen over a period of time shows the morale of employee in the organisation.

7.3.7 Lean Enabler: Autonomous Maintenance

The philosophy of autonomous maintenance in lean manufacturing is used to deliver improvement in utilization of equipments. The aim of autonomous is to develop the operator to become responsible for maintaining the machine in the optimum condition. Implementation of autonomous maintenance involves following steps.

Identify Machine Improvement Activity: The first phase of autonomous maintenance is to identify machine improvement activities. A team including maintenance specialists and operators works together to improve the safety of the machine, improve the condition of the machine and to increase the operator's familiarity with the machine, and the maintenance operations.

The machine condition is improved to make sure that operators can safely take on maintenance tasks. A general review of the machine and environment may be necessary to identify risks. Checks may include unsafe to access areas are improved or appropriately marked (such as confined spaces) all electrical connections are labeled appropriately.

The team works to improve the condition of the machine and workplace to increase the efficiency of any maintenance or operational tasks. The general condition and operation of the machine can be improved in response to specific opportunities, or to ease the transfer of autonomous maintenance tasks. The identification of machine improvement activity involving operators and maintenance specialists will also allow operators to gain better understanding of the optimum condition of the machine and will increase their ability to respond proactively. As with all elements of lean manufacturing enterprise, involving the operators in these improvements will increase the sustainability of improvements and the benefits gained.

Transfer the Specific Tasks to Operators: The maintenance and production team works together to decide which maintenance tasks which can be transferred to operators. These decisions may be based on the historical data of issues that the machine has experienced, such as root-cause solutions to quality issues, lost time analysis, machine failure mode analysis and creating maintenance history. Tasks already performed by the operators should be reviewed. The knowledge of autonomous maintenance tasks to operator carry out by them is essential to effective and efficient autonomous maintenance. The standard autonomous maintenance process must be communicated and displayed to all relevant employees in an accessible and functional method.

Formalize: To formalize the tasks identified for transfer to operators, ensure recording of the task and display and communicate the standard autonomous maintenance process. Each task may require action such as instruction on how to replace a component or may be an inspection activity such as instruction on how to check a gauge. The entire team is involved in generating the standard autonomous maintenance process to ensure that they are effective, quick to understand, unambiguous and easy to update. The standard autonomous maintenance process includes any safety implications, such as risks to be aware of, the best method, the time required to complete the task and how often the task is to be performed.

Sustain: The benefits from any autonomous maintenance program are realized in the long term if they are integrated into the daily practices of all operators. This requires a significant culture change in the ownership of machines and their maintenance, and the expansions of the roles of maintenance specialists. All employees, including plant management, maintenance specialists and production operators, are involved to ensure that the gains made by transferring autonomous maintenance tasks are maintained and further improved.

Initiate Next Cycle: The autonomous maintenance cycle is repeated as the skills and experience of the operators increase, and they are able to accept more advanced tasks. The selection of focus machines or tasks for the following cycles of improvement depends on a performance of various equipments measured in overall equipment effectiveness.

7.3.7.1 Benefits Gained From Autonomous Maintenance

Some of the benefits gained by implementation of autonomous maintenance are

- Reduced downtime because the operator can respond to problems immediately.

- Reduced downtime and quality losses because the operator can respond proactively to machine deterioration before the machine operates outside of the optimum.
- Improved machine design and operation through the increased involvement of operators and maintenance specialists.
- The cycle of skill and task transfer is repeated as a result operator skills and involvement is increased.
- Enhanced the potential of the employees through training and empowering people.

7.4 CHAPTER SUMMARY

Lean manufacturing can be implemented and sustained by people development and manufacturing process improvements. This starts with the formation of different teams for implementing of lean enablers covering all the lean elements. Structured program is essential describing their aim, procedure, potential benefits and every possible other effect of the steps taken. Full Implementation of lean is achieved through adoption of a new way of working in a continuous improvement environment, which can be achieved by strong commitment from management and people development leading to total employee's involvement.

