An Empirical Investigation of Lean Enterprise in Indian Industry

THESIS

Submitted in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

Naga Vamsi Krishna Jasti

Under the supervision of

Prof. Rambabu Kodali

BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE

PILANI (RAJASTHAN), INDIA

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CERTIFICATE

This is to certify that the thesis entitled **An Empirical Investigation of Lean Enterprise in Indian Industry** and submitted by Naga Vamsi Krishna Jasti, ID No 2008PHXF430P for award of Ph.D. Degree of the Institute embodies original work done by him under my supervision.

Signature of the supervisor: RB Kodali 14/7/14

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Date: 14/07/2014

Dedicated

to

my grand parents

Shri K Bapaiah & Late K Masamma

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(Naga Vamsi Krishna Jasti)

Abstract

In today's world the competition moves so quickly that an organization does not have the comfort of absorbing some losses before it loses the war in the market. The key to long-term success is being able to do certain things better than your competitors can do. Hence many companies are in the process of trying to 'do it right the first time' in every process of the business like new product development, supply chain management, marketing and manufacturing processes also. Traditional manufacturing approaches are no longer efficient to stay in the present global market scenario. In response to this, many organizations have started to adopt different philosophies like total quality management, total preventive maintenance, six sigma and lean enterprise etc., in their business processes to stay in the competitive world market. After implementation of such philosophies, these organizations started claiming of becoming world-class manufacturers especially in manufacturing processes. However, many philosophies have implemented to improve manufacturing processes in organizations. Moreover, some organization have started to improve overall organizational functions, start from product development to customer delivery. Lean enterprise is one of the strategy, which can be useful to improve overall organizational processes. It is starts from product development to customer delivery. However, there is no clear consensus among the manufacturers and also the absence of a practical and detailed model to follow is an issue of concern to those organizations interested to implement lean enterprise principles especially for Indian manufacturing organizations. Hence, there is a need for an empirical investigation of lean enterprise in the Indian manufacturing industries.

To fulfill this requirement this study has been undertaken. In the first phase of the study literature review of a lean enterprise is undertaken and the present scenario of implementation of lean enterprise principles among Indian manufacturing industries were analyzed with the help of empirical survey. The existing frameworks for lean enterprise were identified with the help of an extensive literature review. Their validity and reliability in the present Indian industrial scenario was analyzed. It was found that none of the existing frameworks fulfilled the requirements of the present manufacturing scenario. Hence, a framework for lean enterprise was proposed. The proposed framework was developed by performing a comparative analysis of the existing frameworks and empirical data collected from validation of existing lean enterprise frameworks. It is represented in the form of a house having ten pillars supporting the roof of lean enterprise. The foundation was made up of two main elements and the element of knowledge management encompasses all the pillars.

To validate the same, the systematic approach for empirical investigation has been used. A survey instrument was developed to do empirical study across five important sectors of Indian manufacturing industries viz. – automobile, electronics and components, machines and equipments, process industries and textile. Further, the data obtained from the survey is subjected to statistical analysis using statistical computing package SPSS® 18.0v. Various data analysis methods such as descriptive statistics, correlation analysis, reliability and validity analysis, factor analysis and inter item analysis are used. These analyses indicate that the proposed framework is valid in the Indian scenario. Apart from the Interpretive structural modeling (ISM) model and structural equation modeling has been also used. Finally, the applicability of the proposed framework for lean enterprise is checked by providing empirical survey and ISM model also. Thus, it is believed that the proposed framework can help the managers to understand the various initiatives, which will helpful to move towards being the best or excellent organizational activities.

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Chapter 1

Introduction

1.1 Overview

After World War II, Japanese manufacturing industries have struggled with limited resources and less man power. It had also observed customer demand on variety of products in its peak. With that, to fulfill the customer requirements around 1950's, Eiji Toyoda and Taiichi Ohno have started to implement a new approach called as Toyota production system (TPS). It has developed the combination of positive features of craft production and mass production. With that Japanese organizations have started to meet customer requirements with high quality, productivity and low cost. "Toyota Motor Company", which despite the 1973 oil crisis, increased its earnings, and to continued increasing its market share. Even today, Toyota Motor Company is one of the world's most successful automakers that has perpetually outperformed its competitors in terms of quality, reliability, cost, delivery, after sales service etc. Over the last two decades, many researchers such as Womack and Jones, Liker have studied the TPS and documented various principles and practices used by Toyota (Womack and Jones, 1996; Liker, 1998). Krafcik (1988) have coined the phrase "Lean production (LP)" while performed review on TPS. The term "LP" had gained attention from the research world since the publication of the book 'The machine that changed the world' written by researchers from the Massachusetts Institute of Technology (MIT), USA in the year 1990 (Womack et al, 1990). The same book has provided information on the uniqueness and significance of the LP to the globe. Bhasin and Burcher (2006) have discussed LP as a manufacturing philosophy that provides solutions to the organizational activities in long term perspective. Although the principles behind LP are not new in themselves; which can be traced back to the work of pioneers such as Deming, Taylor, Skinner, etc., because of its ability to attain and realize so much more in terms of final outcomes with the deployment of fewer resources (Coffey and Thornley, 2006).

Lean manufacturing (LM) or LP, which is often known simply as "Lean", is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. It is also considered as a generic process management philosophy derived mostly from the TPS and is renowned for its focus on reduction of the original "Toyota seven wastes" in order to improve overall customer value, but there are varying perspectives on how this is best achieved (Nightingale and Mize, 2002). According to Womack et al (1990), LM can be defined "*use less of everything - half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering working hours to develop a new product in half the time. Also, it requires keeping far less than half the inventory on site, results in fewer defects, and produces a greater and ever growing quality of products*". LM is a great competitive weapon that reduces the overall cost of the products and improves the quality. Its goal is to incorporate less human effort, less inventory, less time to develop products, and less space to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner (Sobek-II, 1997). According to Ohno (1988), LM is the set of "tools" that assist in the identification and steady elimination of waste (muda). Examples of such "tools" are value stream mapping, 5S, kanban, and poka yoke. LM makes use of many tools and techniques. Every operation is different and no two companies put these improvements in place the same way and use the same tools and techniques the same way (Hines et al, 2004).

There is a second approach to LM, which is promoted by Toyota, in which the focus is upon improving the “flow” or smoothness of work, thereby steadily eliminating mura (“unevenness”) through the system and not upon ‘waste reduction’. Techniques to improve the flow include production leveling, pull production and heijunka box. This is a fundamentally different approach to most improvement methodologies which may partially account for its lack of popularity (Manjunatha and Shivanand, 2008). The difference between these two approaches is not the goal but the prime approach to achieving it. The implementation of smooth flow exposes quality problems which already existed and thus waste reduction naturally happens as a consequence. The advantage claimed for this approach is that it naturally takes a system-wide perspective whereas a waste focus has this perspective, sometimes wrongly, assumed. Some Toyota staff has expressed some surprise at the tool-based approach as they see the tools as work-a rounds made necessary where the flow could not be fully implemented and not as aims in themselves. Both LM and TPS can be seen as a loosely connected set of potentially competing principles whose goal is cost reduction by the elimination of waste (Monden, 1998). After the huge success rate of lean principles in manufacturing operations, many researchers have started to implement in supply chain management and product development activities also. According to Womack and Jones (1994), the philosophy of LM principles can be implemented not only in manufacturing operations but also across the enterprise. Finally the researchers proposed the philosophy of ‘lean enterprise (LE)’. They defined ‘LE’ as a group of individual functions legally divided but operationally synchronized in organization (Ducharme and Lukansky, 2002). Karlsson and Åhlström (1996) reported the LE as a combination of lean product development, lean procurement, LM and lean distribution. Among the elements of the LE suggested by them, the concept of lean supply chain management deals with both lean procurement and lean distribution.

1.2 Need of an empirical investigation of LE in Indian industry

The Indian industry needs to adopt a global mind set to build scale and achieve cost effectiveness, acquire market access rapidly, strengthen design and innovation skills, build a global or regional operating foot print, and master the ability to manage a world-class talent pool and organization. These actions will form the foundations for an ambitious growth and will need to be supported by a judicious choice of market segments as well as business models. Firms normally have their own strategies for lowering cost, improving product quality and finding marketing networks. The move towards competitive advantage is to a great degree dependent on the firm's ability to bring about qualitative improvement in the quality factors, particularly quality enhancement of knowledge resources. While initiatives are taken at the country and sector levels to enhance competitiveness in the economy, maintaining firm level competitiveness is crucial, if the growth aspirations are to be realized. Individual firms must do this by building abilities to acquire, assimilate, develop new technologies, reduce production costs, cut down delivery time, practice total quality management, enhance productivity and customer service. Generally, use and development of technology is central to competitiveness. However, using technologies efficiently involves building technical understanding, technical information skills, managerial practices and links with other firms as well as institutions which could be termed as 'capabilities' in a broad sense. Such capability development can be slow often a costly and risky learning process.

The secret of competitiveness lies in the effectiveness with which, countries promote the development of technological and managerial capabilities such as LEs (National Manufacturing Competitiveness Council, 2006).

The working group on the automotive industry set up by the planning commission of India in 2002 to project the automotive industry's growth during the tenth five year plan period (2002-2007), their report indicated a major growth prospect in the automotive sector in next 15-20 years period. It has estimated a 300 % increase in the automobile industry’s turnover by 2010, taking it to Rs. 1, 86, 836 crores. In the auto component industry, the working group has estimated a turnover of around Rs. 66,000 crores by 2010 (Chaturvedi, 2003). The Indian auto component industry is undergoing substantive changes in its structure, albeit at a pace slower than warranted for its healthy growth and international alignment. Component manufacturing is a scale driven industry and needs rapid technology up-gradation. Thus, quality consciousness and adoption of best global standards alone would ensure its survival in global supply chain. The industry seems to be striving to achieve this objective. India is still a player of little consequence in the world auto market production. Though there is greater system emphasis, more market orientation and customer focus, continuous improvement culture, there is no significant progress in effective implementation of LE principles (Chaturvedi, 2003). The foremost reason for low implementation of LE principle in Indian auto sector has been identified as lack of top management commitment. Around 70 per cent of the top management teams have not shown interest in implementation of this LE principle because of high cost involved in training the people. To achieve the benefits of LE principles and to be globally competitive, Indian auto sector must focus on effective implementation of LE principles (Khanna, 2004). In any country, growth of automobile industry is an indication of overall economy. A lot of work has to be done by automobile sector in implementing LE principles. Especially, the adoption of leanness as a holistic approach to manufacturing and its elevation to the entire enterprise level has not been done in the Indian industry.

Hence, to promote the development of technological and managerial capabilities, it is necessary that the enterprises should be provided with proper guidelines and directions especially regarding the best lean practices in enterprise. These guidelines or directions are addressed in a framework or model, which paves the way for the Indian industries to achieve LE, and help them compete in global level. For build up competence to mark their presence globally, it is prerequisite for the Indian industries to assess themselves against the practices for LEs, but till now no such framework is available to assess the Indian industries.

1.3 Objectives of the research

Section 1.2 highlighted the growth of Indian manufacturing industry in recent past and importance of LE principles to stay in global competitive market. It becomes imperative to investigate the LE practices being adopted and prescribed by Indian manufacturing industries. The objective of the present research is to carry out an empirical investigation of LE practices in Indian manufacturing industry. This is accomplished by carrying out the following:

- Detailed review of literature in LE in order to understand the progress of lean principles in various research streams, sectors and the empirical research methodology in LE. Hence to identify the research gaps. It involves:
    - Overall review of LE principles and its status in various field of LE content.
    - Analysis of empirical research methodology in LE.

- Perform an empirical study to find out the implementation stage of LE principles across Indian manufacturing organizations through survey questionnaire methodology.
- Evaluation of validity and reliability of LE frameworks in best practice Indian industries
- Classification and analysis of LE frameworks as well as development of a new framework for LE to overcome shortcomings of existing LE frameworks.
- Perform verification with help of various techniques on proposed LE framework.
  - Validity and reliability analysis on proposed LE framework in Indian manufacturing industries with the help of empirical survey.
  - Path analysis of LE framework in Indian manufacturing industry. It involves:
    - Development of interpretive structural modelling (ISM) for LE excellence framework in Indian manufacturing industry.
    - Development of structural equation modelling (SEM) for statistical testing and path analysis.

1.4 Arrangement of thesis

The thesis is organized into seven chapters; chapter two discusses the literature review of LE. Chapter three discusses the implementation status of LE principles in Indian manufacturing industry. The chapter four discusses the validity and reliability of existing LE frameworks in Indian industry. The critical review of existing LE frameworks and development of a framework for LE is discussed in the chapter five. The chapter six describes an empirical investigation of LE framework in Indian industries with the help of reliability and validity analysis. The study is also performed path analysis of proposed LE framework in Indian manufacturing industry. The summary of the work done, contributions of the research, limitations of the study and the scope for future work is presented in chapter seven. The chapter wise arrangement of thesis, brief work done and tools used is shown in Figure 1.1.

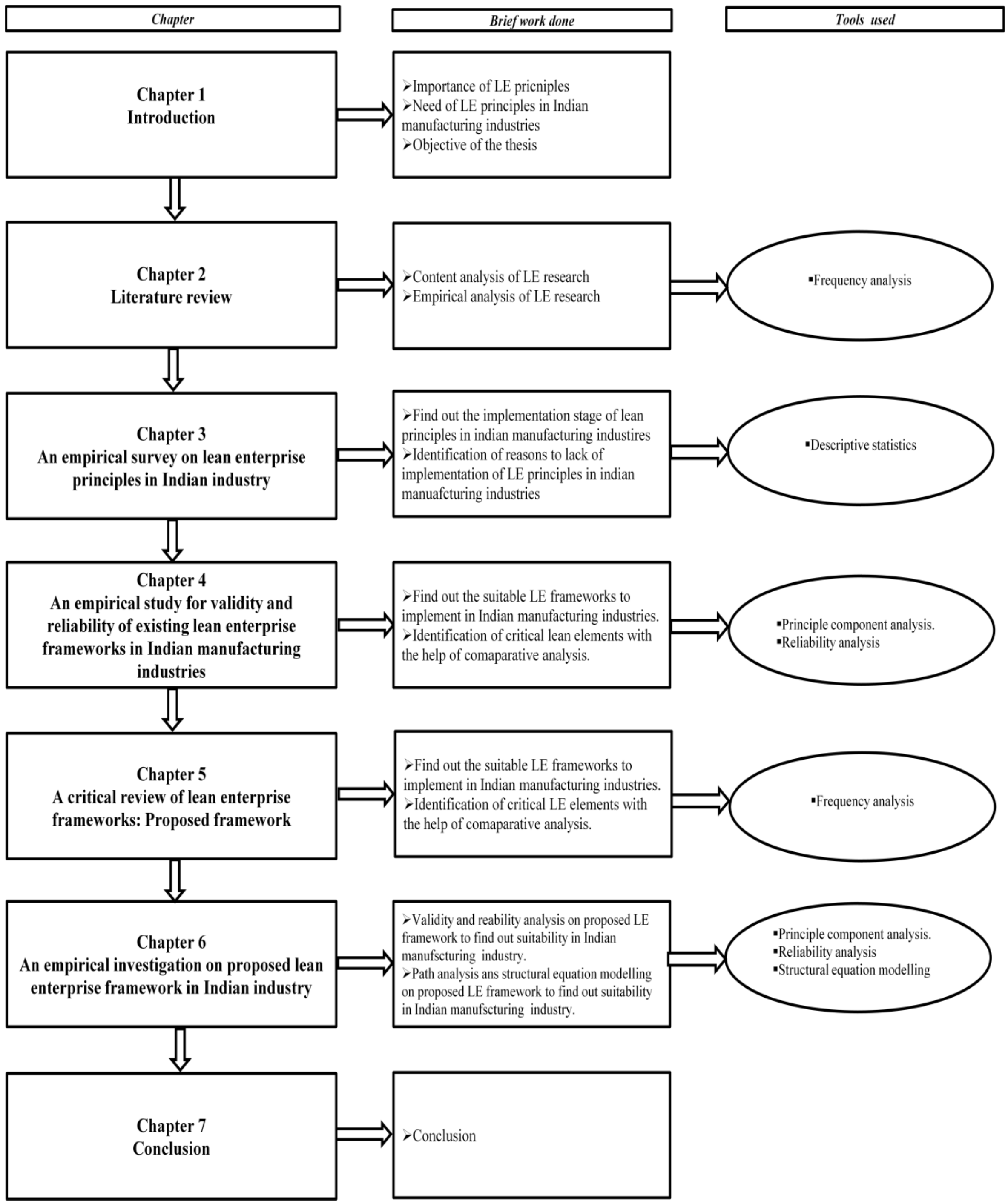

Figure 1.1 Arrangement of thesis, brief work done and tools used

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Chapter 2

Literature review

2.1 Introduction

The foundation of the holistic approach that surpasses the limits of the production, organization and management worldwide has been laid down decades ago. It all started with the introduction of Toyota production system (TPS) led by Taiichi Ohno of Toyota Motor Company (Ohno, 1988). TPS targeted at removing any kind of waste and inconsistency in the production system. TPS consists of two pillars that are Just-in-time (JIT) and Jidoka (Ohno, 1988; Liker 2004). In the beginning, few researchers (Monden, 1998; Pettersen, 2009) have concentrated only on JIT because of its concept of reducing inventory and tangible benefits. The best characteristic of JIT is that it aims at producing the requisite product, at the right time, in right quantity and takes away the unnecessary stocks (Tiwari, et al. 2011). TPS is not only elimination of non-value adding activities from the process but also improving the quality of the product with help of Jidoka. The success of TPS resulted into its wide acceptance by the manufacturing industries globally, later on, it disseminated into other non-conventional industries. The TPS philosophy only preceded the foundation of more widely recognized term of "Lean production (LP)". Now in this current era of global competitiveness, not only the manufacturing organizations are facing enormous pressure from their customers and competitors but it is the challenge for other industries too. All these factors have given way to integration of the LP concept with the complete production process (starting from the product development to the delivery to the customer). This has given rise to the concept of "Lean enterprise (LE)" (Womack and Jones, 1994). LE does not restrict to an organization but it extends beyond its limits. It clearly shows that LE principles make a huge impact on various industry sectors. However, the study observed that a limited number of literature review studies have been conducted on LE principles, which may lead to less chances in finding the gap and filling the required gap in the literature.

Researchers have been attempting to review the state of art of JIT manufacturing/production for last two decades, but with limited sample size. For example, Sohal *et al* (1989), Golhard and Stamm (1991), Keller and Kazazi (1993) have reviewed and presented 'JIT manufacturing systems', that can be generally interpreted as a conceptual literature review which proved to be a landmark in the LP related review literature. Ramarapu et al (1995) carried out literature review on JIT constructs and identified important JIT constructs from empirical and conceptual articles with the sample of 105 articles. In the same year, Zhu and Meredith (1995) conducted a literature of JIT and found important elements of successful JIT implementation in the industry with the sample of 42 articles. It observed that many investigators also performed literature review on sub-elements of JIT such as JIT purchasing. Stamm and Golhard (1993) and Waters-Fuller (1995) were first to perform a literature review on JIT purchasing. Few years later, Garg and Deshmukh (1999) also contributed to the review of JIT purchasing wherein the sample size of the articles was about 38 that was considering a time period of eight years. In the same year, Gunasekaran (1999) carried out literature review on JIT purchasing and successfully proposed a purchasing function based framework to improve efficiency of purchasing. While, Berkley (1992) tried to find out the status of kanban systems in early nineties, Duclos *et al.* (1995) reviewed the status of JIT principles in the service sector in mid nineties. In recent years, many researchers have reviewed LP principles conceptually in the research articles. Hines et al.

(2004) have brought out various criticisms on lean strategy and clarifications on the criticisms. Papadopoulou and Ozbayrak (2005) conceptually studied the journey of the lean principles over a substantial time period of last hundred years. Holweg(2007) reviewed literature and found out various lean elements as well as proposed a framework with the help of empirical study. Kumar and Panneerselvam (2007) also contributed in the literature review with focus on kanban systems in JIT environment with a sample size of 100 articles. Pettersen (2009) studied about LP principles and practices, and concerns related to bottleneck in these elements throughout its period. Moyano-Fuentes and Sacrista´n-Dı´az (2012) have reported the impact of lean principles across the world and industry sectors. Arlbjørn and Freytag (2013) have conducted a literature survey on lean principles and reported the impact of lean on various industry sectors as well as its impact on productivity with a sample size of 154 articles. The same study has its limitations due to the sample size and the selection of the articles was based on only title of the articles. The present study has tried to overcome all the limitations in terms of sample size, various aspects of LE classifications and article selection criteria.

It is noted that very limited number of literature survey based LE related review articles was available although the term lean were introduced twenty five years ago. Hence, there is a need to explore the field of research to find out the gap existing in development of LE literature. The present study made an attempt to provide a comprehensive literature review in the field of LE with quantifiable sample size and over entire span of LE life.

2.2 Methodology for critical review of LE literature

This section of chapter elaborates the methodology adopted for the purpose of providing a comprehensive and critical literature review of LE content oriented and empirical research content in LE. The issues of time horizon of review, journal selection, article selection, article classification and analysis of empirical articles will be discussed under literature review methodology.

Step 1: The assessment period of articles is between 1990 and 2009, a 20 year time horizon. The year 1990 is considered as the starting point of data collection because term ‘LP’ first got popularity in 1990 (Womack et al, 1990). The year 2009 is chosen as the terminating point of data collection for providing a landmark to end data collection.

Step 2: The articles were collected from four major management science publishers viz. *Science Direct, Taylor and Francis, Emerald Online* and *Springer Link* as majority of well referred journals of industrial management are found in these databases.

Step 3: The study has used the nine key words related to lean to search articles: LP, LM, lean supply chain management (LSCM), lean product development (LPD), LE, just-in-time, lean management, lean thinking and TPS. Anand (2009) also adopted similar approach for selection of articles. Articles which were available online but not published in any volume by the end of year 2009 were also considered.

Step 4: Firstly, all the selected research articles are classified under aspects of LE content oriented classification i.e., research methodology, research stream, popular LE elements, LE wastes and frameworks/models. Secondly, the separated LE empirical articles have classified under empirical research methodology defined by Flynn et al (1990). Flynn et al. (1990) explained that any empirical research article can have one or more of the following empirical research designs viz. single case study, multiple case study, panel study, focus group and survey. The study also selected empirical research articles from the selected population of journals on the similar lines. The total list of selected 449 LE related research articles is given in Appendix-A.

a). LE content oriented classification

Every selected article is classified under following classes:

Research methodology of LE

According to Nakata and Huang (2005) and Guo (2008), the nature of the study can be classified in four major categories. Those are conceptual qualitative, conceptual quantitative, empirical qualitative and empirical quantitative. Conceptual qualitative consists of the literature reviews and arguments to develop new perspectives and to build qualitatively explored theoretical framework. Conceptual quantitative uses mathematical tools and secondary data to present cases and proofs to develop new models. On the other hand, empirical qualitative studies employ qualitative approaches to collect primary data. Whereas, empirical quantitative studies require data collection through surveys or experiments and quantitatively analyze the records. The study has segregated all the articles into the four methodologies harmonizing to its predominant research method.

Research streams

According to Karlson and Ahlstrom (1996), LE system covers everything in an organization starting from product development to its distribution to end customers. It describes the concept of LE system consists of LPD, LM, lean procurement, and lean distribution. Lean procurement and lean distribution can be clubbed together under LSCM. The present study has categorized all the articles in four steams only, viz., LM, LPD, LSCM and LE. The study tries to find out dominant field of research streams and give directions to fill gaps in various research streams.

Research articles focus on LE elements

The present section of study further concentrated to find out the most popular LE elements among the researchers' world. Generally, the success of any manufacturing philosophy depends upon the utilization of its elements in organizations and development of various new elements to face future problems. The study investigates to answer the following questions.

1. Which LE elements were seen most repetitively in the considered sample articles?
2. Was there any vital dissimilarity in the conclusion about LE elements from the various studies based on different research methodologies?

The study has considered that the answers to the above two queries are useful in making some suggestions concerning the perspective of LE elements. Zhu and Meredith (1995) and Sila and Ebrahimpur (2002) have followed similar kind of methodology to perform survey on JIT manufacturing and total quality management respectively.

Research articles focus on LE waste

The main purpose of LE is manufacturing the products without any kind of waste. Waste is an activity that will not create any value to the final product. According to Ohno, waste can be classified into seven categories. These are: over production, waiting, transportation, unnecessary inventory, inappropriate processing, defects and unnecessary motion. The study tries to find out the popular LE wastes among empirical approach articles.

Frameworks/models

So far, many of the researchers including Zhu and Meredith (1995), Karlsson and Åhlström (1996), and Pettersen (2009) have proposed various frameworks/models in different articles but most of them did not discuss about the status of implementation of their proposed frameworks/models in real environment. Yosuf and Aspinwall (2000) have discussed that ‘a model’ answers the question of “what is”, whereas a framework answers “how to” questions. The same concept has been followed in the study while identifying the frameworks/models. It was checked whether the corresponding article featured any kind of frameworks/models or not.

b). Empirical research methodology in LE

Every selected empirical research article is classified under following a classification scheme. This classification scheme is adopted from a systematic approach for empirical research given by Flynn et al. (1990). According to them any empirical research consists of six stages. Table 2.1 gives six stages of empirical research. The complete set of selected empirical research articles will be classified as per the six stages of empirical research. Selected literature in Stage I is classified on the basis of purpose of empirical research i.e. establishing a theoretical foundation by theory building or theory verification.

Empirical research can have one of the two purposes either on the basis of empirical data one can propose one’s own theory (called theory building) or one can verify an already existing or newly proposed theory on the basis of empirical data (called theory verification). The classification of selected articles on this basis permits to find out whether the inclination of researchers towards theory building or theory verification. Stage II involves classification of each article on the basis of selection of research design, here articles are classified under; single case study, multiple case study, panel study, focus group, and survey.

Selection of data collection method is in Stage III. In this stage articles are classified under historical archive analysis, outside observation, participant observation, interviews, content analysis, and questionnaires. The classification of articles in Stage IV i.e. implementation stage is as per sample industry, sample size, cross sectional or longitudinal data collection, qualitative/quantitative/triangulated data and type of respondents.

The explanation for each component under which articles are classified in implementation stage is given as follows:

- **Sample industry:** This refers to the industry which has been used in the article to derive the empirical data. When data is collected from multiple industries, then the article is referred as ‘multiple’ and when source of data collection is not mentioned then the article is referred as ‘not mentioned’.
- **Country of sample industry:** This refers to the country from which the data collection has been carried out. There are many instances in the literature when the data has been collected from various countries. In such case, the article is referred in the category of ‘others’. Also in some research papers the country from which data is collected is not mentioned, in such case the article is referred as ‘not mentioned’.
- **Sample size:** It refers to the quantity of data that has been collected from selected population. The sample size has been classified into the range of size of sample size, starting from sample size less than 100 going higher up to 1000 samples or more. For Instance, when sample size is not known, it is referred as ‘not mentioned’ in the classification scheme.

Table 2.1 Six stages of empirical research (Adopted Flynn et al (1990))

Stage	Action	Type	Comments
I	Establishing a theoretical foundation	Theory building (TB) Theory verification (TV)	Some articles may address both theory building and theory verification. Such articles are included in theory building only
II	Selecting a research design	Single case study Multiple case study Panel study Focus group Survey	Some of the article may use more than research design simultaneously; such articles are included under combination research design only
III	Data collection method	Historical archive analysis Participants observations Outside observations Interviews Questionnaire survey	All the research articles will use one or combination of these data collection methods
IV	Implementation	Population selection Sample selection Scale development Questionnaire construction Pilot testing Mailing Analysis of non-respondent data characteristics Data entry	All the steps are required for implementation of survey research design, whereas population selection, sample selection and data entry are enough to conduct other research designs
V	Analysis of data	Descriptive statistics T-tests Chi- Square test Regression /correction Path analysis Cluster analysis Factor analysis	Some cases qualitative analysis and in case studies it is termed as case analysis.
VI	Conclusion	Reporting the analysis	---------------------------

- **Longitudinal/cross-sectional data:** This refers to the time horizon of the research. If the research has been carried out in a short time-span observing one sample only once in the entire period of research it is called as cross-sectional. Longitudinal research is where one observes a single sample for a considerable period of time.

- **Qualitative/quantitative/triangulated data:** This refers to the type of data collected. Quantitative data is one which is given a specific numerical value and a physical unit. Qualitative data is one which is not necessarily quantified e.g. yes/no replies, grading of replies like absolutely necessary, necessary, fine, undesirable etc. Triangulation is when various qualitative and quantitative data collection methods are used together.
- **Type of respondents:** Respondent is a source from which data is collected. Here, it means, the profile of the people who were involved in the research design sample. At times, type(s) of respondent(s) is/are not known, then is referred as 'not mentioned' in the classification scheme.

Step 5: The analysis of classified articles is carried out to identify the gaps, significant findings and suggest direction for future empirical research in LE.

2.3 Analysis of LE research

2.3.1 Selection of articles

A myriad of literature related to theory and practices of LE is available in various publication portals and conferences. But due to various limitations, the search was restricted to articles related to only LE in *Emerald, Science Direct, Springer Link and Taylor and Francis* publication portals. After excluding all the redundancies, the total number of articles found is 848 from the four publication portals. It further filtered out the articles based on focus of the articles on any part of LE principles, which came out to be 718 articles. It was further noted that some of the journals have very limited publications as well as narrow focus on any part of LE. Therefore, it further filtered out such journals that have published less than five articles and only considered operation research journals. Thus, the total number of reviewed articles came down to 449 published in 27 operations research journals. However, the sample size in terms of number of articles is indeed large that is ever considered in past studies of LE. Thus, it helps in increasing the correctness of findings of the study. According to Berenson and Levine (1989), "*To be ninety percent confident of being correct to within 0.1 of the true proportion of all articles, a minimum sample size of 61 articles was needed*". The list of selected journals considered in the current study shown in Table 2.2. It was found that more than 50 percent of the articles on LE have been published in five journals only (IJOPM, IJPR, IJPE, JMTM, and PPC). The study also reveals that the IJOPM and IJPR constitute around 38% of the total articles considered for this review.

Table 2.2 List of selected journals considered in the current study

Journal Name	Acronym	No. of articles	Percentage
International Journal of Operations and Production Management	IJOPM	108	24.05
International Journal of Production Research	IJPR	50	11.14
International Journal of Production Economics	IJPE	43	9.57
Production Planning and Control	PPC	34	7.57
Journal of Manufacturing Technology Management	JMTM	24	5.34
Supply Chain Management An International Journal	SCMIJ	18	4.01
Management Decision	MD	16	3.56
Industrial Management and Data Systems	IMDS	13	2.9
International Journal of Logistics Research and Applications	IJLRA	13	2.9
Integrated Manufacturing Systems	IMS	12	2.67
International Journal of Physical Distribution and Logistics Management	IJPDLM	11	2.45
Computers and Industrial Engineering	CIE	9	2.01
Employee Relations	ER	9	2.01
Robotics and Computer-Integrated Manufacturing	RCIM	9	2.01
Benchmarking An International Journal	AIJ	8	1.78
International Journal of Productivity and Performance Management	IJPPM	8	1.78

Journal Name	Acronym	No. of articles	Percentage
The International Journal of Logistics Management	IJLM	8	1.78
Business Process Management Journal	BPMJ	7	1.56
Assembly Automation	AA	6	1.34
Computers in Industry	CII	6	1.34
Construction Management and Economics	CME	6	1.34
The TQM Magazine	TQMM	6	1.34
European Journal of Purchasing and Supply Management	EJPSM	5	1.11
The International Journal of Advanced Manufacturing Technology	IJAMT	5	1.11
Journal of Operations Management	JOM	5	1.11
The TQM Journal	TQMJ	5	1.11
Total Quality Management and Business Excellence	TQMBE	5	1.11
Total		449	100%

2.4 Analysis of LE content oriented classification

2.4.1 Research methodology

Table 2.3 shows research methodology with various sub-categories. Out of 449 articles in two decades, 270 were of conceptual approach. In other words, it was clear that 60.14% articles (including conceptual qualitative and conceptual quantative) were of conceptual approach, which certainly dominated the empirical approach (39.86%). In this, specifically, conceptual qualitative constituted around 44.1% of the total sample. Around 69% of empirical approach articles were published in the second decade (from 2000 to December 2009), that clearly suggests the positive change towards the empirical approach. Among all the nine sub-methods, literature reviews was the mostly used (42.9%) research methodology shown in Table 2.3, while the other sub-methods like perspective and arguments, content analysis, interviews, experiments and meta-analysis were hardly used. Overall, the study found a rise in empirical approach (either quantitative or qualitative) over the years but still it is in minority as compared to conceptual approach.

Table 2.3 Research methodology with various sub-categories

Research methodology	1990-1999	2000-2009	Total	Percentage
Conceptual qualitative	74	89	163	36.30
Perspectives and arguments	2	7	9	2.00
Literature reviews	72	82	154	34.30
Conceptual quantitative	38	70	108	23.80
Content analysis	1	3	4	0.90
Second data	37	67	104	22.90
Empirical qualitative	30	70	100	22.30
Case study	28	66	94	20.90
Interviews	3	3	6	1.30
Empirical quantitative	25	53	78	17.40
Experiments	0	0	0	0.00
Meta-analysis	1	9	10	2.20
Survey	24	44	68	15.20
Total	167	282	449	100

2.4.2 Research streams

All the articles have been coded on the basis of two factors: research stream (as mentioned earlier) and the period of publication. The period of publication were grouped into two periods of 10 years each. Similar kind of approach was followed by Guo (2008). The distribution of research streams in over two time periods is shown in Table 2.4. Furthermore, 344 articles fall under category of LM stream, 98 articles belong to LSCM stream, while LPD stream and LE stream consist of 3 and 4 articles each respectively. It clearly indicates need of applying lean principles in LPD stream and LE stream to get a better result. When compared the first half with the second half of the period, it is clearly evident that the concept of LM is spreading very quickly across all the industry sectors. The study revealed that LSCM and LM streams articles have more than doubled when compared the first half with the second half of the period. It indicates the importance of LM and LSCM in any industry.

Table 2.4 The distribution of research streams in over two time periods

Research stream	1990- 1999	2000-2009	Total	Percentage
Lean manufacturing	131	213	344	76.6
Lean product development	0	3	3	0.7
Lean supply chain management	35	63	98	21.8
Lean enterprise	2	2	4	0.9
Total	168	281	449	100

Table 2.5 shows the frequency distribution of research streams w.r.t. research methodologies The data in Table 2.5 clearly shows that maximum number of articles were literature reviews of LM stream (121 articles), followed by sub-category of "second data" of the same research stream (83 articles). It is found that "surveys" research methodology have 68 articles overall i.e. 54, 13 and 1 articles of LM stream, LSCM stream and LE stream respectively. All the published articles (3 articles) related to LPD stream were literature reviews. In contrast, no articles of LE level stream were published under conceptual nature.

Table 2.5 The frequency distribution of research streams w.r.t. research methodologies

Research streams	Research methodology										
	Conceptual qualitative		Conceptual quantitative		Empirical qualitative		Empirical quantitative			Total	percentage
	Perspectives and arguments	Literature reviews	Content analysis	Second data	Case study	Interviews	Experiments	Meta-analysis	Survey		
Lean manufacturing	6	120	4	85	64	4	0	7	54	344	76.6
Lean supply chain management	2	30	0	19	29	2	0	3	13	98	21.8
Lean product development	0	3	0	0	0	0	0	0	0	3	0.7
Lean enterprise	1	1	0	0	1	0	0	0	1	4	0.9
Total	9	154	4	104	94	6	0	10	68	449	100

2.4.3 Research articles focus on LE elements

Table 2.6, is a frequency distribution of LE elements studied in the articles. It shows that around 30% of the articles were concentrated on value stream mapping, setup time reduction and kaizen as important LE elements to achieve excellence in manufacturing activities. It also revealed that kaizen (around 46%) is the most popular LE element in empirical (case study) articles, which clearly indicates that many of the organizations have considered LE as a continuous improvement. Supplier involvement (around 45% articles of total 115 articles) was the most popular LE element among exploratory cross sectional methodology. It also identified that kaizen element was received equal importance among all five research methodologies. The most popular LE element among descriptive methodology was value stream mapping (around 37%). The LE elements: 5S, long term supplier-customer relationship, flexible information system were popular in descriptive research methodology articles and least importance was given by other research methodologies. The empirical research methodology articles were given least importance to customer involvement, uniform workload, visual factory and plant layout.

Table 2.6 Frequency distribution LE elements studied in the articles

LE Tools	Conceptual	Empirical	Total	Percentage
Value stream mapping	74	105	179	32.78
Set up time reduction	75	96	171	31.32
Kaizen	61	105	164	30.04
Kanban	72	92	164	30.04
Pull Production	63	74	137	25.09
Small lot Size	54	80	134	24.54
Just in time purchasing	59	69	128	23.44
Elimination of waste	59	69	126	23.08

LE Tools	Conceptual	Empirical	Total	Percentage
Supplier involvement	51	72	123	22.53
Total quality management	65	54	119	21.79
5S	65	50	115	21.06
Standardization of work	55	57	112	20.51
Flexible information system	66	42	108	19.78
Just in time production	49	50	99	18.13
Takt time	44	46	90	16.48
Continuous flow	45	44	89	16.30
Employee commitment	39	47	86	15.75
Multifunctional employees	43	42	85	15.57
Long-term supplier and customer relationship	56	29	85	15.57
Top management commitment	39	41	80	14.65
Total productive maintenance	34	45	79	14.47
Customer involvement	32	43	75	13.74
Uniform work load	35	36	71	13.00
Visual factory	32	30	62	11.36
Plant layout	29	33	62	11.36

2.4.4 LE wastes

Table 2.7 is a frequency distribution of LE wastes studied in empirical articles. It revealed that many of the researchers were implemented LE elements to avoid defects (88.20%) and unnecessary inventory (85.40%) wastes. The study also revealed 83 (46.63% of total 178 empirical approach articles) and 72 (40.44% of total 178 empirical approach articles) empirical qualitative research methodology articles were focusing on avoiding defects and unnecessary inventory LP waste. Waiting and unnecessary inventory LE wastes were shown to be indirectly inter-dependent on each other, which clearly revealed in terms of number of research articles focused on elimination of waiting waste. It also revealed that the researchers did not give equal importance to other LE waste like transportation (54.50%), inappropriate processing (36.51%), over production (33.41%) and unnecessary motions (32.58%) wastes. It also revealed that there was only 12% of the research articles concentrated on all seven types of LE wastes.

Table 2.7 Frequency distribution of LE wastes studied in empirical articles

Type of LE waste	Empirical qualitative	Empirical quantitative	Total	Percentage
Defects	83	74	157	88.20
Unnecessary inventory	72	80	152	85.40
Waiting	69	64	133	74.72
Transportation	41	56	97	54.50
Inappropriate processing	31	34	65	36.51
Over production	25	34	59	33.41
Unnecessary motions	23	35	58	32.58

2.4.5 Lean frameworks/ models

It was checked whether the corresponding article featured any kind of framework/model. The focus of the study is also to know the researcher's focus on particular research stream in developing framework/model in order to achieve the organizational performance. All the frameworks/models were distributed according to the research streams. Table 2.8 shows the frequency of frameworks/models status with respect to research streams. The maximum number of frameworks/models was in LM stream with 58 articles, out of which, only 13 of them had been implemented and also the performance was measured. Whereas, it is found that the researchers' focus on LPD and LE is minimal.

Table 2.8 The frequency of frameworks/models status with respect to research streams

Research streams	Proposed frame work	Proposed model	Proposed and implemented frame work	Proposed and implemented model	Total
Lean manufacturing	18	27	3	10	58
Lean supply chain management	7	13	1	4	25
Lean product development	1	1	0	0	2
Lean enterprise	1	2	0	0	3
Total	27	43	4	18	90

2.5 Analysis of empirical research methodology in LE

2.5.1 Empirical research growth in LE

The present section of study carried out with the aim of making the study more descriptive in nature. This study was based on various trend and pattern analysis in order to formulate better understanding for development of empirical research in LE. The study aimed to find out potential areas for improvement in LE in aspects of empirical research. It is observed that the first empirical research article in LE appeared in *International Journal of Production Economics* in the year 1993 (Ebrahimpour and Withersb 1993). The article reported a survey conducted among JIT and non JIT firms and concluded that philosophical shift may be progressing among USA firms. The frequency distribution of empirical articles in journals since 1993 (rather than 1990) is given in Table 2.9. There may be articles reported before 1993 in any other journal, which are not included in the present study.