The real life case has been studied to examine the implication of lean manufacturing on the performance of manufacturing industry. It is observed that implementation of lean enablers has resulted in improvement of labor productivity, reduction in WIP inventory and improved flexibility by reducing changeover time. This improvement has financial impact as saving of operators has improved labor cost per part manufacturing and hence direct impact on financial results. Concurrently employee's involvement in operational results improvement has positive impact on morale of employees. This case study has supported the fact that benefits gained with implementation of lean have positive impact on the organisational performance in the context of Indian industry.

CHAPTER VIII

CONCLUSION AND FUTURE SCOPE

The chapters in this research thesis discussed the identified key elements of lean manufacturing, their applicability and the extent of their implementation in the Indian context. The chapters also elaborated upon the benefits gained and obstacles faced in implementation by Indian industries. Critical analysis was done to assess the relationship between lean manufacturing and organisational performance in Indian context. This study further discusses, in Chapter VIII, the potential areas of future research which could be taken up by researchers and practitioners for the benefit of industries and society.

8.1 CONTRIBUTION OF PRESENT WORK

- On the basis of literature review, it was observed that lean manufacturing is a vital approach adopted by global manufacturing industries. The study categorizes lean elements and synthesizes them based on their frequency of occurrences. This analysis gives a clear understanding of variables which have been topical issues for researchers and practitioners.
- Since no research study was found in the literature which had evaluated all factors pertaining to lean implementation practices in a comprehensive manner, therefore this study would be useful in assessing the impact of lean manufacturing practices on organizational performance. Measurement of level of lean manufacturing is complicated due to lack of established measurement criteria. Hence, seven factors were established for gauging the level of lean manufacturing. This study explored a new orbit of measuring the lean manufacturing. The factors established in this research may be used as a scale to measure the level of lean manufacturing implementation in any organization.
- Organisational performance measurement criteria was not established earlier, therefore the study proposes ten measures for gauging the organizational performance. These factors may be used as a scale to measure the level of organisational performance for any industry.
- The previous studies did not report any established correlations among the factors responsible for lean manufacturing implementation and among the factors responsible for

measurement of organisational performance. There are many enablers of lean, reported in literature, which impact the organizational performance. Therefore it was a pressing imperative to identify the vital few (drivers) whose enforcement could lead to significant improvement in the organizational productivity. The Interpretive structural modeling is a proven technique which identifies the variables with high driving power and low dependence power through the MICMAC analysis. Hence, this study emphasized on developing the causal structure of lean implementation through interpretive structural modeling. The study identified Kaizen and 5S as the key drivers whereas Standard Work and VSM were found to have high dependence power. The managers in industries generally do not know which factor to implement first in order to improve the organizational performance. Most of them end up acting on variables which have high dependence power. Action on such variables would not correct things and therefore would not improve performance significantly. Many managers in Indian companies act directly on VSM for implementation which then becomes ineffective in improving productivity. VSM being a highly dependent factor would require other factors to be triggered first. Therefore, onus lies on managers to act on factors, 5S and kaizen in this case, with high driving power and low dependence power. Action on 5s and Kaizen would not only improve productivity but would also drive other factors in their successful implementation. Therefore, in a nut shell, the diagraph obtained from the Interpretive structural modeling of lean implementation practices, outlines a roadmap for managers for a systematic action on enablers which would then cause significant improvement in organizational performance. The hierarchical structure developed in this study could be standardized by Indian manufacturing companies as a road map to success.

- The results obtained through SEM analysis further strengthen the insights received from the ISM analysis. 5S and Kaizen were found to impact lean practices significantly (with factor loadings of 0.73 and 0.86, respectively). The conceptual model developed through SEM portrays the impact of lean practices on operational as well as financial performance.
- Impact of lean manufacturing practices on organisational performance was found to have very limited literature support in context of Indian industries. The direct and measurable impact on organisational performance with the implementation of lean manufacturing

practices is established through use of SEM technique. The impact of lean manufacturing practices on the operational performance was found to be 0.78 which can be considered as significant. The lean manufacturing practice also significantly affects the financial performance of an organization. The path coefficient for this relationship was measured as 0.53 in the SEM analysis. Likewise, the impact of operational performance on financial performance was found to be significant with path coefficient as 0.40. The financial performance is best explained through inventory turns (path coefficient 0.93). This study gives a very useful insight to managers that enforcement of autonomous maintenance, 5 S and Kaizen could lead to improvement in the operational performance. The operational performance, which is best explained through productivity, quality and delivery, would improve the financial performance. Therefore, initiatives taken on implementation of lean practices would have a significant impact on inventory turns, revenue growth, profitability and market share.

- Present work has highlighted the significance of lean manufacturing and its positive and direct impact on organisational performance hence may provide a direction to Indian industries to remain competitive in global market. The organizations can prioritize the lean practices based on the quantified scores presented by the SEM analysis in this study.
- This study may highlight the importance of lean manufacturing in Indian industries in an appropriate manner and may motivate the industry to use this approach for improving the organizational performance.
- Contribution of this work may help practitioners in finding out the weak areas pertaining to the lean implementation practices. Poor level of performance indicators, both financial and operational, would indicate lack of focus on high impact enablers. Strategies could then be formulated to implement such enablers in the organization to achieve appropriate results.

8.2 IMPLICATIONS OF THE STUDY

This research has several implications on performance improvement in the industries with the implementation of lean manufacturing. The managerial insight gained may help managers and policy makers to select the appropriate variable for enforcement to achieve significant improvement in the productivity. Following section gives a broader explanation on the insight gained.

8.2.1 Managerial implications:

This research has a number of implications for the professionals:

- This study organized the lean manufacturing elements into distinct categories. Many elements of lean manufacturing which are actually same, but are being practiced by industries with different names. Hence this research has identified a list of unique elements which could encompass all with no ambiguity and overlaps. In addition to this, the research has identified significance of each element in the Indian industry context. Hence practitioners are expected to adopt the appropriate elements as tools to implement lean manufacturing.
- Methodology for implementation of several elements at the same time is discussed with the deployment of enablers to make lean implementation easy. This may be adopted by practitioners for flawless implementation of lean manufacturing to achieve enhanced performance.
- Organisational performance measurement factors have been identified in this research. This may provide support to professionals for measuring organisational performance in both aspects i.e. operational and financial performance.
- The interrelationships among the lean manufacturing factors and organisational performance are identified in this research. This may support practitioners in implementing lean factors in sequential manner. Additionally, focus may be given to appropriate organisational performance factors based on their individual rankings for monitoring the performance of the organization.
- The positive relation between lean manufacturing and enhanced organisational performance provides a direction to managers for ways to overall success of the business.

In brief; many conceptual developments of this study may be significant for the practical use, hence this research study has got substantial amount of practical values.

8.2.2 Implications for Academia

This research has provided significant implications for academicians, which may be helpful for future research.

- The implementation of lean manufacturing may be explored in business sectors other than manufacturing industries.
- This study was conducted mainly in medium and big size industries where the general employees (mainly respondents) understand the lean manufacturing and its implications. The findings of this study may be explored in small and micro level manufacturing industries.
- This research may be used as the base line for further research and the topic may be used as a class room teaching.

8.3 LIMITATIONS OF THE PRESENT STUDY

This study is based on a survey conducted form manufacturing organizations from India. Mainly bigger firms have been considered for survey considering the application and knowledge of lean may be better in bigger industries as compared to the small scale industries.

- To keep the survey questionnaire simple it was restricted to manufacturing organisations and the service industry was not included.
- Though more than one opinion was collected from each manufacturing plant to improve personal bias but some responses given by respondents might be prejudiced.
- Seven enablers of lean manufacturing practices are considered in this study but there may be some more factors representing the lean practices and may be left out.

- This research has been conducted considering the lean variables pertaining to the Indian manufacturing Industries. These variables are likely to change in a different system pertaining to change in country, type of industry and social culture. However, the methodology adopted in determining the correlations amongst factors in the study, more or less, would remain same. This may attract researchers and practitioners globally to establish correlations in context to their environment.

- ISM technique is based on expert opinion so correlation and ranking of practice performance parameters may differ with change in the experts.
- This study presents the current condition and may not be acceptable in the coming years due to change in benchmarking of practice performance parameters.