Over the last two decades, there has been an exponential growth in the number of empirical research articles published in LE. The number of empirical research articles were 39.64% of total articles (178 out of 449 LE articles) published since 1990. It is observed that around 50 percent of the empirical research articles were published in seven journals: IJOPM, IJPR, IJPE, SCMIJ, IMDS, IMS, and PPC. The highest number of articles were published in IJOPM (108) related to LE, out of which around 46 (42.6%) articles were of empirical in nature. When the study consider total empirical article in the present review, IJOPM contribution was 25% of total empirical articles. The frequency of empirical articles published on LE is shown in histogram in Figure 2.1.The distribution of empirical research articles in LE according to year of publication is also shown in Figure 2.2. The graphical representation of the empirical research articles indicated the increasing trend. The histogram indicated that the growth of the empirical research articles in the last seven years was continuously increasing and particularly there was steep rise in 2008 and 2009. The year 2008 have the highest number (21) of published articles.

Table 2.9 The frequency distribution of empirical research articles in journals

Journal Name	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
AA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	4
BIJ	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2	4
BPMJ	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	3
CME	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	4
ER	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	3
EJPSM	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	4
TQMM	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
IMDS	0	1	1	0	0	0	0	0	2	2	1	0	1	1	1	0	0	10
IMS	0	0	2	0	0	0	0	0	3	2	0	0	0	0	0	0	0	7
IJLM	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	4
IJLRA	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	1	1	6
IJOPM	0	5	5	7	2	2	1	3	1	2	3	3	2	3	2	2	3	46
IJPDLM	0	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0	0	5
IJPE	1	0	2	0	1	1	1	1	0	2	1	0	0	0	2	0	1	13
IJPR	0	0	0	0	0	0	0	1	1	1	1	0	1	0	3	5	1	14
IJPPM	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1	5

Journal Name	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
JMTM	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	2	6
JOM	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	4
MD	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	0	0	5
PPC	0	0	0	0	3	0	0	0	0	0	0	0	1	1	1	0	2	8
SCMIJ	0	0	0	0	0	2	1	0	1	0	0	0	0	2	1	3	1	11
IJAMT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
TQMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
TQMBE	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	3
Total	1	8	12	7	8	10	8	5	9	13	6	7	14	14	15	21	20	178

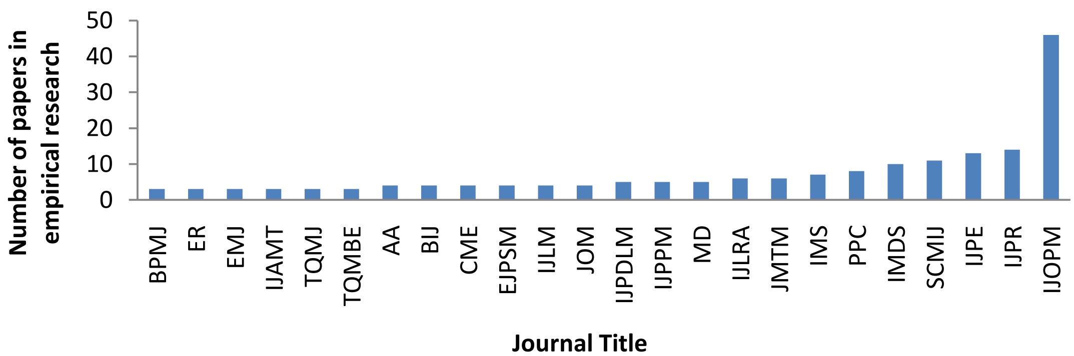

Figure 2.1 The frequency of empirical articles published on LE

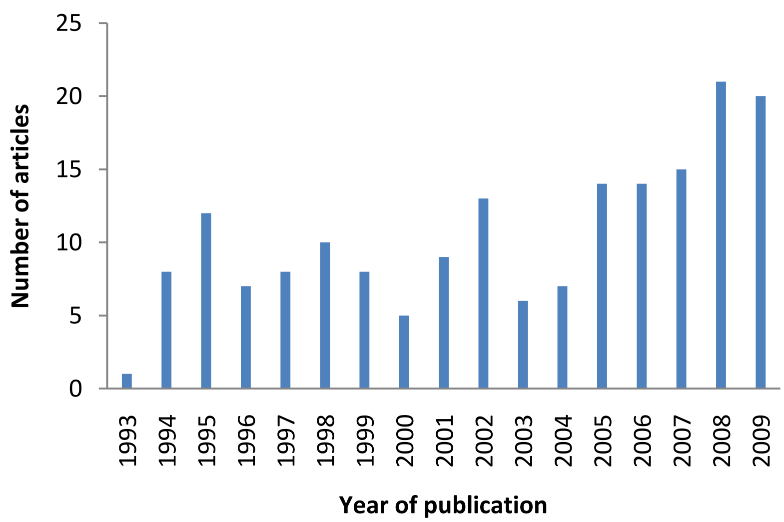

Figure 2.2 Distribution of empirical research articles according to year of publication

2.5.2 Purpose of empirical research

Generally, when any article is investigated on empirical research, it should serve one of the two purposes, viz., theory building or theory verification.

Theory building requires making use of existing theories and practices to develop new concepts (Glaser and Strauss, 1967; Flynn et al, 1990; and Lynham, 2000). According to Kuhn (1996), theory building definition is "*New theory, however special its range of application, is seldom or never just an increment to what is already known. Its assimilation requires the reconstruction of prior theory and the re-evaluation of prior fact, an intrinsically revolutionary process that is seldom completed by a single man and never over night*". Theory verification is used to verify existing theory by testing the generated hypotheses within specific conditions. The same concept has been used in the present study to classify the articles. Theory building generally addresses four vital questions: what are the constructs, how and why they are correlated, whom the constructs apply to, and when they are applicable (Dubin, 1978; Kaplan, 1964). Generally the final three questions are considered as boundary conditions that are placing "limitations on the propositions generated from a theoretical model" (Whetten, 1989). Whereas, theory verification is helpful to researchers to test proposed theories in various circumstances and sectors. Table 2.10 shows the number of articles on theory building and theory verification.

Table 2.10 The number of articles on theory building and theory verification

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total**
Theory building	0	6	8	4	5	4	3	4	8	4	6	4	6	7	7	9	9	94
Theory verification	1	2	4	3	3	6	5	1	1	9	0	3	8	7	8	12	11	84
Total	1	8	12	7	8	10	8	5	9	13	6	7	14	14	15	21	20	178

From Table 2.10, it is evident that researchers were evenly inclined towards theory building and theory verification. Overall, number of articles published in theory building exceeds the theory verification by small number. Most of the theory verification articles were published during last two years of the present study, which shows that the inclination of researchers towards theory verification is significantly increasing.

2.5.3 Selection of research design

To perform empirical research, there are various research design methods like single case study, multiple case study, panel study, focus study and surveys. But the most widely used approach is the survey research method and is used in operations management (Flynn et al 1990). The description of the research designs are as follows: single case study deals with single process/location/plant/area of research. It can be used to develop small samples to test and develop complex relations between various variables to build a new theory (Wacker, 1998). In multiple case studies, data are collected from multiple process/location/plant/area of research. According to the present study, it is observed that multiple case studies were preferred for validating the existing theory. Panel studies involve use of experts' views to come to some conclusion. Focus group study is the physically assembling of all the experts and their views. Finally, survey research design is the scientific tool in operations management which can provide quantifiable, reproducible results (Dillman 2000). The number of articles in each research design is given in Table 2.11.

Table 2.11 The number of articles in each research design

Research design	Number of articles	Percentage
Single case study	82	46.06
Multiple case study	12	06.74
Panel study	1	0.56
Focus study	2	1.13
Survey	75	42.14
Combination	06	3.37
Total	178	100

As shown in Table 2.11, single case studies were the most popular choice amongst researchers as an investigative tool, which contains 46 % (82 articles) of total articles. The next most popular choice was survey research design, which contains 42.13 %(75 articles) of the total empirical articles (178 articles). Multi case studies were reporting only 12 articles (6.74%). While panel study and focus group articles constitute only 1 and 2 articles respectively. The articles that involved both single case study and survey research were only 3.37% (6 articles) of total empirical articles.

Frequency distribution of single case study articles in LE is shown in Table 2.12. Trends in Table 2.12 clearly suggest that the maximum number of articles published in single case studies were from IJOPM (12 articles) followed by SCMIJ (8 articles). On the other hand IJLM does not seem to have focus on single case study. Whereas, AA, CME, EMJ and IJAMT were reported only single case study articles. Other journals like BIJ, BPMJ, EJPSM, IJLRA, IJPPM, JMTM, PPC, SCMIJ, TQMJ and TQMBE reported more than 50% of their article on single case study. The study reporting that there was steep rise in single case study research design during year of 2008 and 2009. There was no single case study article published before 1994. It was notable that the maximum number of single case study articles published in a year reported by IJOPM and PPC in year 1995 and 1997 respectively. Interestingly, there was no single case study article reported in year 2000. Table 2.13 gives Frequency distribution of survey research articles in LE. In survey research, the journal IJOPM leads with the maximum number of articles published (29 articles) which accounts for around 40% of the total survey articles. Whereas, BIJ, EJPSM, IMDS, IMS, IJLM, IJPDLM, IJPE, JMTM and JOM were published more than 50% articles on survey research design of the total published articles in their journals. In contrast, Journals like AA, BPMJ, CME, EMJ, IJLRA, PPC and IJAMT does not have much contribution towards survey research design.

The study is aimed to find out, which is the most used research design applied to theory building and theory verification. Table 2.14 shows the number of articles in research design vs. theory building and theory verification. Table 2.14 clearly indicated that the single case study research design was preferred to verification of existing theory where as survey research design was preferred to theory building. Multiple case study research design reported very less number of articles and whatever reported was focused on theory verification. Whereas, the focus study and panel study were used for developing new theory.

Table 2.12 Frequency distribution of single case study articles in LE

Journal title	1994	1995	1996	1997	1998	1999	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	Percentage of total no. of papers selected
AA	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	4	100
BIJ	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	50
BPMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	66.67
CME	0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	4	100
ER	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	33.34
EJPSM	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	50
EMJ	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3	100
IMDS	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	3	30
IMS	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	3	42.86
IJLM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IJLRA	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	4	66.67
IJOPM	2	3	2	1	0	0	0	1	0	1	0	0	1	0	1	12	26.09
IJPDLM	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	2	40
IJPE	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	4	30.77
IJPR	0	0	0	0	0	0	0	0	0	0	1	0	3	1	1	6	42.86
IJPPM	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	4	80
JMTM	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	50
JOM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	25
MD	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	20
PPC	0	0	0	3	0	0	0	0	0	0	1	1	0	0	1	6	75
SCMIJ	0	0	0	0	1	1	1	0	0	0	0	2	0	2	1	8	72.73
IJAMT	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	100
TQMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	66.67
TQMBE	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	66.67
Total	3	4	2	4	4	4	4	6	1	2	6	9	8	11	14	82	

Table 2.13 Frequency distribution of survey research articles in LE

Journal title	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	Percentage of total no. of papers selected
AA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BIJ	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	50
BPMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ER	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	33.34
EJPSM	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	2	50
EMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IMDS	0	1	0	0	0	0	0	0	2	1	0	0	1	0	1	0	0	6	60
IMS	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	4	57.14
IJLM	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	3	75
IJLRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IJOPM	0	2	2	5	1	2	0	2	1	1	3	1	2	3	1	1	2	29	63.04
IJPDLM	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	60
IJPE	1	0	1	0	1	0	0	1	0	1	1	0	0	0	1	0	0	7	53.85
IJPR	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	2	0	6	42.86
IJPPM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	20
JMTM	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	3	50
JOM	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	3	75
MD	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	40
PPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCMIJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	9.09
IJAMT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TQMJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	33.34
TQMBE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	33.34
Total	1	4	7	5	4	2	2	4	5	6	5	4	5	5	5	6	5	75	

Table 2.14 The number of articles in research designs Vs theory building and theory verification

Research design	Theory building	Theory verification	Total	Percentage
Single case study	29	53	82	46.06
Multiple case study	3	9	12	6.74
Panel study	1	0	1	0.56
Focus study	2	0	2	1.13
Survey	56	19	75	42.14
Combination	03	03	06	3.37
Total	94	84	178	100

2.5.4 Selection of data collection method

Data collection is an important phase for any empirical research. The several well-known methods of data collection are participant's observations, outside observations, interviews, historical archive analysis and questionnaire survey. The methods can be used in various combinations to facilitate better results. For example combinations of interviews, historical archive analysis and questionnaire (IHQ) or interviews, historical archive analysis and participant observation (IHP) or interviews and historical archive analysis (IH) can be used to get the desired results. Simpson et al (1998) used combining semi structured interviews and historical archive analysis (IH) methods, to get actual data from the largest Malaysian car company while they were investigating adaptability and applicability of JIT principles. In the same way, other combinations can be formed to collect data and other information in myriad situations.

Historical archive analysis is proven methodology to collect data and analysis of variables (Wittink, 2005). It is generally used in alignment with interviews either for multiple or single case studies. According to Flynn et al. (1990), the unbiased nature of historical archive analysis is its major advantage. The most widely used method is the questionnaire survey method and it is also a useful technique for single and multiple case studies, panel and focus groups (Flynn et al., 1990). But the major bottleneck of this design is determining the reliability, validity and generalization of questionnaire approach. Interview method involves interacting with respondents and taking their opinions. This method can be utilized in combination with other methods like questionnaires, historical archive analysis or any other data collection method. Like interviews or questionnaires, participants' observation is not a widely used approach. In order to record the participant's data, observer needs to be part of the system. It is the ideal method for framing hypothesis and developing new theories (Soni and Kodali 2013). Simpson et al (1998) has reported that one of the researcher spent some months in automobile plant to build research questionnaire and hypothesis. On the other hand, outside observation was done by employing an unbiased observer to collect data in systematic manner (Flynn et al. 1990). This method is widely used for single and multiple case studies along with panel study.

The frequency distribution of data collection methods in empirical research in LE is shown in Table 2.15. It was observed that questionnaire surveys were the most widely used data collection method (35.96%). Historical archive analysis was the second most preferred technique accounting for 10.12% of the total. On the other hand, in 25.84% of the articles, there was not enough information about data collection methods. Out of 178 articles, 132 articles were employed some of the data collection methods. The articles, in which the information about the data collection method was not given, were mostly of either single or multiple case study research design.

Table 2.16 shows the frequency distribution of data collection methods in research designs. It is seen in Table 2.16 that survey research was the most widely used research design of which questionnaire survey (QU) was the most favored mode for collection of data. As for single case studies, historical archive analysis (HA) appeared to be the most suited data collection method.

Table 2.15 The frequency distribution of data collection methods in empirical research in LE

Data collection methods	Number of articles	Percentage
Participants observations (PO)	2	1.12
Interviews, historical archive analysis and questionnaire (IHQ)	2	1.12
Interviews, historical archive analysis and participants observation (IHP)	4	2.25
Interviews and historical archive analysis (IH)	5	2.81
Outside observations (OO)	7	3.93
Interviews and questionnaire (IQ)	7	3.93
Participants observations (PO) and outside observations(OO)	8	4.49
Interviews (IN)	15	8.43
Historical archive analysis (HA)	18	10.12
NA	46	25.84
Questionnaire survey (QU)	64	35.96
Total	178	100

Table 2.16 The frequency distribution of data collection methods in research designs

Research Design	HA	PO	OO	IN	QU	OC	IH	IHQ	IHP	IQ	Total
Single case study	17	2	2	5	2	6	1	2	3	3	43
Multiple case study	1	0	0	5	2	0	4	0	0	0	12
Panel study	0	0	0	0	1	0	0	0	0	0	1
Focus study	0	0	0	2	0	0	0	0	0	0	2
Survey	0	0	5	3	59	2	0	0	1	4	74
Total	18	2	7	15	64	8	5	2	4	7	132

2.5.5 Implementation

The implementation phase of any research design starts with selection of data collection method. For each research design, the steps of implementation may vary from situation to situation. Like interviews, participant or outside observation, historical archive analysis may not require questionnaire organization or content analysis. In the same way, interviews need not require non respondent characteristics or pilot testing. Keeping the aforementioned in mind, a generalized classification scheme for implementation steps has been used. Soni and Kodali (2013) followed the same approach to analyze empirical research on supply chain management. The implementation steps classified into the following classes:

- Sample industry
- Country of sample industry
- Sample size
- Longitudinal/ cross-sectional data
- Qualitative/ quantitative/ triangulated data
- Type of respondents

2.5.5.1 Sample industry

It is important to find out the range of industries from which the data is collected. The articles, if it has the data from more than one segment of manufacturing sector, those are termed as 'Multiples'. In the present scenario, the concept of LE is not only restricted to one type of industry but it is applicable to almost all the industries. In order to improve understanding of industry influence on LE, the samples of articles are classified on basis of the industry sector. The Confederation of Indian Industry (CII) code was used for this purpose.

Table 2.17 shows the frequency of data collection in each sector. According to the present study the process sector lacks focus in implementing lean principles since many researchers carry a notion that lean principles are practiced in the manufacturing industry and it cannot be applied to other sectors. So it was clearly reflecting that the manufacturing sector (86.52%) was the most preferred sector by the researchers to collect data. When the study considered sub categories of manufacturing industry, 31.46% articles used data from the automobile and auxiliary Industry and 11.24% articles used data from information communication technology and electronics (ICTE) industry. In rest of the 59 articles, data was collected from multiple industries. The focus of researchers to collect data from other such as food processing, oil and gas, infrastructure, health care and chemical industries was minimal.

Table 2.17 The frequency of data collection in each sector

Industry	No. of articles	Percentage
Manufacturing sector	154	86.52
Aerospace	6	3.37
Auto components	12	6.74
Automobile	44	24.72
Chemical	6	3.37

Industry	No. of articles	Percentage
Information communication technology and electronics (ICTE)	20	11.24
Others	7	3.93
Multiples	59	33.15
Service	10	5.62
Health care	3	1.69
Information and communication technology	4	2.24
Tourism and hospitality	3	1.69
Infrastructure	9	5.06
Infrastructure	7	3.94
Oil and gas	2	1.12
Agriculture	5	2.8
Food processing	5	2.8
Total	178	100

2.5.5.2 Country of sample industry

Generally, country of sample industry plays a vital role on results due to various cultural and economics variations. Hence the present study further concentrated on to analyze the country of sample industry. It indicates the country from which the data is collected. The authors have considered that the data is gathered from more than one country, those are termed as 'Multiples'. Table 2.18 shows the frequency of data collection w.r.t. country/ region. It was not surprising that USA and UK were at the forefront so far as LE implementation was concerned. The USA, UK and Spain together account for 65% of the articles as countries of sample data collection. Also the developing countries like India, Brazil were contributed significantly. Another interesting outcome from the study was that there seems to be lack of academic interest and research on LE in the countries like Ghana, Greece, Iran, Thailand and Turkey.

Table 2.18 The frequency of data collection w.r.t. country/ region

Country/ Region	Number of articles	Percentage
Australia	2	1.12
Brazil	3	1.69
Canada	1	0.56
China	3	1.69
Egypt	1	0.56
Europe	3	1.69
Finland	2	1.12
Germany	2	1.12
Ghana	1	0.56
Greece	1	0.56
India	6	3.37
Iran	1	0.56
Italy	4	2.25
Japan	3	1.69
Korea	1	0.56
Malaysia	2	1.12
Multiples	7	3.93
New Zealand	2	1.12
Scotland	1	0.56
Singapore	6	3.37
South East Asia	1	0.56
Spain	17	9.56
Sweden	5	2.81
Taiwan	2	1.12
Thailand	1	0.56
The Netherlands	1	0.56
Turkey	1	0.56
UK	39	21.92
USA	59	33.15
Total	178	100

2.5.5.3 Sample size

It indicates the amount of data collected from selected population. It is generally known that the large sample size gives better results compared to small sample size. But if the sample size is larger, an important factor is the cost of the survey is high and takes more time. Considering all the issues, the present researchers are keen to find out the various sample size used by past research articles in LE. Table 2.19 shows the frequency of range of sample size (X) used by researchers in survey design. The study classified the sample size into various range groups. The prominent ranges identified were 0-100, 100-200 and 200-300. The highest number of articles falls in range 0 to 100 (35 articles). Table 2.19 also clearly indicates the decreasing trend of number of articles as the sample group range is increasing. Only 3 articles (1.69%) were sample size of more than 1000.