8.4 SCOPE OF FURTHER WORK

An exhaustive study was conducted to capture the impact of lean implementation practices on the organizational performance. Structural equation modeling, Interpretive structural modeling and statistical techniques were used to evaluate the impact of lean implementation practices on operational as well as financial performance of an organization in Indian context. This scope of this study was limited to the assessment of impact of lean implementation practices on organizational performance. However, the researchers and practitioners could further extend this work in a number of ways which have been discussed in the following section.

- Although a thorough study of the lean manufacturing practices implementation and its impact on organisational performance of Indian industries has been done considering different practice and performance factors but still few might have remain untouched. In this study collection of data was limited to the practitioners and customer opinion was not included for validation of results declared by practitioners. Practitioners and researchers may bridge this gap by taking opinions from customers and stakeholders. This may help in knowing the exact status of customer results.
- Survey could be expanded to include small scale industries in assessment on lean parameters.
- This research study, also invite practitioners and researchers to further elaborate this work by standardizing all elements into lean award model framework (LAM) based on which all companies pertaining to Indian manufacturing would participate. They would then get rated on LAM and subsequently get awarded based on their performance.

8.5 CONCLUDING REMARKS

The research domain of lean manufacturing has strong significance for the industries specifically related to the manufacturing sector. The literature reviewed revealed that practitioners have reported improvements in their productivity through the implementation of one or more lean practices. Hence the need was felt to identify and categorize all lean practices,under one umbrella, which lead to improvements in the organizational performance. It was found in the literature review, that a few scanty research studies were conducted in the past which had assessed the impact of all lean practices together and quantified their impact. This research study has addressed this gap and has quantified the impact of all lean practices on organizational performance. This study analyzed the status of lean manufacturing in the context of Indian industries, its level of implementation and impact on organizational performance.

The empirical investigation has been used in this study to investigate the significance, benefits and effectiveness of lean manufacturing in improving organizational performance. The study found that productivity and quality were major factors which explained operational performance. it could be well inferred from the SEM analysis that enforcement of all lean practices particularly, Autonomous maintenance,5s and Kaizen can lead to significant improvements in operational performance which could be reflected through increase in quality and productivity. Lean initiatives lead to increase in productivity and cost and hence improves financial results. Simultaneously employee’s morale has direct impact over organisational performance.

In this way the study discovers and validates that lean manufacturing implementation has positive impact on organisational performance of the Indian industries. The results conclude that effective implementation of lean manufacturing is very much helpful in organisational performance improvement. Indian industry should focus more on lean initiatives within their manufacturing operations to improve productivity, quality, cost competitiveness, improved financial results and higher morale of employees.

This research used ISM as a tool for the assessment of causal relationships and driving and dependence powers of all factors associated with lean manufacturing practices. The methodology was very effective in modeling qualitative variables and incorporated the accurate feedback given by the subject experts from the manufacturing Industry. The causal relationships developed and the MICMAC analysis gave very insightful inferences for practitioners to incorporate in their implementation strategies. Further a strong statistical tool, Structural Equation Modeling, was used to assess the impact of lean practices on the operation performance and financial performance of the organization.

The ISM analysis done in this research study could be useful in outlining implementation strategy for lean practices whereas; the SEM analysis did the quantification of impact of lean practices on operational as well as financial performance. This quantified result could be used in assessing the organizations for their readiness to implement lean.

This research illustrates that lean manufacturing implementation is an effective proposal to improve operational performance regardless of the type and size of the industry. Lean manufacturing implementation results in exceptional enhancement in organisational performance parameters simply by focusing on waste identification and elimination with continuous improvement cycles. It requires comparatively low investment thus becomes more relevant to Indian industries to achieve the desired results.

Lean manufacturing promotes participation and involvement of employees to prompt operational initiatives to improve upon productivity, quality, cost and morale and thus Indian industries can face the global competition. Finally, it is expected that this study will encourage Indian industries to initiate the essential transformation in their manufacturing environment for implementation of lean manufacturing to obtain paramount benefits.

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APPENDIX 1

BRIEF PROFILE OF THE RESEARCH SCHOLAR

Rakesh Kumar is a research scholar in YMCA University of Science and Technology, Faridabad, India. He is holding Bachelor's degree in Mechanical Engineering from Jamia Millia Islamia University, New Delhi, Masters of Technology in Mechanical Engineering with specialisation in manufacturing and automation technology from YMCA University of Science and Technology, Faridabad and Masters of Business Administration with specialisation in operations form Indira Gandhi National Open University, New Delhi.

He has 28 years of professional experience in various industries. Presently he is working as a Plant Manager in a multinational company in National Capital Region Delhi, India. He has research interests in lean manufacturing and operations management. He is the author of many papers at national and international levels.

APPENDIX 2

FIRST DRAFT MAIL SENT TO RESPONENTS

<< Full Name>>

<<Company Name>>

<< Address>>

Dear <<First Name>>,

I am a research scholar, conducting research on lean manufacturing and its effect on organizational performance. The purpose of this research is to measure the extent of use of lean manufacturing practices within different Indian industries. Your company may or may not have adopted lean practices; however, it is important for you to participate in this research. For concluding the research on pan India basis, we need information from as many companies as possible.

A questionnaire is attached with the mail for collecting the necessary information. We have taken care to minimize the time required for completion of the questionnaire. There are three pages in this survey. First page is about your profile and about your organisation. There are few questions in general information page where you may or may not be interested in answering so; if you do not want to answer you may keep if empty but I will request you to answer all the questions. All the questions are mandatory to answer in sheet number two and three. For your response you may click on the appropriate box to provide an answer in numerical form. Once you click, the box will show checked. If by mistake; you have clicked the wrong box and want to alter; click it again and it will be unchecked. Alternatively you may print the questionnaire, fill your response manually and send the scanned copy. You are requested to complete your response and return it as soon as possible.

Please be assured that information about you or your organization will remain completely confidential and this data will not be used anywhere other than research purpose. You are requested to complete and return the survey within the ten days so that I can complete my research on time.

Thank you for your support and contribution to this research.

Regards

Rakesh Kumar

Research Scholar, YMCA University of Science and Technology, Faridabad

APPENDIX 3

FOLLOW UP MAIL SENT TO RESPONENTS

<< Full Name>>
<<Company Name>>
<< Address>>

Dear <<First Name>>,
Three weeks ago, I sent you a mail requesting for your support in conducting a survey on lean manufacturing and its impact on the performance of your company. In case if you have already completed the survey and returned on my mail, please ignore this mail and I thank you for supporting me in conducting my research. If you have not yet completed the survey, please treat this mail as a gentle reminder.

I appreciate the importance of your opinion and hence I am bothering you again. Hence I request you again to complete and return the survey within the ten days so that I can complete my research on time.

Your support is very much appreciated.

Regards
Rakesh Kumar
Research Scholar, YMCA University of Science and Technology, Faridabad

APPENDIX 4

LIST OF PUBLICATIONS OUT OF THESIS

List of Published Papers

S. No.	Title of Paper	Name of Journal where published	Volume number and issue	Year	Pages
1	Effect of Lean Manufacturing on Organisational Performance of Indian Industry: a Survey	Int. J. Productivity and Quality Management,	Volume17, No. 3	2016	380–393
2	Evaluation and Benchmarking of Lean Manufacturing System Environment: A Graph theoretic approach	Uncertain Supply Chain Management,	Volume 4 issue 2	2016	147-160
3	Lean Manufacturing in Indian Context: A Survey	Management Science Letters	Volume 5	2015	321–330
4	Analysis of Significant Lean Manufacturing Elements through application of Interpretive Structural Modelling (ISM) approach in Indian Industry	Uncertain Supply Chain Management	Volume 4 issue 1	2015	83-92
5	Literature Review and Implications of Standard Work Implementation in Indian Industry- A Case Study	International Journal of Latest Trends in Engineering and Technology	Volume 4 Issue 3	2014	50-63.
6	Barriers in Implementation of Lean Manufacturing System in Indian industry: A Survey	International Journal of Latest Trends in Engineering and Technology	Volume 4 Issue 2	2014	243-251

List of Published Papers

S. No.	Title of Paper	Name of Journal where published	Volume number and issue	Year	Pages
7	Operational performance improvement by implementation of value stream mapping– a case study from Indian industry.	Int. Journal of Productivity and Quality Management	Volume 19 Issue 4	2016	526-541