Table 2.19 The frequency of range of sample size used by researcher in survey design

Range of sample size (X)	Frequency	Percentage
0 < X <= 100	35	19.66
100 < X <= 200	29	16.29
200 < X <= 300	15	8.43
300 < X <= 400	3	1.69
400 < X <= 500	1	0.56
500 < X <= 600	1	0.56
600 < X <= 700	0	0
700 < X <= 800	1	0.56
800 < X <= 900	1	0.56
900 < X <= 1000	0	0
1000 < X	3	1.69
NA	89	50
Total	178	100

2.5.5.4 Longitudinal/ cross-sectional data

Cross sectional studies give a snapshot of a sample of respondents at a particular point in time. Whereas, longitudinal studies used to track response of the same people over a period of time, which will give changes more clear and accurate. Longitudinal studies are more time and cost consuming studies than cross sectional studies (Rindfleisch, et al. 2008). Table 2.20 shows the frequency of use of longitudinal/ cross-sectional data in LE. It clearly indicated that cross-sectional data (95.51%) remains the mode of the data collection predominant in comparison to longitudinal data (3.93%). Very less number of articles in longitudinal data (7 out of 178 articles) clearly indicates very less research activity in this area because it is a time consuming process (Soni and Kodali 2013). Only one article was published that uses both types of data.

Table 2.20 The frequency of use of longitudinal/ cross-sectional data in LE

Data	Number of articles	Percentage
Cross-sectional	170	95.51
Longitudinal	7	3.93
Both	1	0.56
Total	178	100

2.5.5.5 Qualitative/quantitative/triangulated data

Qualitative research gives a clear cut picture of the problem without numerical measurements but less number of respondents. Quantative research provides more number of responses and concrete numerical conclusions. Both the approaches have their strengths and weaknesses. However, they can be tremendously efficient in amalgamation with one another, i.e., triangulation research method (Johnson and Christensen, 2010). Table 2.21

shows the frequency of articles on the basis of qualitative/ quantitative/ triangulated data used in empirical research in LE. It was clearly seen that the quantitative data (66.29%) was dominating over qualitative data (23.04%) while the triangulated data accounts for only 10.67% of the total articles.

Table 2.21 The frequency of articles on the basis of qualitative/quantitative/ triangulated data used in empirical research in LE

Type of data	Number of articles	Percentage
Qualitative	41	23.04
Quantitative	118	66.29
Triangulated	19	10.67
Total	178	100

It is of immense importance to know what type of data is used in theory building and theory verification. Table 2.22 shows frequency of use of qualitative/ quantitative/ triangulated data for theory building and theory verification. The main observation was that the quantitative data type was prevalent in both theory building (59.57%) and theory verification (73.81%). Triangulated type was very little share in theory verification (only 3 articles) in comparison to theory building. It was evident that quantitative data favored by the researchers.

Table 2.22 The frequency of use of qualitative/ quantitative/ triangulated data for theory building and theory verification

	Qualitative	Quantitative	Triangulated	Total
Theory building	22	56	16	94
Theory verification	19	62	3	84
Total	41	118	19	178

2.5.5.6 Type of respondents

This indicates the background/ designation of the individuals who were subject of the research design sample. When type of respondent (s) is missing then it is termed as not mentioned (NA). For the success of empirical study, it is really important to have the right target of respondents. The frequency of type of respondents in LE empirical research is given in Table 2.23, which gives frequency of type of respondents in LE empirical research. Many researchers preferred data collections through multiple respondents (25.84%) instead of single type respondents. When this study considered single respondents, it was found that many of the researchers collected data from the middle level management (14.61%) to get effective information to their empirical analysis. Besides this, few researchers also solicited the opinion of executives, workers/ employees and CEOs (Top level management).

Table 2.23 The frequency of type of respondents in LE empirical research

Type of respondent	Number of articles	Percentage
Top Level Management	9	5.06
CEO	3	1.69
Directors	1	0.56
Executives	5	2.81
Middle Level Management	26	14.61
Lean managers	2	1.12
Logistics managers	3	1.69
Managers	21	11.8
Lower Level Management	9	5.06
Engineers	1	0.56

Type of respondent	Number of articles	Percentage
Employees	8	4.5
Others	49	27.52
Multiples	46	25.84
Farmers	1	0.56
Informants	1	0.56
Vendors	1	0.56
Not Mentioned	85	47.75
Total	178	100

2.5.5.7 Data analysis techniques

According to Flynn et al. (1990), empirical data needs to be analyzed leading to generalization, in order to frame new hypothesis or to validate an existing theory. According to Montoya-Weiss and Calantone (1994), the total data analysis techniques are classified into four groups. Table 2.24 shows the list of most widely used data analysis techniques (DAT's) with methods in empirical research.

Table 2.25 shows the frequency of data analysis techniques in LE empirical research. The contents of the table not only show the quantitative DAT's but also consist of qualitative analysis. It also represents the population of qualitative analysis and case studies handling qualitative data. In present review 43 articles were used qualitative analysis techniques to analyze their data. The descriptive statistics was the highest number (19.66%) of the published articles closely followed by statistical interpretation of parameters (16.85%). A few researchers (around 3.93%) used a combination of various techniques.

Table 2.24 List of widely used data analysis techniques with methods in empirical research

S.No.	Data analysis techniques	Methods
1	Descriptive statistics	Means, Frequencies, and Proportions
2	Tests of differences/ similarities	T-Test, Binominal test, Analysis of variance [ANOVA], Multiple ANOVA [MANOVA], and X_2 test
3	Measures of dimensionalities	Factor analysis, Cluster analysis, and Discriminate analysis
4	Statistical interpretation of parameters	Correlation analysis, Canonical correlation analysis, Regression analysis, Path analysis, and Structural equation models [SEMs]

Table 2.25 The frequency of data analysis techniques in LE empirical research

Data analysis techniques	Number of articles	Percentage
Descriptive statistics	35	19.66
Tests of differences/ similarities	18	10.11
Measures of dimensionalities	14	7.87
Statistical interpretation of parameters	32	17.98
Combinations	7	3.93
Qualitative analysis	43	24.15
Others	29	10.73
Total	178	100

2.6 Research gap and need for future research in LE

This is the first of its kind attempt to solely discuss the descriptive statistics of empirical research methodology and content oriented classification in LE. The study has included a large sample size of the articles as well as the number of journals (27 journals) considered for the critical review of content oriented classification and empirical research methodology in LE. The field of LE is growing very fast and regularly new articles are coming up on the subject. It inspired the researchers to study an exhaustive list of article samples for self-contemplation and decipher the steps of LE history and present the future of empirical research and LE content in LE. The outcome of the study clearly brings out the growth of LE literature in the field of content oriented classification and empirical research methodology since its inception. It has shown significant improvement during the period of 2002-2009.

2.6.1 Significant findings from content oriented classification of LE

- The magnificence of LE philosophy is growing day by day due to its positive impact on productivity of organizations and fulfillment of customer requirements. All this made to significant growth in published articles in various journals. It was evident from the last quarter of review period (i.e., 2005-2009) that there was a drastic increase in the number of published articles, which is 38.30 % of the total articles considered in the present study during the last two decades.
- In the section on research methodology, it found that most of theory building was taking place through the procedure of conceptual methodologies whereas, a few through the empirical methodologies. The focus of researchers should now be on establishing and testing new hypothesis with the help of techniques like case studies, surveys etc. rather than working solely on theory building. Flynn et al (1990) and Swamidass (1991) have reported the importance of empirical research study and its effects on operations management. Subsequently, other researchers started focusing on empirical research. Pannirselvam et al (1999) found that empirical studies consisted only 18% of published research articles in operations management when conducted survey during 1992-1997. He had conducted the survey during the early stage of the

empirical research that was one of the reasons to get the less empirical publication articles in that study. In the present study, it is found that the growth of empirical research was continuing in the area of LE, which constitutes around 40% of total research articles. This fact is further reinforced by the increased number of empirical research publications in the last two years of the study period, which contains 25 % of total empirical research articles. Although empirical research is increasing at a faster rate, it has to further advance to get better benefits to the organizations.

- Initially most of the lean principles were implemented in operational level to improve productivity and reduce non-value added activities. That is one of the reasons among all research streams, why LM research stream dominates over the other three research streams. After successful implementation of lean principles in operational level, Womack and Jones (1994) proposed a concept called "LE" which also includes LSCM and LPD. This new thinking is further strengthened by Hines el at (2004) who reported that the growth of lean principles is not just a production strategy but a philosophy. Hence, there is a need for spreading research in the field of LPD research stream and LE research stream. The further studies may cover this issue by promoting the topics and effective exploration.
- Many researchers were focused to avoid unnecessary inventory and waiting wastes. The researchers like Domingo et al (2007), Dhandapani et al (2004) and Sahoo et al (2007) shows in their case study that the manufacturing sector was suffered from excess inventory and lead times due to improper systematic planning. When the study considered the service sector, most of the industries are struggling to provide service to the customer within the stipulated time period (Fournier et al., 1998; Fornell, 2008).

The aforementioned issues may have influenced the researchers to solve problems in the area of inventory and waiting. Jasti et al. (2012) conducted case study on transportation waste in steel manufacturing industry, which shows 60% of trucks movement decreased by changing the plant layout. This resulted not only in cost saving but also in achieving green supply chain by reducing hazardous exhaust gases from the vehicles. The researchers like Daugherty (1994), conducted survey and proposed a model to avoid all kinds of waste in manufacturing or service activities. It shows there is a need to concentrate on all kinds of wastes to give better service to the customer as well as to increase productivity of the organization.

- The study's focus on LE elements clearly revealed that value stream mapping was most popular LE element. The subsequent most popular LE elements were setup time reduction, kanban and kaizen. The study in previous section revealed that defects, unnecessary inventory and waiting LE wastes were mostly focused by researchers and practitioners. The LE elements like value stream mapping, set up time reduction, kanban and kaizen were used to avoid defects, unnecessary inventory and waiting LE wastes in any organization. Hence, it also strengthens the outcome of the previous section of study. The LE elements like long-term supplier-customer relationship, top management commitment, visual factory, plant layout etc. were discussed many times in conceptual approach articles but when it comes to implementation part very few case study articles were implemented these elements in their organization. According to Zhu and Meredith (1995), education and training is very important element to successful implementation of any kind of advanced manufacturing philosophy. In the present study, education and training element didn't get place in top 25 LE elements. It clearly showed that many organizations did not implement education and training as an important element in their organization. Many researchers (Hines et al., 2004; Holweg, 2007; Pettersen, 2009) have reported that most of the organizations have implemented LE strategy in “bits and pieces” in their organization instead of the complete package across the whole industry. Mohanty et al (2007) also reported that many organizations were gained initially due to implementation of LE, but later, they were not able to sustain the initial results. It was happening due to improper understanding of LE system (Anand and Kodali, 2010). These were most important failure factors, since many industries did not able to implement or maintain long time LE philosophy in the organization. Hence, the study suggests that organizations should implement various LE practices or adapt one particular successful LE framework across the whole organization as well as practice it as a long term philosophy.

- Most of the researchers were proposed a framework/ model in conceptual as well as empirical nature. But only a few researchers were attempted to measure the performance of their frameworks/models in an organizational environment. Every researcher has to take responsibility to gather data from organizations and has to perform theory verification on their proposed framework/ model on the basis of available data. Most of the frameworks/models are only concentrated in the area of operational level than the enterprise level. It was clearly evident that most of the frameworks/ models belong to the category of LM research stream instead of LE research stream. Hence, there is a need of developing frameworks/models with respect to LE research stream.

2.6.2 Significant findings from empirical research methodology in LE

- The empirical research is on increasing trend in the field of LE. There was evidence that approximately 70% of the empirical articles got published in the second decade (i.e. from January 2000 to 2009).
- Both theory building and theory verification were popular among researchers but of late, i.e., in the last two years, the researchers' focus was shifted more on theory verification. One of the significant finding was that theory building and theory verification were having almost equal number of articles and both are advancing promisingly in the field of empirical research. But when the study considered all 449 (conceptual and empirical) articles of LE, only 24.27% (109 articles) of articles came in theory verification category. Hence it emphasizes that there is a need to focus on theory verification in empirical research in the field of LE. Most of the theory building was conceptual in nature and there were only 26.94% of the articles reported in empirical theory building category of the total articles (449 articles). It shows the researchers have to concentrate to build the theory applying the empirical research.
- Most popular empirical research in the field of LE was case study approach. Scudder and Hill (1998), reviewed empirical articles in operations management during period of 1985-1995 and reported that major proportion of empirical research have been conducted by applying survey research design. According to that review, case study research design articles were only half of the survey research design articles. But the present study concluded that case study research design was the most used by the researchers. The majority of the researchers were used case study

research design for theory verification process, whereas some researchers were used case study research design for theory building process as well. According to Glaser and Strauss (1967), theory building is comparison of existing data and theory, and continuous improvement between theory and development (Lynham, 2000). The case study research can be contributed in all phases of theory building (Dooley 2002). So, there is a need of developing theory through the process of case study research design instead of conceptual nature.

- Survey research design was mostly used for theory building process than theory verification. When the existing theory is validated with larger sample size, survey research design is most efficient tool. Since advancement of the information technology, conducting survey research design through questionnaire survey is become very simple and minimum budget compared to the other research design. So, the researchers have to promote to use survey research design in the area of theory verification. Panel study and focus study were highly discouraged by researchers due to its limitations. These designs need to be encouraged because LE principles being strategic in nature can take advantage of panel study and focus study research designs.
- The majority of data was collected using questionnaire method. The questionnaire tool was mostly used in survey research designs. Other data collection methods like outside observation and participants observation were less in use. Participants observation method is a time consuming process and difficult to gather the data (Bryman, 2004), but it gives proper conclusion to the researchers. Due to these limitations, most of the researchers did not prefer to collect data through participant

observation method although it gives efficient and useful conclusions. The advantages of participant observations seem to be nullifying its limitations and hence it can be promoted. Historical archive analysis and interviews were most preferred data collection methods in single case study and multi case study research designs. Many of the researchers were depending on single source of data collection instead of getting information in different forms. The study is suggesting that data collection should be through a combination of methods to draw meaningful conclusions.

- LE principles are spreading across various sectors due to its positive impact on manufacturing sector in terms of productivity and profit of the organization. It has been proven in service sector (Piercy and Rich 2009), infrastructure sector (Pheng and Tan, 1997) etc. According to the present study, most of the LE empirical articles were addressing issues from manufacturing sector like automobile, ICTE and aerospace industry. LE principles applied to other sectors like agriculture, construction, service etc were hardly found in the present study, so there is a need to focus on the aforementioned sectors.
- It was noticeable that empirical research in LE was predominantly performed in developed countries like USA, UK and Spain. The contributions of developing and undeveloped countries were minimal. Most of multinational companies are establishing their units in developing and undeveloped countries to reduce labor cost, new market for their products and low cost raw material (Sachan and Datta, 2005).The researchers have to focus on these countries as well. The study suggests that the developed countries' researchers have to collaborate with other countries' researchers to get multiple country samples and region/culture-

independent results from the survey. The developing countries like India and China are the manufacturing hubs in the present global scenario due to availability of man power and resources. But the contributions of empirical articles from these regions were significantly less. It is time for the enterprises and researchers to focus on these avenues to reduce cost and improve profit margins. Finally, there is a need to bring the researchers across the globe on single platform to get better results.

- The sample sizes especially in survey research were very small. The actual scenario is highlighted by the fact that 94% of research articles were based on sample size less than 300. Malhotra and Grover (1998) reported that 30% of the operations management survey studies suffered from statistical conclusion errors due to small sample sizes. The usage of Internet is increasing for surveying the public (Couper 2000). Many advantages of using the Internet include cost savings in terms of eliminating the printing and mailing survey instruments (Cobanoglu et al 2001). Accordingly, it would be better if researchers use advanced technology like Internet or World Wide Web to get more responses from respondents. To achieve higher survey response accuracy, the researchers must try to use larger sample sizes. Other important aspect of web survey is global respondents from worldwide population. It is useful to develop culture-independent conclusions.

- The researchers were restricting their studies to cross-sectional data instead of longitudinal data collection because of its shorter time span. According to Bhasin and Burcher (2006), LE is viewed as a philosophy and requires long term commitment to achieve better results. So, in order to get the better idea of the LE system, the researchers have to give equal priority to the longitudinal data collection method. Since longitudinal data span has a longer period of research, it can provide better analysis of the system than cross sectional data study.

- Empirical research in LE is predominantly executed with quantitative data (66.29%) in both theory building and theory verification processes than qualitative data (around 23%). But researchers were used only around 10% of triangulated data in their articles. Hussey and Hussey (1997) have highlighted importance of triangulated data to overcome potential bias and sterility of single method approaches in data collection methods. Accordingly, the researchers have to promote use of triangulated data to overcome limitations of only qualitative or quantitative data. It is found to be most suitable for theory verification.
- The types of respondents were restricted only to a smaller segment of people. To have better research outcomes, the researcher should expand the participant circle to the global level.
- Data analysis techniques used in LE empirical research were statistical descriptive and statistical interpretation of parameters. Statistical descriptive method is the oldest analysis technique whereas statistical interpretation of parameters is the most advanced technique (Guo2008). After inventing personal computer and new software tools, researchers can perform more complex data analysis using advanced software packages like partial least square and statistical package for the social sciences. While case studies are analyzed mostly by qualitative analysis unlike survey which are performed using quantitative data.

2.7 Conclusion

There is a steady increase in literature related to LE in the last two decades. After looking at the wide range of research articles in a numerous of journals it can be easily concluded that the concept of LE has a big impact on academicians, industries and researchers worldwide. The study has examined a set of 449 articles in terms of content oriented classification and empirical research in LE. The articles were collected related to "LE" only from online database of e-journals available on *Emerald, Science Direct, Springer and Taylor and Francis* portals. In the first stage, the study has shortlisted 449 empirical research articles from a selected 848 articles (both empirical and conceptual articles) on LE. It clearly shows that last quarter portion of this present study contributed around 40% of total considered articles in the present study. The study suggested that there is a need to focus more on empirical research to build theory as well as theory verification. Most of the researchers are applying lean principles in manufacturing field instead of applying across all activities of an organization. Many of the organizations have used LE practices to avoid only a few LE wastes instead of all seven wastes. The organizations have practiced LE principles as "bits-and-pieces" instead of a complete package across the organization activities. Every organization needs some systematic kind of methodology to implement LE principles across all activities. But most of the authors proposed frameworks/models in the area of LM research stream instead of LE research stream. So the study suggested that there is a need to develop frameworks with LE approach instead of particular activity of the organization. The results from the study clearly show rise in the number of empirical research articles. The complete set of shortlisted articles was assorted into various stages of systematic approach to perform literature review on empirical research. In the present study, it reveals that both theory building and theory verification were popular among researchers but they found to be biased towards cross-sectional data studies. Single case study was found to be most prominent research design among researchers and utilization of questionnaires to collect data was most preferred method. Among data analysis techniques, descriptive statistics ruled the research based on quantitative data suppressing qualitative data. The study has identified the gaps in present empirical research with showing directions for future of empirical research in LE and reciting the important findings of review. Overall the study can be suggested that the empirical research in LE is on increasing trend but also there is a need for researchers to have more interregional research collaborations in terms researchers, increase the catchment of research in Asian and other developing countries. There is a need to focus more on theory verification, alternate research designs like focus study panel study, longitudinal data collection studies and promote triangulated data and large sample size data collections to get better and prominent results. The researchers have to apply LE principles other sector industries like service and infrastructure sectors. The study also observed that many case study approach articles were focused to implement limited LE principles instead of implementing a complete set of LE principles in the organization. To encourage the professional to implement a set of LE principles, the researchers need to develop more numbers of LE frameworks, which acts as guiding torch to the professionals.

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Chapter 3

An empirical study for implementation of lean enterprise principles in Indian industry

3.1 Introduction

Lean enterprise (LE) philosophy offered various benefits to the industrial world; however, many of the organizations were not able to grasp the advantages of LE philosophy yet. In particular, the industries in fastest developing countries like India up to recently were working on Henry Ford proposed mass production methodology. To survive in the present globalization environment competition, the Indian manufacturing industries started to implement LE practices after the globalization. Still so many industries in India are not able to implement LE principles due to lack of knowledge on LE practices, financial support, employee support and top management support. Hence, the present study attempts to find out the implementation stage of LE practices and list out various barriers to implement LE practices in Indian manufacturing industries. The present study has conducted literature survey to find out similar kind of studies in the past. The study found that many researchers have conducted similar kind of studies, which are survey-based LE principles' assessment work in Australian manufacturing industry (Sohal and Egglestone, 1994), electronics manufacturing (Doolen and Hacker, 2005), Spanish ceramic tile industry (Tomas and Antonio, 2006), Malaysian electrical and electronics industry (Wong et al, 2009), Malaysian automotive industry (Nordin et al 2010), and across Thailand manufacturing industry (Rahman et al, 2010).

The present section of study further investigated to find out whether the similar kind of research studies was performed in India. It was found that Eswaramoorthi et al (2011) conducted similar survey-based study on machine tool industry, which focused on importance of implementation of LE principles in Indian machine tool industry. It also focussed on the priorities, barriers and familiar LE tools in Indian machine tool industries. The sample of the study was restricted to only 43 responses from Indian machine tool industry. Further it was found that Ghosh (2013) conducted research study to find out the important LE practices and the operational performance after implementation of LE principles in Indian manufacturing industry. The preceding study also found out the importance of various tools and techniques of LE through a given ranking based upon survey results. One of the constraints of the study was the sample size and was focused only on limited area of LE elements and their performance on productivity, lead time etc. The study was restricted to only 79 survey responses across Indian manufacturing organizations. Hence the present study tries to overcome all shortcomings of the previous studies in LE principles' assessment in Indian manufacturing organizations. The study is also helpful to find out the various hurdles to implement LE principles across Indian manufacturing sector. Generally, many factors are impacting on LE principles implementation, which includes the back ground industry, understanding of LE principles, drivers for LE implementation, area of LE implementation, what type of obstacles faced by organizations to implement LE principles, what type of LE waste avoided by the organization, what type of benefits expected by the organization, what type awareness created among employees of the organization before implementation of LE principles, what type of LE tools used by the organization to implement LE principles. These factors are playing major role to find out the implementation stage of LE principles in Indian manufacturing industry as well as why many Indian manufacturing organization have failed to implement LE principles in the organizations. Hence, the present study tries to find out all aforementioned variables to find out the implementation stage of LE principles in Indian manufacturing industry.

3.2 Research methodology

The main objective of the present section of study is to trace the implementation stage of LE principles across Indian manufacturing industry. The survey questionnaire methodology was chosen to achieve the objective of the study. The cross-sectional study was conducted across Indian manufacturing industry. The survey questionnaire was developed with exceptional precautions to get proper response from the respondents. To conduct validity of the questionnaire, the study administered the survey questionnaire to professionals six each from academic and industry. The expert suggestions were incorporated in final format of the survey questionnaire. The present study also conducted pilot study to validate the content validity of the survey questionnaire in one of the major Indian auto component industry.

The survey questionnaire was divided into two parts: part A and part B. Part A of the survey questionnaire captures: organization profile and personal information of the respondent. Part B of the survey questionnaire captures: what is motive of the LE principles implementation, which part of organizational operational area they have implemented LE principles, what kind of LE tools, techniques and practices they have used in the organization, what kind of LE waste they have removed from the organization, what is the respondent understanding of LE principles, and what are all the major obstacles to implement LE principles in their organization. The present study used five-point Likert scale to get the responses for each item for the LE practices and other issues. The indication scale given to the respondents was in the following manner: (1) indicates no implementation (0 percent), (2) indicates little implementation (around 25 percent), (3) indicates some implementation (around 50 percent), (4) indicates extensive implementation (around 75 percent), and (5) indicates complete implementation (100 percent). The format of questionnaire is given in Appendix-B. The present study collected manufacturing industry database from Confederation of Indian Industries (CII) directory in 2011. The present study targeted the respondents at the level of managing directors/CEO's, production managers, maintenance managers, logistics managers and also quality managers. The main manufacturing industry sectors considered are the automobile, electronics, engineering, process and textile industries (Sharma and Kodali, 2008).

Finally the survey questionnaire was sent to 753 targeted organizations to get the responses from the Indian manufacturing organizations. Dillman (1978) has proposed some of the practices to improve the response rate of any survey questionnaire from any industry sectors. The present study was implemented those suggestions to get more responses from the Indian manufacturing industry. The questionnaire was posted along with covering letter and stamped self postal address envelop to the respective organizations. After six weeks, a second survey questionnaire was sent to those who did not respond for the first questionnaire. Moreover, some of the respondents have communicated through e-mail and telephone conversation. Simatupang and Sridharan (2004) have used similar kind of methodology to get huge responses in their empirical study. In all the present study received 196 responses from various Indian manufacturing industries. After complete evaluation of all the responses, the present study did not consider 16 responded survey questionnaires as the respective organizations were not implemented any kind of LE principles. Hence the study has considered only 180 useful responses from the received responses. It clearly indicated that the response rate was 23.6 per cent. If the response rate of any empirical survey is more than 18%, then it is considered as good response rate (Sharma and Kodali, 2008). The response rate from each individual sector were: automobile (28.22%), machine equipment (26.31%), electrical and electronics (17.37%), process (18.67%), and textile (37.29%). The statistics of the individual sector responses are shown in Table 3.1. The number of responses from the automobile sector was more than other sectors considered in the study, which was 31.66% (57 responses) of total responses received from all the sectors. Machine equipment industry sectors occupied second place in terms of response numbers, which was 22.22% (40 responses) of total responses. The remaining sectors, i.e., electrical and electronics, process industry and textiles industry responses' contributions were 18.33% (33 responses), 15.56% (28 responses) and 12.22% (22 responses) respectively.

Table 3.1 The statistics of the individual sector responses

Industry	No. of responses received by post	No. of responses received by mail by email	Total No. of responses received	Sample Size	Response rate
Automobile	28	29	57	202	28.22
Machinery Equipment	16	24	40	152	26.31
Electrical and electronics	9	24	33	190	17.37
Process	11	17	28	150	18.67
Textile	7	15	22	59	37.29
Total	71	109	180	753	23.9

3.3 Analysis and key findings

The present study attempted to find several factors such as respondents' understanding of LE principles, the main drive force to implement it in their organization, which part of the operations area LE principles were implemented, what are the main obstacles to implement LE principles in their organizations, what kind of LE waste removed from their organization, the familiar LE elements among the respondents, and finally, which are the LE principles implemented in their organization.

3.3.1 Industry background

The present study focuses on the back ground of the industries and the respondents responded to the survey. The study found that 57.22% of the respondents were working in Indian based organizations. Around 28.33% of the respondents were working in foreign based organizations. The remaining 14.45% of the responded professionals was working with joint venture organizations. Around 91.83% of the respondent organizations were implemented some sort of LE principles in their organization. Few of the organizations were implementing some kind of advanced manufacturing techniques like total quality management, total productive maintenance etc., which are the part of the LE principles (Shah and Ward, 2003). Hence the study considered only the responses from LE principles' implemented organizations to do the analysis.

The present study further concentrated to find out the respondent size of the organization. The classifications of organizations were based upon following the guidelines given by Rahman et al (2010). The preceding study proposed that organizations having employees more than 200 numbers could be classified as large scale (LS) industry. Accordingly the present survey data revealed that 71.67% of the respondent organizations were LS industry. The remaining 28.33 % of the respondents were representing small and medium scale (SMS) industry. The study also finds out how long a particular organization has been implementing LE principles. The response of the survey shows that many of the organization have started implementation of LE principles. Around 57.22% of the responded organizations were implemented the LE principles more than one year and less than five years period. The study further analyzed and found that only 21.11% of the organizations were implemented LE principles in their organization more than five years and less than ten years. The study also found from the survey that only 15% of the responded organizations were implemented the LE principles in their organization for more than ten years. It clearly indicates that most of the Indian organizations have started implementation of LE principles very recently. Table 3.2 shows the key characteristics of the respondents.

Table 3.2 The key characteristics of the respondents

		Frequency	Percentage
Number of employees	<=200	51	28.33
	> 200	129	71.67
Ownership	Indian owned	103	57.22
	Foreign owned	51	28.33
	joint owned	26	14.45
Lean principles implementation	0<years<1	13	7.22
	1<years <5	103	57.22
	5<years <10	37	21.11
	10<years	27	15.00

3.3.2 Understanding of LE principles

In order to find out the understanding of LE principles among the respondents, the present study requested them to indicate what they are thinking about LE principles. The respondents were given eight choices to describe the LE principles (Wong et al, 2009). The main emphasizes of LE is waste elimination and continuous improvement methodology. Out of 180 valid received responses, the study revealed that many of the respondent organizations have understood that it was a waste reduction (average mean score value 4.32) and continuous improvement process (average mean score value 4.19), which clearly shows that many of the professionals have knowledge about LE principles from Indian manufacturing industries. Moderate number of the industry professionals understand LE as tools and techniques to improve operations (average mean score value 3.14) and Toyota production system (average mean score value 3.02). Interestingly, the roots of LE philosophy came from Toyota production system (Krafcik, 1988), which might be the reason for many respondents to reply in that manner.

A closer investigation on survey data revealed that only small number of the respondents have understood that LE was a fully integrated manufacturing philosophy (average mean score value 1.6). The results clearly show that organizations have started to believe LE principles as long term manufacturing philosophy across Indian manufacturing industries (Bhasin and Burcher, 2006). A very few professionals (average mean score value 1.12) of the respondent organizations understood that LE principles were a way of life. The mean average score values of understanding of LE is given Table 3.3.

Table 3.3 The mean average score values of understanding of LE

S.No.	Understanding of LE philosophy	SMS industries mean	LS Industries mean	Total mean
1	Waste reduction	3.79	4.53	4.32
2	Continuous improvement	3.76	4.36	4.19
3	Tools and techniques to improve operations	2.08	3.56	3.14
4	Toyota production system	2.16	3.36	3.02
5	A fully integrated management philosophy	1.72	2.14	1.60
6	A system to organizing and managing product development, supplier and customer relations	1.2	1.55	1.45
7	Headcount reduction	1.10	1.45	1.35
8	A way of life	1.02	1.16	1.12

3.3.3 Drivers of LE implementation

The present study analyzed the drive force to implement LE principles in the respondent organizations. In this regard, the study requested the respondents to provide what are the influencing factors for implementation of LE principles in their organization. The similar methodology was performed by Wong et al (2009) in their study on Malaysian electrical and electronics industries. According to the present survey, the main influencing factor to implement LE principles in the organizations was customer satisfaction. It exhibits average mean score 3.56. Many of the SMS manufacturing industries implemented LE principles due to their customer requirements. Other driving factors, which influenced to implement LE principles in their organizations were continuous improvement programme (average mean score 3.18) and best manufacturing practices (average mean score 3.15). The driving factor that influenced the least to implement LE principles in their organization was increase flexibility of the production (average mean score 1.933). The average mean score values of the drivers to implement LE principles are given in Table 3.4.

Table 3.4 The average mean score values of the drivers to implement LE principles

S.No.	Drive force to implement LE principles	SMS industries mean	LS industries mean	Total mean	SD
1	Drive to focus on customers	3.64	3.53	3.56	0.77
2	Continuous improvement programme	2.81	3.33	3.18	0.91
3	Desire to employ world best practice	2.56	3.38	3.15	0.98
4	Development of key performance indicators	2.34	2.66	2.57	0.81
5	The need for survival from internal constraints	2.45	2.74	2.66	0.98
6	To increase market share	1.43	2.3	2.05	0.67
7	To increase flexibility	1.24	2.21	1.93	0.89

3.3.4 Area of LE principles implementation

One of the objectives of the present study is to find out the implementation stage of LE principles in key area of the organization. Wong et al (2009) have mentioned 14 key areas of the manufacturing organization to implement LE principles. The key areas of the organizations are: scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques. The present study finds out the average mean score for each key practice area. A higher average mean score designates a higher degree of implementation of the particular key area. The average mean score of all 14 key areas were ranging from 1.96 to 4.49. While arranging the average mean score in descending order, the study found that customer key area showed high average mean score value of 4.49. The second highest ranked key area of LE principles implementation in Indian manufacturing industries was inventory key area (average mean score 4.32). The subsequent key areas were quality, suppliers and layout with average mean scores of 4.15, 4.06, and 3.88 respectively. Whereas, the least average mean score of the key area was product design, which was 1.96. The study further investigated the reason behind the low average mean score for product design. The study understood that many of the SMS industries and a few of LS industries have received their product designs from the customer. Hence many of the SMS and LS industries did not implement LE principles in their product designs. The average means score values of implementation area wise are given in Table 3.5.

The present study further finds out what are the differences in implementation of LE principles in SMS and LS industries. The study observed that there was significant differences in terms of average mean score in the key areas of product design, safety and ergonomics, employees, management and culture, and scheduling. The LS industries are relatively financially stronger than SMS industries. Hence the LS industries can spend more budget resources in the above mentioned five key areas, which was one of the factors that may be influencing differences in terms of average mean score value. In the study, it is clearly identified that LS industry employees were well trained and empowered than SMS industry. The LS industries have well established product design and development teams compared with SMS industries.

Table 3.5 The average mean score values of implementation area wise

S.No.	Key Areas	SMS industries mean	LS industries mean	Total Mean	SD
1	Customer	4.56	4.46	4.49	0.59
2	Inventory	3.54	4.62	4.32	0.81
3	Quality	4.22	4.12	4.15	0.84
4	Suppliers	3.9	4.12	4.06	0.87
5	Layout	3.3	4.11	3.88	0.83
6	Tools and techniques	3.22	3.97	3.76	0.88
7	Work processes	3.51	3.78	3.7	0.96
8	Material handling	3.12	3.82	3.62	0.85
9	Equipment	2.93	3.9	3.62	0.98
10	Scheduling	2.2	3.97	3.47	1.05
11	Management and culture	2.23	3.65	3.25	1.2
12	Safety and ergonomics	2.12	3.25	2.93	1.29
13	employees	2.56	2.88	2.79	1.19
14	Product design	1.09	2.31	1.96	1.05

3.3.5 Obstacles of implementing LE principles

The present study also investigated the obstacles of implementing LE principles in Indian manufacturing industries. The study identified 16 obstacles to implement LE principles in any manufacturing organization based on literature survey as well as communicated with industry professional (Wong et al, 2009; Eswaramoorthi et al, 2011). The sixteen obstacles to implement LE principles are: lack of top management support, failure of past LE projects, financial benefits not recognized, does not practice what is preached, lack of time to implement, lack of know – how to implement, company culture or national culture, budget constraints, employee resistance, backsliding to the old ways of working, lack of communication, lack of manufacturing facility, lack of support from suppliers, frequent design changes, the customer orders are highly fluctuating/varying, and lower volume of demand.

The present survey revealed that major obstacle to implementation of LE principles in Indian manufacturing industries was employee resistance, which showed an average mean score of 3.76. In many organizations, employees were lacking job security due to LE implementation in their organization, which is a myth in reality. Hence the study suggested that the organization needs to conduct training and create trust in the mind of employees before going to implement LE principles in their organization. The second and third major obstacles were: a systematic LE approach missing or lack of know-how to implement and budget constraint, with average mean scores of 3.44 and 3.37 respectively. The study separated the SMS industry responses from the LS industry responses. It clearly indicates that the SMS industries were struggling to implement LE principles due to inadequate manufacturing facility and lack of support from their top management, which was reflected in the present survey responses. The averages mean score value of obstacles to implement LE principles is given in Table 3.6.

Table 3.6 The average mean score values of obstacles to implement LE principles

S.No.	Obstacles	SMS industries mean	LS industries mean	Total mean	SD
1	Employee resistance	3.62	3.82	3.76	0.81
2	Lack of systematic lean approach	3.22	3.38	3.44	0.83
3	Budget constraints	3.81	3.27	3.37	0.8
4	Backsliding to the old ways of working	3.12	3.06	3.22	0.93
5	Lack of communication	2.98	2.88	3.09	1.12
6	Lack of time to implement	2.89	2.81	3.04	0.65
7	Lack of manufacturing facility	3.92	2.54	2.84	1.27
8	The customer orders are highly fluctuating	2.81	2.44	2.77	1
9	Frequent design changes	2.12	2.03	2.48	0.84
10	Lack of top management support	3.75	1.94	2.42	1.22
11	Company culture or national culture	3.02	1.82	2.33	1.17
12	Lower volume of demand	2.12	1.69	2.24	0.86
13	Does not practice what is preached	2.69	1.58	2.16	1.01
14	Lack of support from suppliers	1.78	1.47	2.08	0.88
15	Failure of past lean projects	1.56	1.31	1.96	0.89
16	Financial benefits not recognized	1.62	1.15	1.85	0.57

3.3.6 Type of LE wastes

The main objective of LE is to find out the non value added activities and to avoid these activities from the manufacturing line. According to Ohno (1988), waste could be classified into seven categories: over production, waiting, unnecessary motion, transportation, inventory, inappropriate processing and defects. The present research tried to find out which types of wastes were removed from their respondent organizations. The first highest waste that could be reduced by these respondent industries was inventory waste with average mean score value of 4.05 of the total respondent organizations. Many of the respondent industries effectively reduced defects waste with average mean score value of 3.77 of total respondent organizations. It clearly indicated that most of Indian manufacturing industries were struggled with more inventory and defects in the production, which may be one of the reasons to implement LE principles. A very few industries were identified transportation waste by applying LE principles in their organization. The averages mean score values of each waste identified by Indian manufacturing industries are given in Table 3.7.

Table 3.7 The averages mean score values of each waste identified by Indian manufacturing industries

S.No.	Type of Waste	SMS industries mean	LS industries mean	Total mean	SD
1	Inventory	3.84	4.13	4.05	0.50
2	Defects	3.94	3.70	3.77	0.94
3	Inappropriate processing	3.16	3.27	3.24	1.13
4	Waiting	2.92	3.04	3.01	0.85
5	Unnecessary motion	2.45	3.06	2.89	0.84
6	Over production	2.34	2.57	2.51	0.88
7	Transportation	1.88	2.14	2.07	0.84

3.3.7 Benefits of LE principles

Generally many of the organizations and case study research works have reported that LE principles implemented organizations have benefitted in various aspects of production. Hence the present research also tried to find out the benefits enjoyed by the implemented organizations in respect of cost, quality, inventory, productivity, decrease in response time, flexibility, etc. The present research survey revealed that many of the organizations were benefited more in reduced inventory due to implementation of LE, with average mean score value of 4.1of the total respondent organizations. The present study also revealed that the quality of the product and productivity of the manufacturing lines improved significantly with the help of LE principles with respective average mean score values of 4.00 and 3.95of the total respondent organizations. When the quality of the product and productivity of the manufacturing have improved, it reduces the production scrap. The survey also revealed that respondent organizations were benefited in terms of scrap reduction due to implementation of LE principles with average mean score value of 3.52 of the total respondent organizations. Many of the research studies proved that response times improve drastically due to implementation of LE principles. The present research survey also revealed similar kind of results in terms of response time improvement benefit received due to implementation of LE principles with average mean score of around 3.41 of the total respondent organizations. The averages mean score values of organizations received benefits from LE implementation is given in Table 3.8.