List of Accepted Papers

S. No.	Title of Paper	Name of Journal	Present status	Year
1	Application of Interpretive Structural Modeling (ISM) Approach for the Analysis of Barriers affecting Lean Manufacturing implementation in Indian Manufacturing Industry	International Journal of Business Performance and Supply Chain Modelling	In Production	2016

List of Papers in National Conferences

Sr. No.	Title of Paper	Name of Conference	Year of conference	Place of conference
1	Lean Manufacturing System: An overview	National Conference on Trends and advances in Mechanical Engineering, TAME	Oct 19-20 2012	YMCA UST, Faridabad
2	Lean manufacturing: elements and its benefits for manufacturing industry	National Conference on Trends and Advances in Mechanical Engineering, TAME	Oct 19-20 2012	YMCA UST, Faridabad

APPENDIX 5

General information

Respondent's profile

1 Respondent's Name (optional)……………………………………………

2 Designation (optional)……………………………………………………

3 Department………………………………………………………………………

4 Working with current organisation ………………………years

5 Total experience ……………..years

Company's profile

1 Name of organisation (optional)…………………………………………

2 Nature of business

- ☐ Automobile ☐ FMCG ☐ Service
- ☐ IT ☐ Pharmaceuticals

Others (please specify)…………………………………….

3 Main Product:……………….

4 Location (city):……………..

5 Location (state):………….

6 Nos. of employees:

- ☐ Below 50 people ☐ 51-100 people ☐ 101-250 people
- ☐ 251-500 people ☐ 501-100 people ☐ 1001-2000 people
- ☐ 2001-5000 people ☐ More than 5001 people

7 Annual turnover in crore Rupees

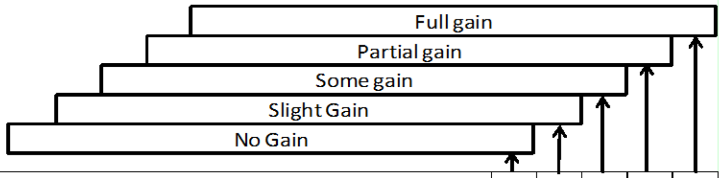
- ☐ Below 1 Cr ☐ 1-5 Cr ☐ 5-10 Cr
- ☐ 10-15 Cr ☐ 15-25 Cr ☐ 25-50 Cr
- ☐ 50-75 Cr ☐ 75-100 Cr ☐ 100-150 Cr
- ☐ 150-250 Cr ☐ 250-500 Cr ☐ 500-1000 Cr
- ☐ 1000 -1500 Cr ☐ 1500-2500 Cr. ☐ More than 2500 Cr

The below questions are related to your plant for gauging the extent of **<u>implementation of lean manufacturing practices</u>** . Please select the appropriate score for each of practice ranging from 1 to 5 indicating from "No implementation" to "Full implementation".

- Full implementation → 5
- Partial implementation → 4
- Some implementation → 3
- Slight implementation → 2
- No implementation → 1

Lean manufacturing practices	Measurement criteria	1	2	3	4	5
5 S	5S training is delivered to each employee	☐	☐	☐	☐	☐
	5S is practiced throughout the plant.	☐	☐	☐	☐	☐
	5S is monitored periodically and improvement actions are initiated	☐	☐	☐	☐	☐
Kaizen	Suggestion scheme is in place and working.	☐	☐	☐	☐	☐
	Kaizen process is practiced by shop floor person.	☐	☐	☐	☐	☐
	Kaizen meeting is held periodically	☐	☐	☐	☐	☐
Lost Time Analysis	Lost time is monitored on bottle neck machines	☐	☐	☐	☐	☐
	Lost time data is anaysed and actions are initiated	☐	☐	☐	☐	☐
	Setup time reduction is practiced on machine .	☐	☐	☐	☐	☐
	Periodical review of bottleneck process or equipment is in place	☐	☐	☐	☐	☐
Visual management	Equipments are identified with sinages	☐	☐	☐	☐	☐
	Process parameters are displayed on shop floor	☐	☐	☐	☐	☐
	Andons are connected to equipments interventions	☐	☐	☐	☐	☐
	Manufacturing performance is displayed on shop floor	☐	☐	☐	☐	☐
Autonomous maintenance	Operators are involved in improving equipment conditions.	☐	☐	☐	☐	☐
	Equipment operational efficiency improvement projects are undertaken by shop floor person	☐	☐	☐	☐	☐
	Shop floor teams works for basic condition improvement of machines.	☐	☐	☐	☐	☐
	There is a chase for reduction of cycle time	☐	☐	☐	☐	☐
Standard Work	Cell balancing is evaluated periodically and actions are initiated	☐	☐	☐	☐	☐
	Standardised work instructions are available on work centers	☐	☐	☐	☐	☐
	Work sequence and content are same even the operator changes	☐	☐	☐	☐	☐
	Cellular manufacturing concept is employed in equipment layouting.	☐	☐	☐	☐	☐
Value stream mapping	Rate of production is controlled by customer requirement.	☐	☐	☐	☐	☐
	Cycle time and operating efficiency is monitored periodically	☐	☐	☐	☐	☐
	Value stream mapping is performed periodically	☐	☐	☐	☐	☐
	FIFO is followed between production stations where ever designated.	☐	☐	☐	☐	☐
	Production lot formation is controlled by Heijunka system.	☐	☐	☐	☐	☐