Table 3.8 The average mean score values of organizations received benefits from LE principles implementation

S.No.	Benefits	SMS industries mean	LS industries mean	Total mean	SD
1	Decreased inventory	3.54	4.32	4.10	0.54
2	Improved quality	3.70	4.12	4.00	0.63
3	Improved productivity	3.47	4.14	3.95	0.59
4	Reduced waste or scrap	2.50	3.92	3.52	0.79
5	Improved response time	2.98	3.58	3.41	0.91
6	Increased profit	3.08	3.37	3.29	0.94
7	Reduced cost	2.89	3.23	3.13	1.12
8	Improved flexibility	2.27	3.12	2.88	1.14

3.3.8 Awareness of LE elements

Many of the research articles were proposed and implemented various elements and techniques under LE system. Some of the researchers tried to gather the complete list of the LE processes, tools and techniques used in various research studies. In this category of the study, Pavnaskar (2001) has conducted research and identified a total of 101 LE elements, techniques and practices from the existing literature. The preceding study tried to help the organizations to establish relationship between LE elements and manufacturing waste. Shah and Ward (2003) identified 21 LE elements in their literature review study. Anand and Kodali (2009) conducted literature survey to find out the unique elements of LE to propose conceptual comprehensive framework of LE. The conceptual framework proposed 69 elements from the existing literature survey of the LE. The present study adapted complete set of LE practices, tools and techniques proposed by Anand and Kodali (2009). The preceding study also proposed conceptual LE framework along with stepwise procedure for implementation of LE. Nordin et al. (2010) classified all LE elements into five categories. The five categories are: process and equipment, manufacturing planning and control, human resource management, supplier relationship and customer focus. The present study combined supplier relationship and customer focus under roof of supply chain management.

One of the objectives of the present study was to find out the real awareness of LE elements among Indian manufacturing industry professional. The study clearly revealed that a value of 2.88 was found as the total average of the levels of awareness of the investigated LE elements. The study clearly indicates that the awareness of LE elements among Indian manufacturing industry professional were fairly good. The most popular LE elements among Indian manufacturing professional were cross functional team and multi functional workers, which have mean score of 4.22 and 4.17 respectively. The study revealed that concurrent engineering (average mean score =1.09), focused factory production (average mean score =1.12), rolling production plans (average mean score = 1.12) and 5S (average mean score =1.17) were least popular LE elements among Indian manufacturing industry professionals. The study also analyzed that mistake proofing or pokayoke, one piece flow, kanban system, pull production were most familiar elements among professionals, which revealed that in terms of average mean score more than 4.00 in 5 point scale. The average mean score of LE elements awareness by respondents is given in Table 3.9.

Table 3.9 The average mean score values of LE elements awareness by respondents

S.No.	LE elements	SMS industries mean	LS industries mean	Total mean	SD
1	Cross functional team working	3.48	4.51	4.22	0.76
2	Multi skilled workforce	3.44	4.45	4.17	0.82
3	Kanban system	3.98	4.08	4.05	0.89
4	Pull production	3.88	4.07	4.02	1.01
5	One piece flow	3.87	4.07	4.01	0.88
6	Pokayoke	3.79	4.08	4	0.8
7	Statistical process control	3.27	4.27	3.98	0.81
8	Just-in-time delivery	3.73	4.04	3.95	0.81
9	Small lot production	3.65	4.05	3.93	0.75
10	Takt time	3.63	4.03	3.92	0.99
11	Value stream mapping	3.67	3.99	3.9	0.7
12	Successive checking	3.5	4.05	3.89	0.91
13	Defects at source (Self inspection)	3.63	3.96	3.87	0.91
14	Multi functional training	3.56	3.98	3.86	0.86
15	Elimination of waste	3.61	3.96	3.86	0.84
16	Single minute exchange of dies	3.48	4	3.86	0.81
17	Commonization and standardization of parts	3.42	4.02	3.85	0.79
18	Layout change or U-shaped Cell	3.51	3.97	3.84	0.86

S.No.	LE elements	SMS industries mean	LS industries mean	Total mean	SD
19	Workload or Line balancing	3.48	3.97	3.83	0.91
20	Order based production	3.3	4.01	3.81	0.79
21	WIP reduction	3.51	3.94	3.82	0.87
22	Design for manufacturing	3.68	3.85	3.8	0.89
23	Continuous improvements	2.5	4.31	3.8	0.82
24	Work standardization	3.71	3.77	3.75	0.83
25	Use of problem solving tools	3.67	3.76	3.73	0.95
26	Total productive maintenance	3.43	3.81	3.7	0.99
27	Visual control	3.1	3.91	3.68	0.86
28	Cycle time and lead time reduction	3.45	3.75	3.67	0.87
29	Use of EDI with suppliers	3.55	3.69	3.65	0.95
30	Sole sourcing or supplier reduction	3.46	3.7	3.63	0.82
31	Rewards and recognition	3.48	3.65	3.6	0.8
32	Standardized containers	3.41	3.58	3.53	0.79
33	Information sharing with suppliers	3.38	3.57	3.52	0.79
34	Production smoothing	3.26	3.54	3.46	0.92
35	Synchronization	3.13	3.57	3.44	0.83
36	Maintain spare capacity	3.21	3.44	3.37	0.8
37	Quality circles	2.11	3.72	3.27	0.93
39	Supplier involvement in design	2.22	3.4	3.07	0.67
40	Total quality management	2.72	3.15	3.03	1.27
41	Cellular manufacturing	2.15	3.02	2.77	1
42	Group technology	2.11	3	2.75	0.93
43	Computer integrated manufacturing	1.3	2.86	2.42	1.22
44	Supplier training and development	1.98	2.51	2.36	1.18
45	Use of multiple small machines	1.98	2.34	2.24	0.79
46	Process sharing	1.87	2.29	2.17	0.94
47	Andon (Warning lights)	1.58	2.2	2.03	1.02
48	Jidoka (Autonomation)	1.67	2.08	1.96	0.89
49	Long term supplier relationship	1.13	2.13	1.85	0.57
50	Product and process simplification	1.28	1.93	1.74	0.57

S.No.	LE elements	SMS industries mean	LS industries mean	Total mean	SD
51	Flat organization structure	1.12	1.91	1.69	0.6
52	Storage space reduction	1.12	1.9	1.68	0.59
53	Long term employment	1.16	1.83	1.64	0.59
54	Automation	1.12	1.77	1.58	0.58
55	Quality certification	1.12	1.77	1.58	0.59
56	New process or Equipment technologies	1.04	1.77	1.56	0.58
57	Suggestion schemes	1.01	1.73	1.53	0.55
58	Mixed model manufacturing/ scheduling	1.05	1.72	1.53	0.54
60	Communication between employees	1.03	1.62	1.46	0.52
61	Employee empowerment	1.12	1.56	1.44	0.54
62	Employee participation	1.17	1.51	1.42	0.53
63	Job rotation	1.12	1.45	1.36	0.51
64	Job enlargement or Nagara system	1.17	1.34	1.29	0.5
65	Safety improvement programs	1.01	1.38	1.27	0.49
66	Housekeeping (5S)	1.01	1.24	1.17	0.43
67	Focused factory production	1.01	1.16	1.12	0.34
68	Rolling production plans	1.01	1.16	1.12	0.32
69	Concurrent engineering	1	1.12	1.09	0.29

3.3.9 LE principles implementation

The responses of survey questionnaire revealed the stage of LE principles implementation in Indian manufacturing organization with the mean value varying from 4.01 to 1.2. The most popular constructs were multi skill work force, cross functional team working, kanban system, statistical process control, small lot production and pull production in LE principles implementation among Indian manufacturing industries with respective average mean scores of 4.19, 4.14, 4.11, 4.11, 4.08 and 4.02 on five point scale. The LE constructs like concurrent engineering, rolling productions roll, focused factory production, and mixed model manufacturing/ scheduling were least priority with respect to implementation of LE principles in Indian manufacturing industries, which revealed an average mean score values of 1.56, 1.56, 1.67 and 1.80 respectively. The study also analyzed that poka yoke, value stream mapping, workload or line balancing, work standardization, single minute exchange of die, one piece flow, visual control were moderately implemented in Indian manufacturing industries, which reflected in terms of average mean score value of above 3.8. The study further concentrated only on group/ category of the LE average mean score that revealed manufacturing planning and control and process and equipment have 3.29 and 3.10 respectively. The main group/category like human resource management and supply chain management of the LE practices have least average mean score in the present survey, which were 2.65 and 2.95 respectively. The averages mean score of implementation of LE elements are given in Table 3.10.

The present section of study also tried to find out which LE elements were mostly used to avoid popular seven LE wastes in their organization. The study found that many of the LE elements were used to avoid defects, inventory and inappropriate processing kinds of LE waste. It revealed that 53 LE elements were used to avoid defect LE waste from the manufacturing processes of the responded organizations. The study revealed that 38 LE elements were used to remove inventory LE waste. The study further revealed that 35 LE elements were used to avoid inappropriate processing. The LE elements like kanban, pull production system, small lot size, and JIT delivery were used widely among Indian manufacturing sector to avoid inventory LE waste. It also revealed that poka yoke, supplier sourcing, quality circles, statistical process control, multiple skilled workforce were most frequently used LE elements to avoid defect waste from Indian manufacturing industries. The popular list of LE elements used to avoid each LE waste is given in Table 3.11.

Table 3.10 The average mean score values of implementation of LE elements

S.No.	Group/category	LE elements	SMS industries mean	LS industries mean	Total mean	SD
1	Process and equipment		2.27	3.42	3.10	0.78
1.1		Statistical process control	3.10	4.51	4.11	0.95
1.2		Pokayoke or Mistake proofing or Defect prevention	3.30	4.25	3.98	0.76
1.3		Work standardization	3.65	4.11	3.98	0.76
1.4		Value stream mapping	3.01	4.36	3.98	0.67
1.5		Single minute exchange of dies	3.21	4.26	3.96	0.76
1.6		One piece flow	3.57	4.02	3.89	0.83
1.7		Takt time	2.97	4.10	3.78	0.99
1.8		Successive checking	2.93	4.02	3.71	0.83
1.9		Commonization and standardization of parts	2.99	3.94	3.67	0.84
1.10		Standardized containers	3.21	3.85	3.67	0.86
1.11		Continuous improvements	2.34	4.17	3.65	0.73
1.12		Use of problem solving tools	2.78	3.95	3.62	0.87
1.13		Design for manufacturing	2.65	3.82	3.49	0.81
1.14		Layout change or U-shaped cell	3.10	3.59	3.45	0.76
1.15		Maintain spare capacity	2.45	3.79	3.41	0.74
1.16		Defects at source (Self inspection)	2.86	3.47	3.30	0.87
1.17		Total productive maintenance	2.80	3.39	3.22	0.86
1.18		Total quality management	2.13	3.62	3.20	0.98
1.19		Synchronization	2.12	3.32	2.98	0.99
1.20		Cellular manufacturing	1.58	3.53	2.98	0.79
1.21		Group technology	1.67	3.37	2.89	1.06
1.22		Computer integrated manufacturing	1.10	3.14	2.56	0.97
1.23		Andon (Warning lights)	1.20	3.10	2.56	0.88

S.No.	Group/category	LE elements	SMS industries mean	LS industries mean	Total mean	SD
1.24		Use of multiple small machines	1.56	2.80	2.45	0.85
1.25		Process sharing	1.76	2.47	2.27	0.99
1.26		Housekeeping (5S)	1.03	2.50	2.08	0.56
1.27		New process or Equipment technologies	1.04	2.39	2.01	0.51
1.28		Automation	1.02	2.23	1.89	0.42
1.29		Product and process simplification	1.12	2.17	1.87	0.51
1.30		Focused factory production	1.04	1.92	1.67	0.45
1.31		Concurrent engineering	1.00	1.78	1.56	0.32
2	Manufacturing planning and control		2.77	3.5	3.29	0.78
2.1		Kanban system	3.45	4.37	4.11	0.82
2.2		Small lot production	3.65	4.25	4.08	0.83
2.3		Pull production	3.77	4.12	4.02	0.94
2.4		Workload or Line balancing	3.24	4.27	3.98	0.87
2.5		Visual control	3.12	4.15	3.86	0.78
2.6		Production smoothing or Load levelling	3.12	3.87	3.66	0.87
2.7		Order based production	2.97	3.79	3.56	0.84
2.8		Elimination of waste	3.10	3.74	3.56	0.77
2.9		WIP reduction	3.16	3.61	3.48	0.94
2.10		Cycle time and lead time reduction	3.10	3.59	3.45	0.81
2.11		Jidoka (Autonomation)	1.12	2.46	2.08	0.78
2.12		Mixed model manufacturing / scheduling	1.05	2.10	1.80	0.48
2.13		Rolling production plans	1.12	1.73	1.56	0.42
3	Human resource management		1.66	3.04	2.65	0.6
3.1		Cross functional team working	3.10	4.62	4.19	0.84

S.No.	Group/category	LE elements	SMS industries mean	LS industries mean	Total mean	SD
3.2		Multi skilled workforce	3.67	4.33	4.14	0.78
3.3		Rewards and recognition	3.10	3.67	3.51	0.97
3.4		Multi functional training	2.10	3.94	3.42	0.93
3.5		Quality circles	1.93	3.40	2.98	0.94
3.6		Suggestion schemes	1.01	3.02	2.45	0.45
3.7		Safety improvement programmes	1.05	2.79	2.30	0.44
3.8		Communication between employees	1.03	2.66	2.20	0.51
3.9		Flat organization structure	1.06	2.46	2.06	0.54
3.10		Long term employment	1.02	2.36	1.98	0.48
3.11		Employee participation	1.06	2.34	1.98	0.41
3.12		Job enlargement or Nagara system	1.02	2.30	1.94	0.32
3.13		Employee empowerment	1.08	2.21	1.89	0.38
3.14		Job rotation or Flexible job responsibilities	1.03	2.23	1.89	0.46
4	Supply chain management		1.86	3.38	2.95	0.72
4.1		Sole sourcing or supplier reduction	2.78	4.18	3.78	0.95
4.2		Information sharing with suppliers	2.40	4.28	3.75	0.81
4.3		Just-in-time delivery	3.10	3.87	3.65	0.75
4.4		Use of EDI with suppliers	2.70	3.90	3.56	0.84
4.5		Supplier proximity	2.25	3.92	3.45	0.79
4.6		Supplier involvement in design	1.56	3.86	3.21	0.78
4.7		Supplier training and development	1.45	3.04	2.59	0.89
4.8		Quality certification	1.04	2.66	2.20	0.59
4.9		Elimination of buffers	1.04	2.66	2.20	0.57
4.10		Storage space reduction	1.08	2.45	2.06	0.45
4.11		Long term supplier relationship	1.04	2.35	1.98	0.52

Table 3.11 The popular list of LE elements used avoid each LE waste

S.No.	Type of lean waste	LE elements	No. of LE Elements used
1	Over production	Order based production, Storage space reduction, Small lot production, Use of EDI with suppliers, Mixed model manufacturing/scheduling, Job enlargement or Nagara System, Elimination of buffers, workload or Line balancing, Group technology, Communication between employees	10
2	Waiting	Information sharing with suppliers, Layout change or U-shaped cell, Use of multiple small machines, Use of EDI with suppliers, Production smoothing or Load levelling, Maintain spare capacity, Workload or Line balancing, Synchronization, Communication between employees, Single minute exchange of dies	37
3	Unnecessary motion	Layout change or U-Shaped Cell, Cross functional teams, Kanban system, Maintain spare capacity, Total productive maintenance ,Group technology ,Single minute exchange of dies, Communication between employees, Value stream mapping, Successive checking	13
5	Inventory	Small lot production, Kanban system, Pull production, Continuous improvement program or Kaizen, Long term supplier relationship, Just-in-time delivery (from suppliers and within workstations), Sole sourcing or supplier reduction, Cross functional teams, One piece flow, Cellular manufacturing	38
6	Inappropriate processing	Cross functional teams, Suggestion schemes, Visual control, Multi skilled workforce, Continuous improvement program or Kaizen, Work standardization, Quality circles, Total quality management, Multi functional training, Supplier training and development	31
7	Defects	Multi skilled work force, Quality circles, Suggestion schemes, Pokayoke or Mistake proofing or Defect Prevention, Sole sourcing or supplier reduction, Defects at source (Self inspection),Cross functional teams, Statistical process control, Successive checking, Use of problem solving tools	53

3.4 Significant findings and future directions

The present study tried to present significant insight into current state of LE principles' implementation among Indian manufacturing organization. The study also concentrated on various factors related to LE principles and its impact on various operational activities.

- The study tried to find out the implementation of LE principles in SMS industries and LS industries. The LS industries (around 71.67%) were more advanced in respect of LE principles implementation than SMS industries (around 28.33%). Majority of the SMS industries (around 60%) have implemented LE principles recently, i.e., just a few years back. According to Papadopoulou and Ozbayrak (2005) and Sim and Rogers (2009), LE is the long term manufacturing strategy, which needs to be implemented in organizations with long term goals and benefits. The SMS industries were always tried to focus on short term benefits and profits than long term quality achievement due to financial instability. Most of the customers of the SMS industries were LS industries. The LS industries have to come forward and help their suppliers in respect of LE principles implementation so that both organizations will get the complete benefits of the LE principles in terms of quality, productivity and cost of the product. Most of the Indian LS industries (around 60%) were also partially implemented LE principles in various departments of the organization very recently (less than 5 years) and started to get the partial benefits with respect to cost, quality and productivity of the organization. However the Indian LS industries have to implement LE principles in their entire organization instead of particular area of the organization to get the complete benefits of the LE principles.

- The study revealed that many organizations were implemented LE practices to achieve the customers satisfaction (mean value is 3.56) and continuous improvement (mean value is 3.18) in the manufacturing plant. Many researchers (Anand and Kodali, 2010, 2009) have reported that implementation of LE principles also provides lot of flexibility to the organization in the aspects of manufacturing various products. But very few organizations understood that the importance of LE principles to improve the flexibility of the organizations (mean value is 1.93). Hence, the study suggests the organizations management has to provide the complete training programme to understand and get the attention of employees about LE principles by revealing various benefits obtained with the implementation of LE principles.
- Many of the Indian manufacturing industries understood LE principles as waste reduction process (mean value is 4.32) and continuous improvement programme (mean value is 4.19). According to Bhasin and Burcher, (2006), LE is a fully integrated management philosophy that delivers long terms benefits to the organization. Still many of the Indian manufacturing organizations were implemented it as only a waste reduction process in manufacturing operations in shop floor. Very few of the Indian manufacturing organization professionals understood that it is fully integrated management philosophy. Hence the Indian manufacturing industries have to expose LE principles to their professionals as a way of life (mean value is 1.12) and long term management philosophy (mean value is 1.60) instead of the waste reduction process only in the manufacturing activities within the shop floor of the organization.
- The present study tried to focus on area of the implementation of LE principles in the Indian manufacturing organization. The study revealed that many of the Indian

manufacturing industries were implemented in the key area of customer (mean value is 4.49). Many of the organizations were neglected to implement LE principles in the area of product design, employees and safety and ergonomics, it was clearly reflected in average mean values are 1.96, 2.79 and 2.93 respectively. Many of the studies have proved that lean product development and design is one of the best methodologies to develop successful product within market acceptable cost. In the present global scenario, the important factor of the product development is time to market (Gupta and Wilemon, 1990; Thomke and Fujimoto, 2000). The traditional development processes have to consider one initial good idea and use it to do the development to achieve the final acceptable outcome (Ward et al., 1995). Generally the entire traditional process used to work within the boundary wall of the initial idea. Whereas, lean product development processes is different than normal traditional product development processes with respect to thinking beyond the boundaries (Stalk Jr., 1988). It broadly tries to collect all the possible set of initial ideas, gradually eliminate weaker solutions and unite several solutions to decide the ultimate solution of the product (Clark and Fujimoto, 1989). Many of the professionals used to think that gathering lots of ideas and discarding it to find out the final solutions is the waste and time consuming process. But, the information gathered from this processes is recoded and reused for future needs, which is considered as value added waste. An important finding from the present study was that organizations were given least importance to the employee area. If any organization has to implement LE principles in their organization the employees of the organization should be well equipped in terms of knowledge. Otherwise the objective of the implementation of LE principles cannot be fulfilled without help of the employees of the organization. The study also revealed that safety and ergonomics was another important factor neglected by Indian manufacturing industries. The organizations have to concentrate more on safety and ergonomics to improve the morale and reduce the fatigue of the employees. These two factors also impact on productivity of the organization (Gyekye, 2006).

- The present research revealed that employee resistance (mean value is 3.76) was the major obstacle to implement LE principles in Indian manufacturing industry. Many of the shop floor workers felt that LE principles were increasing their activities and giving a sense of job insecurity. Hence the organizations have to create complete awareness about LE principles and its impact on the organization business, productivity and workers flexibility (Haynes, 1999). Many of the Indian manufacturing industries struggled with lack of systematic approach (mean value is 3.44) to implement LE principles in their industries. The study found that many of the researchers (Doolen and Hacker, 2005; James-Moore and Gibbons, 1997), have proposed various frameworks to implement LE principles in the various organizations. But the studies failed to focus on defining the various steps of implementation procedure and also relationship between various LE elements. Hence the present study suggested to the researchers across the world to not only develop a framework comprising of various LE elements, but also incorporating various steps and procedures to implement LE principles and also there has to be explanation of clear relationship between the various LE principles. The literature survey of the study found that only one framework has shown clear steps and procedure to implement LE elements across manufacturing organizations, which was developed by Anand and Kodali (2010) in field of lean manufacturing.

- The study also analyzed what type of LE waste should be removed with the help of LE elements in Indian manufacturing industries. The study found that Indian manufacturing industries were concentrated mostly on inventory, defects and inappropriate processing, which clearly reflected in its mean values were 4.05, 3.77 and 3.24 respectively. It clearly indicated that Indian professionals were utilized LE elements as waste reduction process in operational area only. Many of the Indian manufacturing industries were not able to identify transportation waste (mean value is 2.07) due to lack of knowledge to apply LE elements. Jasti et al (2012) found 60 percentage transportation wastes in one of the Indian process industry and suggested to avoid transportation waste through their case study research methodology. The case study also concluded that transportation waste can help to improve green supply chain management. Hence the professionals have to understand the importance of all seven wastes and try to avoid all types of waste instead of concentrating on few LE wastes.
- The study analyzed the awareness of the LE elements among Indian manufacturing professionals. The study found that 29 LE elements (69 LE elements) were least understood by Indian manufacturing professionals. Most of the professionals have awareness on most popular and frequently used LE elements instead of the complete set of LE elements. Some of the most popular LE elements like jidoka (mean value is 1.96) and 5S (mean value is 1.17) have least average mean score. To get maximum benefits of the LE implementation, the professionals should have clear knowledge on the complete set of LE elements. The manufacturing industries should develop continuous training programme to create awareness as well as interest to implement LE elements in the industry.

- The study brings out the implementation stage of LE elements among Indian manufacturing industries. The similar kind of analysis was performed by Eswaramoorthi et al. (2011) to find out the most frequently implemented LE elements in the Indian machine tool industries. The preceding study revealed that a very few number of LE elements were practicing effectively across Indian machine tool industries. However Indian machine tool industries were in the beginning stage of LE principles' implementation. The present study considered different types of manufacturing industries to comment on implementation of LE elements across Indian manufacturing industries. The study found that 31 LE elements were given least preference to implement among Indian manufacturing industries. The numbers of LE elements that were implemented in Indian manufacturing industries were quite in line with the awareness of the LE elements among organization professionals. The study found similar kind of results regarding awareness of LE elements among the professionals. The study found important evidence that many of the manufacturing organizations were projecting that LE principles can be implemented only in manufacturing planning and control (mean value is 3.26) as well as process and equipment (mean value is 3.10) groups. Many of the Indian manufacturing industries were not implemented effectively LE elements in human resource management group except very few LE elements like cross functional team working and multi skill force. Hence the present study suggested that all LE elements of four groups should be implemented effectively across Indian manufacturing industries to get real fruits of LE implementation. The study also tried to show the most important LE elements to avoid various LE wastes from the Indian manufacturing industries, which may help the beginners of the LE implementation manufacturing industries.

3.5 Conclusion

The present research study has given a significant insight to find the present stage of LE principles implementation and its related issues among Indian manufacturing industries. The study prepared a survey questionnaire to identify existing level of understanding of LE principles among professionals, drive force to implement LE principles, areas of implementation of LE principles, obstacles to implement LE principles, type of LE waste avoided by implementation of LE principles, benefits received from LE principles implementation, awareness among manufacturing professional about LE principles, the implementation stage of various LE principles among Indian manufacturing industries and identification of popular LE principles to avoid popular seven LE wastes. The survey questionnaire administered to six experts each from academic and industry to conduct content validation. The result of the survey clearly shows that most of the respondent organizations were implemented some sort of LE principles in their industries. The study revealed that majority of the organizations was categorized in transition mode (< 5 years) of LE principles implementation. The Indian manufacturing industries should be aware and understand the main purpose of LE principles implementation. The major constraints to implement LE principles were employee resistance and lack of awareness about LE principles among industry professionals. The study found that many of the manufacturing industries were used LE principles to avoid few LE wastes instead of the complete list of LE wastes. Hence the present study strongly suggests that Indian manufacturing organizations should conduct frequent training programmes to their organization work force to understand how to practice LE concepts in details in their organization and encourage them continuously to achieve the vision and mission of LE principles. The study also revealed that majority of the organizations were implemented in specific area of the manufacturing operation with very few popular tools of LE instead of following any systematic approach to implementing LE principles across whole organization. This kind of approach may not useful to achieve long term organizational goals. The study suggests that the organizations should be implement LE principles across the organizational activities instead of “bits-and-pieces” to fulfill long term goals of the organization. The study suggests to the future researchers to not only propose new LE frameworks but also to propose the steps and stages to implement the LE frameworks across manufacturing industries. It also suggested that a systematic LE framework is needs to Indian manufacturing organizations, which will act as clear cut guiding torch to the organization managers to implement LE principles across organization. Hence, the study tries to find out suitable existing LE frameworks to implement in Indian manufacturing industries in future chapter of the present study.

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Chapter 4

An empirical study for validity and reliability of existing lean enterprise frameworks in Indian industry

4.1 Introduction

India's economy has situated itself positively as a centre of competitive supply, technology innovation, design, and business activities. However, when the study is considering the availability of vast natural resources, human resources, economy and manufacturing potentials in India, it can be easily seen that India is still unexploited with the resources. It indicates that the prospects for India are immense, but various constraints also exist like aspects of culture and organizational thinking, etc (Sharma and Kodali, 2008). Indian manufacturing industries are struggling to achieve better productivity rate due to various constraints. The following numbers are clear indication of how much Indian manufacturing industry is lagging compared with other Asian countries. The average growth rate in terms of productivity in manufacturing in India is 4.95% in comparison to 7.31% of China, 9.45% of Singapore and 8.65% of Pakistan (Upadhye et al 2010). Thus, the government and industries have to take responsibility to overcome the various challenges that are faced by Indian manufacturing industries.

To compete in the global marketplace, Indian firms have to implement advanced manufacturing systems and practices. It is an integrated combination of processes, people, machine systems, communication, organization structures and computers. The final objectives are to achieve economic products, competitive performance, responsiveness, flexibility in the system, quality products and services (Kakandikar et al, 2009). Some of the most extensively practiced and implemented advanced manufacturing techniques/philosophies for change are lean enterprise (LE) system, just-in-time production system, total quality management system and business process reengineering (Lee and Oakes, 1996). But looking at the other side of the coin, according to Strozniak (2001), there is less than 20 percent of Indian industries practicing advanced manufacturing systems like LE principles in their organization. It is very much a clear indication that how much Indian manufacturing industry is struggling in implementation of advanced manufacturing systems. Very few Indian companies, including Hero Group, Maruti and their ancillaries, Kalyani Group, Bajaj Automobile, and Mahindra & Mahindra are implementing the advanced manufacturing philosophies in their companies to achieve required objectives of the organizations. However, it is clear that very few manufacturing industries were successful in implementation of LE principles. The previous chapter of the study also clearly revealed that many organizations have implemented LE principles in specific area of the organization instead of overall organizational activities. Hence, many organizations not able to get full benefits of LE principles implementation. To get full benefits, the Indian manufacturing sector has to think the ways to achieve excellence in all aspects of business activities. To meet these objectives of Indian manufacturing industries, a systematic approach needs to be developed that not only fits the Indian manufacturing industries but also incorporate the best practices established by other countries.

Instead of developing a new LE framework from ground level, any research needs to check usefulness of the existing LE frameworks in Indian environment. The study conducted a nationwide survey to find out suitable frameworks to implement in Indian manufacturing industries. The study investigated the obtained results and is bringing out in the present section of the study. In particular, the section of study covered: first, finding the existing LE frameworks from literature and perform their validity analysis for Indian environment; second, carrying out reliability analysis on selected LE frameworks to check the reliability of the frameworks and the third is performing the frequency distribution analysis to identify significant elements. Sharma and Kodali (2008) conducted a similar kind of study on manufacturing excellence frameworks.

4.2 Identification of existing LE frameworks

The term framework doesn't have clear cut definition from the research world. However, it is very popular term in the LE literature. Many researchers are using model in the place of framework or vice-versa. It is all happening due to lack of clarity about what is framework or model. The present study investigated what is a framework. Few researchers tried to give proper definition of the framework and model. Yusof and Aspinwall (2000) reported that 'a model can answer to the question of "what is" with the overall perception or elements put down together, whereas a framework attempts to answer "how to" questions and presents an overall relationships and method forward'. According to Aalbregtse et al. (1991), a framework is a device that used to define the whole blue print of the management business objectives and also tries to present the methodology to reach the organization business goals. Hakes (1991) argued that the strong framework build up fundamental relationship among the theory and practice of the organizations. The mathematical model is just a model but it should not consider as a framework. These models are generally useful to take a decision based on value calculated. A framework consists of a set of fundamental tools, techniques, principles with complete discussion on the actions to be performed (Popper, 1994). Struebing and Klaus (1997) discussed that a framework projects the complete action plan and ensure each individual step build up methodology also. According to Anand and Kodali (2009), a framework can be useful to the managers of the organization as a guiding torch, which can assist and shows the required path during implementation of the new advance manufacturing philosophies in an organization. Gunjan and Kodali (2013) reviewed entire existing literature on the framework and concluded that the framework should fulfill the following conditions:

- A framework is not only a recommended bunch of elements to be considered in that system, but it should give information about the complete relationships amongst the elements of system under study.
- A framework should discuss the important steps and stages of activities and how these are vital for the required purpose.
- A framework should give information about what all activities are involved and connection of various elements of frameworks with those activities.

To achieve LE excellence in any industry, many researchers, professionals, and experts have proposed different frameworks. These frameworks can give the direction to attain LE excellence in their organizational activities and fulfill the customer requirements. The study found 31 LE frameworks by conducting literature survey in various online publication portals, which includes four publications of houses considered in literature review chapter, Sage and Google online portals. The study has considered articles, which are published between years 1990 to 2012. The complete list of framework considered in the present study is given in Appendix-C. The complete coverage of all frameworks may not be viable due to various constraints regarding resources accessibility. Hence the study is considering only widely acceptable and used frameworks to conduct analysis in Indian manufacturing industry environment. The study is projecting the present list of LE frameworks as representative of total LE framework existing in the literature. The complete list of LE frameworks consider in the present study has given in Table 4.1.

Table 4.1 The complete list of LE frameworks considered in the present study

Frameworks	Comments on framework
Cook and Graser (2001)	There is argument that LE principles are more suitable to implement in high volume production industry. The proposed framework has developed to implement LE principles in low volume production industry such as aerospace and defense industry also. The framework has mostly covered all department of manufacturing industry.
Karlsson and Åhlström (1997)	This framework is just a modification of theoretical concept of the LE, such that it is suitable for application for small and medium scale manufacturers. The focus of the framework was restricted only on supply chain management activates in the small and medium scale industry.
Sayer and Williams (2007)	It consists of twelve elements. The main objectives of the framework are to improve customer satisfaction and workforce morality also.
Czarnecki and Loyd (2009)	The framework is proposed to implement in high volume production line in automotive industry. It is developed based on specific production line due to more focus on manufacturing related elements.
Czabke (2007)	This framework is developed to implement in secondary wood product industry. It is focused on manufacturing, non-manufacturing, human resource, customer relationship and supplier relationship. The framework has proposed conceptually and validated with the help of case study approach.
CTRM Aero Composites (2008)	The framework is developed to implement LE in supply chain organizations. The framework tried to implement aero composites including vendors of that particular organization. The framework proposed various stages to achieve excellence in LE principles implementation.
Lean Breakthru Consulting Group (2007)	The framework developed to fulfill the requirement of its customers. The consulting organization has given importance to three key areas of the organization, which are production, product development and supply chain activities. However, the organizational workforce generally plays vital role in the implementation of LE principles in any organizations.

Frameworks	Comments on framework
J.E. Boyer Company, Inc. (2005)	The framework is developed to achieve excellence in electrical manufacturing organization environment. The proposed elements classified into three broad categories, which are lean operations, lean supply chain and lean design. The limitation of framework is absences many key areas of organization such as human resources etc.
Beason (2008)	The framework has consisted of four elements, which are leadership and culture, workforce development, operational excellence, business results. The framework was described how to implement the complete elements in the organization. These elements are implemented in three stages, which are stabilization, supply chain integration and sustainability.
Conner (2001)	According to framework author, the LE principles can be implemented in small workshop. The framework developed to implement in small and medium scale industry. The framework consisted lean manufacturing techniques, total quality management, total organizational buy-in, and sales, production, inventory planning are four wheel of the LE. The vision of organization was driving force of LE.
Unlimited Possibilities Consulting LLC (2007)	The framework is developed by global consulting organization to provide solutions to their clients. The consulting organization believed that the successful deployment of the LE requires a comprehensive approach, giving equal attention to traditional lean tools and techniques (lean manufacturing) as well as business infrastructure and social lean (changes in philosophy, culture and decision making).
Fraunhofer IPA Slovakia (2011)	The framework is developed by one of leading consulting organization in Europe. The framework has categorized complete set of elements into four parts, which are lean manufacturing, lean logistics, lean product development and lean administration. It has covered all parts of organizational activities.
The MIT Lean Aerospace Initiative(2011)	The theoretical framework is developed by the MIT Lean Aerospace Initiative. The framework has used many organizations to benchmark their organizational activities.
Crawford (2008)	It is a conceptual based framework. The framework was developed based on Womack and Jones (1994) LE concept. The framework emphasizes importance of information flow, capital flows and value stream to the customer in the organization.

Frameworks	Comments on framework
Scrimshire (2009)	The framework is developed to fulfill the requirement of civil construction organization. The focus of the framework restricted only on people, processes and materials. The complete list of elements have classified under aforementioned three categories.
Columbus (2009)	The framework is proposed by consultant to the manufacturing organization. The complete set practices are classified into three categories, which are lean production processes, system change initiatives, and enterprise level practices. The framework did not address issues from lean product development.
Unisa Strategic Partnerships (2003)	It is training organization. It is conducting workshops to develop LE framework as per their client requirements. However, The organization was built standardize framework for LE. The framework is completely concentrated on manufacturing operations only. The organization given least importance to product development and employee relation activities.
Industrial Solutions, Inc (2008)	The framework is proposed six key elements to fulfill the implementation of LE principles in any organization. However, the framework only deals manufacturing, quality and human resources related issues only. It is not given any importance to resolve issues from supply chain and product development issues.
Lucansky et al.(2003)	The framework is developed to implement all kind of industries including pharmaceuticals, biotech's and medical devices. However, the framework has more focus on manufacturing and supply chain activities. The framework authors working as consultant for biomedical medical industry. It may be factor to concentrate less on product development.
Wyrick Enterprises (2005)	The framework has developed to provide manufacturing solutions to any organization based on complaints received from their customer. The framework suggested set of tools techniques to react customer complaints within the short span of time. The main objective of the framework is to improve customer satisfaction levels. It neglected the importance of product development in the LE framework.

Frameworks	Comments on framework
Karen Martin and Associates (2005)	Karen Martin and Associates helps organizations-from start-ups to Fortune 500 companies, Government agencies and non-profits-deliver higher quality goods and services faster and at lower cost, while creating safe and stimulating work environments. They were providing solution for implementation of lean principles in their operations. The organization has developed a framework to make standardize the operations, which they were performed.
Zayko (2006)	The author is performed a systematic review of lean principles and its reflections on manufacturing industries. Based on the review, the author has proposed a conceptual LE framework. The author also described the complete implementation of proposed framework with the help of various hypothetical conditions.
Archfield Consulting Group(2004)	The framework developed by Archfield consulting group. It is used to perform training to their customers. The framework proposed eight elements, which are concentrating more on manufacturing operations instead of whole organization.
Productivity Asia Inc (2004)	It developed LE strategy to fulfill the organizational requirements. The complete set of elements are proposed based on lean manufacturing, lean logistics, total productive maintenance, six sigma, lean administration and people empowerment.
Bohan and Accorti (2008)	The framework has developed by lean consultants to implement in high volume metal stamping company. The framework has helped to develop the effective matrices to find solutions to a particular organization. The limitation of the framework is concentrated only solve the problems in manufacturing operations.
Moffitt Associates Consultants (2006)	The framework proposed by Moffitt associates consultants. The framework developed with six important key elements. The six elements plays important role to improve manufacturing activities. The framework is not given importance to improve product development processes and human resources.
Lean Enterprise LLC (2008)	The framework has proposed by consulting organization to train their customer. The complete set of elements has classified into three groups, which are foundation, strategy and lean tools. The framework has presented the complete steps, methods and guidelines to be followed to implement lean principles in a particular stage.

Frameworks	Comments on framework
Broadsight Analysis Lean Enterprise (2007)	The framework developed by Broadsight consulting organization to provide solutions to their service and infrastructure industry customers. The framework has develop to fulfill three main objectives, which are improve material and information flow, elimination seven wastes and improve organization design.
Canford Consultants (2008)	The framework is developed by Canford consultant group to provide training to their customer in the field of LE. It is simple framework developed with the help of Toyota production system. The main objectives of the framework are to improve the customer orientation of organization, perform only value added activities and ensure smooth flow of operations.
Just- in-Time Enterprise Institute (2009)	It is a consulting organization, which provides complete solutions to transfer from non lean organization to lean organization. The framework has covered all important areas of the organization to implement LE.
Howardell (2008)	The author tried to propose the skill set required for employees of the organization to attain LE in any organization. In the same study, the author has proposed framework with eleven key elements to achieve LE excellence in any organization.

4.3 Research methodology for conducting the empirical investigation

The different stages of the systematic approach for the research methodology has described in subsequent part of the present section of study.

4.3.1 Theory verification

The first step is to analyze the existing LE frameworks for validity and reliability in Indian industries.

4.3.2 Selecting a research design

To accomplish the validity and reliability analysis of the existing frameworks of LE in the Indian scenario, a cross-sectional survey was used.

4.3.3 Implementation

A cross-sectional study by using survey research design was conducted on chosen multi-sectional industries of manufacturing sector. A survey questionnaire was prepared to collect data for the present study. In order to achieve the objectives of the present research, the study focused on different multi-sectional industries in manufacturing industrial sectors, i.e. the automobile industry, process industry, machinery equipment, electrical and electronics and the textiles industry (Sharma and Kodali, 2008). The Confederation of Indian Industry's (CII) database directory for the year 2011 was referred to collect the addresses of manufacturing industries. The employees involved in the survey were from various levels like Managing Directors/CEO's, production managers, maintenance managers, logistics managers, human resource managers, product managers and quality managers.

A structured questionnaire was developed using the five-point Likert scale. The scale ranged from 1 to 5, where (1) means not important, (2) means less important, (3) means important, (4) means more important, and (5) means most important. The complete details of questionnaire are given in Appendix-D. The study requested the respondents to consider each framework as independent entity and as part of a path towards achieving LE excellence. The questionnaire consisted of two parts: section A and B. "A" is the background information of the organization and the respondent information and "B" is a structured questionnaire of all considered framework in the present study. The objective of study and instructions to fill the survey were discussed in the covering letter, in which, also enclosed general information regarding the present study and email communication address of the present study authors . In early stage of questionnaire development process, the study consulted the experts from industries and academics. The comments and feedback of the experts were considered and a few minor enhancements were made especially in questionnaire format. Most of the experts gave the feedback on questionnaire format and finally declared that it was suitable for data collection. To make sure, the study performed a pilot study to reinforce the experts' feedback. The study expected that the respondents have basic idea about the lean principles and practices. The language used in the each LE framework is simple for easy understanding to the respondents. However, the authors gave their contact details in covering letter to the participants, in case of any ambiguity on the questionnaire elements.