The below questions are related to your plant for gauging **benifits of lean manufacturing** practices.
Please select the appropriate score for each element ranging from 1 to 5 indicating from "No gain"



Benefits	Measurement criteria	1	2	3	4	5
Productivity	Changeover time reduction	☐	☐	☐	☐	☐
	Increase in productivity	☐	☐	☐	☐	☐
	Reduction in unplanned breakdown	☐	☐	☐	☐	☐
	Improvement in OEE	☐	☐	☐	☐	☐
Quality	Reduced inspection,	☐	☐	☐	☐	☐
	Reduced rework,	☐	☐	☐	☐	☐
	Reduced scrap	☐	☐	☐	☐	☐
	Reduced numers of customer complaints	☐	☐	☐	☐	☐
	Reduced cost of poor quality (COPQ)	☐	☐	☐	☐	☐
Cost	Reduction in inventory cost	☐	☐	☐	☐	☐
	Reduction in distribution expenses	☐	☐	☐	☐	☐
	Raw material yield improvement	☐	☐	☐	☐	☐
	Reduction in utility cost	☐	☐	☐	☐	☐
Delivery	Improved delivery rating of supplier	☐	☐	☐	☐	☐
	Improved delivery rating to customer	☐	☐	☐	☐	☐
	Reduced throughput time	☐	☐	☐	☐	☐
	Improved flexibility	☐	☐	☐	☐	☐
Safety	Reduced numbers of first aid cases	☐	☐	☐	☐	☐
	Reduced numbers of accidents	☐	☐	☐	☐	☐
	Improved actions on safety improvement	☐	☐	☐	☐	☐
Morale	Improved core competencies of employee	☐	☐	☐	☐	☐
	Increse in no. of kaizens per head	☐	☐	☐	☐	☐
	Employees participation in trainings	☐	☐	☐	☐	☐
Inventory turns	Inventory analysis is performed periodically	☐	☐	☐	☐	☐
	Product follows unidirectional flow while manufacturing.	☐	☐	☐	☐	☐
	Production order is generated by next station through pull syste	☐	☐	☐	☐	☐
	Inventory turns is improving year over year	☐	☐	☐	☐	☐
	Overall reduction in inventory cost year over year	☐	☐	☐	☐	☐
Revenue growth	Increase in revenue per customer	☐	☐	☐	☐	☐
	Increase in revenue year over year	☐	☐	☐	☐	☐
	Increase in product price with value addition	☐	☐	☐	☐	☐
	Addition of revenue source i. e. cousultancy, royality income e	☐	☐	☐	☐	☐
Profitability	Increase in profitability of plant	☐	☐	☐	☐	☐
	Return on working asset (ROWA)	☐	☐	☐	☐	☐
	Improved cash flow	☐	☐	☐	☐	☐
Market share	Existing customer are retained	☐	☐	☐	☐	☐
	Increase in demand from customers	☐	☐	☐	☐	☐
	Increase in share of business per customer	☐	☐	☐	☐	☐
	Added new customers	☐	☐	☐	☐	☐

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