A final version of the questionnaire was sent to a sample of 753 manufacturers, which were selected from a population of Indian manufacturing industries. Four weeks later, the authors sent 182 postal reminders and 423 emails to non-responding organizations and also communicated personally over telephone. The authors received 186 replies from various industries of Indian manufacturing sector, which puts the response rate at 24.70 percent. However, the authors did not consider six incomplete questionnaire responses to final analysis, whereas the remaining 180 manufacturer responses were considered, which make the response rate at 23.90 percent. According to Sharma and Kodali (2008), a response rate of 18 % is considered to be adequate in Indian manufacturing industrial conditions. The study has understood that there were no guidelines available to decide right sample size to perform the factor analysis. In this aspect, the study performed literature review and revealed that different sample sizes such as at least 150-300 cases (Hutcheson and Sofroniou, 1999) or around 200 is reasonable (Comery and Lee, 1992). Costello and Osborne (2005) reported that a large sample size helps to get more appropriate results. The statistics of the individual sector responses are shown in Table 4.2.

Table 4.2 The statistics of the individual sector responses

Industry	No. of responses received by post	No. of responses received by email	Total No. of responses received	Sample size	Respons e rate
Automobile	25	30	55	202	27.23
Machinery equipment	17	25	42	152	27.63
Electrical and electronics	12	20	32	190	16.84
Process	13	18	31	150	20.67
Textile	5	15	20	59	33.90
Total	72	108	180	753	23.90

4.3.3.1 Reliability analysis

Reliability analysis is used to find out whether the survey instrument is producing the repetitive results at any time it is administered to the same respondent under same settings regardless of who administers them (Flynn et al, 1990). Walsh and Betz (2001) discussed four types of reliabilities: test-retest reliability, alternate forms reliability, split-half reliability, and internal consistency reliability. Many researchers have preferred to use internal consistency method due to its various advantages like consistent method and only require a single application to get required results (Sureshchandar et al 2001). Cranbach's alpha coefficient is the most commonly used to measure internal consistency of any framework (Cronk, 2004). It can be calculated using standard commercial package SPSS 18v, which is a user-friendly software package (Flynn et al, 1990).

4.3.3.2 Validity

Validity is defined as the extent to which any measuring instrument measures what it is intended to measure (Carmines and Zeller 1979, Ngai et al., 2004). Initially few researchers proposed four types of validity analysis. Over a period of time, many researchers like Creswell, (2002), and Muijs (2004) amalgamated both concurrent validity and predictive validity. Finally the researchers proposed three different types of validity analysis. Those are: (1) content validity, (2) criterion related validity and (3) construct validity. Reliability is a necessary condition for validity, but reliability is not sufficient to determine validity alone (Pierce, 2007). In the present study, validity analysis can be carried out by using three measures:

1. Content validity is determined by qualitative approach and a judgment made by panel of experts. The main objective of content validity is used to check whether all aspects of the attributes are considered in the survey instrument (Ngai et al., 2004). It can be determined by expert opinions and cannot be determined by statistical methodologies (Nunnally, 1978).
2. Criterion validity is used to determine how well outcomes obtained from one-data-gathering-instrument and supported by other surveys or questionnaires. It can be determined by comparing the results of the various data gathering instruments. It gives information about the extent of observations of two different surveys differentiating from each other. The criterion-related validity is validated by simple correlation, for testing a scale of constructs for a single outcome.
3. Construct validity provides the researcher with confidence that a survey actually measures what it is anticipated to measure. It can be measured through empirical survey and cannot be directly evaluated. Principle component analysis is most reliable method to perform construct validity. Principle component analysis is conducted to check whether all elements are loading on a single factor i.e., unidimensionality of the scales towards a single construct. In the present study, the principle component analysis has been used to check unidimensionality of each framework (Sharma and Kodali, 2008).

4.4 Results and discussions of empirical study

The validity analysis was performed on each LE framework to find eligible LE frameworks that used for further investigation. The content validity of the questionnaire items was performed by two stages: initial stage, the questionnaire was administered to six practitioners in industry and six academicians from Birla Institute of Technology and Science, Pilani. The feedback given by them was incorporated in the questionnaire. Final stage, the questionnaires were also sent to academicians in other prestigious institutions and also pilot study was conducted in one of the reputed automotive industry. The sample size of the pilot study is 30 samples in middle and top level management, who have complete knowledge about LE principles. The comments and feedback of the experts were taken into consideration and a few minor enhancements were made especially in questionnaire draft format. Finally, the questionnaires were sent to the various Indian manufacturing organizations.

Criterion-related validity has been used to check whether the frameworks' measure positively related to the level of LE excellence in an organization. The present study did not evaluate criterion-related validity of the frameworks due to implementation level of LE was not incorporated. The study assumed that the respondents carried out a validity analysis on their respective frameworks in their manufacturing environment. The similar kind of approach was followed by Sharma and Kodali (2008) in their research on manufacturing excellence frameworks.

Finally, the construct validity of each framework was conducted. The objective of the construct validity is to check whether it measures the concept or the theoretical construct it was anticipated or designed to measure. The validity analysis can be performed on any scale, but the scale should satisfy two conditions: One is unidimenasionality of the scale (Gerbing and Anderson, 1988). Unidimensionality is used to check whether all elements are concentrated towards the main target of the measurement (Gerbing and Anderson, 1988; Pierce et al., 1989). Secondly, the scale should fulfill the reliability conditions as well (Ahire et al, 1996). Hence, on total considered frameworks, the unidimensionality checks as well as the reliability analysis were conducted. The principle component analysis was used to conduct construct validity on all 31 LE frameworks. The factors extracted from each framework are listed in Table 4.3. The analysis shows that only eleven frameworks displayed unidimensionality with respect to LE. Table 4.4 shows an example of a component matrix for the framework of Archfield consulting group, which is result of the principal component analysis for the factor extraction.

Table 4.3 Factors extracted from each framework

Name of the framework	Number of factors extracted
Cook and Graser	1
CTRM Aero Composites	3
Lean Breakthru Consulting Group	1
J.E. Boyer Company, Inc.	2
Beason	1
Conner	1
Karlsson and Åhlström	1
Unlimited Possibilities Consulting LLC	1
Fraunhofer IPA Slovakia	3
The MIT Lean Aerospace Initiative	4
Crawford	2
Sayer and Williams	2
Czarnecki and Loyd	3
Scrimshire	2
Columbus	3
Unisa Strategic Partnerships	5

Name of the framework	Number of factors extracted
Industrial Solutions, Inc	1
Lucansky et al	2
Wyrick Enterprises	4
Karen Martin & Associates	3
Zayko	1
Archfield Consulting Group	1
Productivity Inc	3
Bohan and Accorti	1
Moffitt Associates Consultants	7
Czabke	3
Lean Enterprise LLC.	3
Broadsight Analysis Lean Enterprise	2
Canford Consultants	2
Just- in-Time Enterprise Institute	1
Howardell	2

Table 4.4 A component matrix for the framework of Archfield consulting group

Elements	Component
5S	.724
Visual management	.763
Pull production	.609
Waste elimination	.741
Standard work	.807
Zero defects	.861
Work force empowerment	.796
Continuous improvements (Kaizen)	.800

Extraction method: Principal component analysis

The frameworks displaying unidimensionality are:

1. Cook and Graser
2. Lean Breakthru Consulting Group
3. Beason
4. Conner
5. Karlsson and Åhlström
6. Unlimited Possibilities Consulting LLC
7. Industrial Solutions Inc
8. Zayko
9. Archfield Consulting Group
10. Bohan and Accorti
11. Just- in-Time Enterprise Institute

Internal consistency or reliability of the frameworks can be checked by inter-item analysis. One of the most commonly used indicator of internal consistency is Cronbach's alpha coefficient. Preferably, the framework Cronbach alpha coefficient of a scale should be above 0.7, which is considered to be good (Pallant, 2005; Soriano-Meier and Forrester, 2002). Cronbach alpha coefficients of selected eleven frameworks were more than 0.7 and a mean of more than 3.5. Table 4.5 shows the mean and reliability analysis results for the selected frameworks.

Table 4.5 Mean and reliability analysis results for the selected frameworks

Framework name	Cook and Graser	Lean Breakthru Consulting Group	Beason	Comer	Karlsson and Åhlström	Unlimited Possibilities Consulting LLC	Industrial Solutions, Inc	Zayko	Archfield Consulting Group	Bohan and Accorti	Just- in-Time Enterprise Institute
Overall mean	4.2	3.65	4.10	4.03	3.96	4.11	3.73	3.77	3.89	3.84	3.70
Cronbach's alpha	0.78	0.789	0.87	0.86	0.72	0.794	0.85	0.90	0.895	0.86	0.877

Table 4.6 shows the reliability analysis for the framework of Archfield consulting group. From these selected frameworks, most important elements were recognized by applying frequency distribution analysis. The criteria for chosen elements were generally having a mode (most frequently occurring value) of four or more and mean of more than 3.5. The sample frequency distribution analysis statistics performed on the framework of Archfield consulting group is shown in Table 4.7. Most of the constructs in each framework were recognized. Finally, a total of 44 elements were recognized from the eleven frameworks. The study observed that many LE frameworks concentrated more towards manufacturing activities instead of complete organizational activities. Hence, the study is also tried to find out critical elements all the field of LE research.

Table 4.6 Reliability analysis for the framework of Archfield consulting group

4.6.1 Summary item statistics

Number of cases : 180	Mean	Minimum	Maximum	Range	Maximum/ minimum	Variance	N of items
Item means	3.89	3.65	4.083	0.433	1.119	0.023	8
Inter-item correlations	0.522	0.338	0.714	0.376	2.109	0.012	8

4.6.2 Item-total statistics

Elements	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
5S	27.2333	21.13	0.635	0.499	0.886
Visual management	27.3333	20.939	0.697	0.598	0.88
Pull production	27.4667	22.172	0.517	0.351	0.897
Waste elimination	27.1	21.208	0.652	0.57	0.884
Standard work	27.2667	20.945	0.721	0.641	0.877
Zero defects	27.0333	21.016	0.793	0.684	0.872
Work force empowerment	27.3167	20.631	0.707	0.645	0.878
Continuous improvements (Kaizen)	27.0667	21.817	0.715	0.625	0.879

4.6.3 Reliability statistics

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
0.895	0.897	8

Table 4.7 The sample frequency distribution analysis performed on the framework of Archfield consulting group

		5S	Visual management	Pull production	Waste elimination	Standard work	Zero defects	Workforce empowerment	Continuous improvement
N	Valid	180	180	180	180	180	180	180	180
	Missing	0	0	0	0	0	0	0	0
Mean		3.8833	3.7833	3.65	4.0167	3.85	4.083	3.8	4.05
Median		4	4	3.5	4	4	4	4	4
Mode		4	4	3	4	3	4	3	4

Hence, similar kind of study were performed on lean manufacturing (35 frameworks) , lean supply chain management (30 frameworks), lean product development frameworks (35 frameworks) to identify critical elements in the field of LE. The complete details of lean manufacturing, lean supply chain management and lean product development frameworks are given in Appendix- C. The study performed reliability and validity analysis on these frameworks, which clearly revealed that 11 lean manufacturing frameworks, 9 lean supply chain management frameworks and 8 lean product development frameworks were shown high reliability and unidimensionality. The study also found 44, 46, and 42 elements from lean manufacturing, lean supply chain management and lean product development respectively. Out of 176 elements (LE elements (44), LM elements (44) LSCM elements (46) LPD elements (42), the study was filtered out 106 elements after avoiding the duplication. The complete set of LE frameworks results are presented in Appendix-E.

4.5 Conclusion

The objective of the present article is to conduct validity and reliability analysis on existing LE frameworks applied to Indian manufacturing industry through questionnaire survey. The study reported that most of the frameworks exhibited high level of reliability and a few frameworks displayed unidimensionality w.r.t the construct, i.e. the LE it measures. Most of the constructs exhibited a high mean and mode score, which was examined through the frequency distribution analysis. Finally, the frameworks displayed different constructs with a certain amount of overlap between them. When the study investigated those selected eleven frameworks, many important constructs were not found like knowledge management, customer relationship management and total productive maintenance. Very few frameworks reported importance of top management commitment in their frameworks. Bohan and Accorti framework didn't consider important elements like total quality management and continuous improvement. Hence, it clearly shows that none of the existing frameworks can be used in its present form due to various limitations. Interestingly, even single framework was not reported from Indian manufacturing industry. It shows that there is a need of development of new framework, which can be more useful to fulfill the present vacuum and for Indian manufacturing industry. In the present scenario, LE is an important alternative for Indian manufacturing sector to battle with the global companies. Hence, the Indian manufacturing industries needs a LE framework to compete with global players, which needs to be developed considering all the present aspects of Indian manufacturing industries. However, a complete development of a LE framework is beyond the scope of the present section of the study. It is carried out as a part of fifth chapter of the study.

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Chapter 5

A critical review of lean enterprise frameworks: Proposed framework

5.1 Introduction

Many researchers and consultants were published articles with adoption of LE principles across the whole organization activities from product development to delivery. Many researchers and consultants were also proposed various frameworks to implement LE principles across the whole organizations. The frameworks were built on various LE elements that can also be termed as building blocks of LE framework. According to Anand and Kodali (2009), many of the organizations struggled to get full benefits by implementing LE principles in the organization. The reasons were improper understanding by managers and lack of knowledge of the employees in the organization. Secondly, the previous chapter of the study also proved that none of the existing LE frameworks were useful in the present existing form to implement in Indian manufacturing industries. The root causes for the aforementioned problems are lack of comprehensive list of LE principles, practices and techniques (which will be called elements from now on) and lack of a comprehensive structural framework with a set of elements as a coherent whole. As understood so far it can be seen that LE is an imperative for competing in the global market and the Indian industries have been found wanting in their efforts to survive the changed scenario. There is a requirement for an appropriate framework for providing direction and guidance to an organization in achieving the LE excellence in the present Indian market scenario. A framework shall suit the Indian milieu as well as provide strategic directions for the Indian Industry. Hence, the present study is attempting to critically review the LE literature to find out the inconsistencies in a sample of existing LE frameworks available in various sources and suggest the future directions to improve LE frameworks. The study also tried to fulfil gap with the help of developing a new framework for LE.

While reviewing any framework, it should analyze whether the proposed framework is a novel framework or adoption of existing frameworks. Womack and Jones (1994) have proposed LE from LM concept in the year 1994. Many researchers (Dahlgaard and Dahlgaard-Park, 2006; Engstro¨m et al., 1996; Lewis, 2000) were raised questions of whether LE concept is defined or not. Other researchers have made attempts to define LE in the literature (Papadopoulou and Ozbayrak, 2004; Shah and Ward, 2007; Holweg, 2007; Hallgren and Olhager, 2009; Pettersen, 2009).These evidences clearly suggested that LE research field is a relatively new concept in the operations research field. In any emerging field, researchers are encouraging to propose novel frameworks instead of adoption of any existing frameworks (Soni and Kodali, 2013). To verify aforementioned statement, the present study tries to find out inclination of LE researchers towards developing a novel framework or adopting existing frameworks. To do the same, the present study tries to answer the following research question (RQ1):

(RQ1): What is the position of framework development in LE research field?

Academicians, practitioners and consultants plays major role to develop any emerging philosophies and to make it useful to the organizations' regular practices. Generally academicians are participating in theory building, whereas, practitioners and consultants adopt these theories and practice in real environment. It is very important to find out the contribution of academicians, practitioners and consultants in developing the various LE frameworks in the literature. If any field matures as a discipline, its theory building should be supported by practice (Tranfield and Starkey, 1998; Croom et al., 2000; Storey et al., 2006). Hence the above discussion gives rise to another research question (RQ2)

(RQ2): What is the proportion of academicians/ practitioners/consultants based frameworks in existing LE frameworks?

Once the study identified the contribution of academicians, practitioners and consultants based frameworks in the field of LE frameworks, another important factor is the applicability of the LE framework in real work environment. Flynn et al (1990) revealed that theory verification is equally important or sometimes more important than theory building. Otherwise the real usage of theory building concepts will not fulfil the requirement actually it is intended for. The study revealed that the number of publications in terms of theory verification and theory building articles were equal in the field of LE in chapter 2 i.e., literature review. The same study also revealed that very few LE frameworks were verified through various verification methodologies. Hence the present study focuses to answer the following set of research questions:

(RQ3): How often are LE frameworks verified?

(RQ4): What kind of mode is used to verify the framework?

The success of any LE framework depends on what LE elements are considered in that framework and how coherent these LE elements are as a framework (Anand and Kodali, 2009). Hence the present section of research study tries to answer the following set of research questions:

(RQ5) What are the elements considered in proposing LE framework?

(RQ6) What is the degree of standardization of proposed elements in various LE frameworks?

The present research study anticipates answering six research questions raised in the present section. The present study also tries to analyze inconsistencies in the existing LE frameworks and critically review all existing LE frameworks in various aspects. The complete analysis is useful to develop a new LE framework to overcome all limitations of existing frameworks in the field of LE.

5.2 Methodology for the review of LE frameworks

This step is used to respond research questions raised in section 5.1 of the present study. To answer above research questions, the study has classified framework into two broad categories. These two broad categories are: Generic criteria and LE specific criteria.

5.2.1 Generic criteria

Novelty of framework: In this criterion, the framework verifies the nature of building procedure. The framework is developed based on an existing LE framework or if it is not so, then the framework is called as a novel framework. It provides the information to the researchers about the trend of theory building in aspects of LE frameworks. Generally novel frameworks have lack of research efforts to develop a new framework. In the initial stage of any theory building process, the number of novel frameworks is on higher side. On the other hand, adopted frameworks in relation to novel frameworks if higher in number, then the frameworks have restricted boundary of paradigm. Once the theory building comes to the mature stage, the researchers start to develop new theory based on existing theory available in literature. The present classification is useful to answer the RQ1.

Source of framework: According to Yusof and Aspinwall (2000), the frameworks can be classified into three categories. These categories are: academicians based, practitioners based and consultant based frameworks. An academician based framework is developed with the help of academic research carried out at academic institutions. If the framework is developed from the successful industry implementation or from a case study, it is called as practitioners based framework. If the framework is proposed by experienced consultants that kind of frameworks are called as consultants based framework. This kind of analysis is helpful to find out real gap between theory and practice in LE frameworks. The study used the present classification to answer RQ2.

Framework verification: The present section of the study finds out solution to RQ3. According to Flynn et al (1990), theory verification plays vital role to build useful theory in any field of work. Hence the study made attempts to find out whether the proposed framework was verified by applying any verification methodology or the researchers were simply proposed it. Generally verification of any framework will give its importance and applicability in a given condition. If any framework is developed conceptually or based on desk research, it is left alone without checking its applicability in any real scenario. Under these conditions, the gap is increased between academic theory building and practitioners' real life scenarios. If any framework verified by applying various methodologies, then the practitioners have shown interest to implement such kind of frameworks in their real life scenario. In some cases, these kinds of verification processes are helpful to improve or strengthen the proposed framework to greater extent. After strengthening these frameworks, it may get wider acceptance from industry practitioners and consultants. Hence, the present study tries to find out how many LE frameworks are verified.

Mode of verification: The present part of the study is helpful to give clarity on RQ4. The framework can be verified through various methodologies: case study, survey, focus group, panel study, Delphi methods and combination of any of these modes. Case studies' verify approach is a qualitative data approach obtained from interviews or secondary data sources. Surveys' verify approach uses quantitative data obtained from industry employee responses. Focus group and Delphi studies use responses from the experts and specialists in the given domain of the framework. The present study tries to find out the most popular verification methodologies used by various researchers, which help to find out the appropriate research verification methodology to the future researchers.

5.2.2 LE specific criteria

Elements of the framework: Generally any framework consists of a group of elements and defines the relationship between the elements. Only a few of the elements were suggested by several researchers often in various frameworks due to its importance. The author is interested to find out the frequently used elements in various frameworks proposed by several researchers and also to find out the degree of standardization of the elements in the field of LE. The classification is helping to find out answers to the RQ5 and RQ6.

After conducting classification of the frameworks, the complete analysis is performed on classified data in light of research questions posted in the introduction section of the present chapter. The result of the present analysis will help to find out the inconsistencies in the existing LE frameworks and also provides the future directions to build new frameworks in the field of LE. The present analysis also provides the information to develop adapted framework in the field of LE.

5.3 Classification and analysis of LE frameworks

As identified in previous chapter of the study, thirty one frameworks were categorized according to generic and LE specific criteria. The complete discussion regarding the same are presented in subsequent part of the present section.

5.3.1 Novelty of the framework

Novelty or originality form of research plays a vital role to develop theoretical content of the specific field. However updating the existing theory as per present day's requirements also equally plays a vital role in the theory building procedures. In order to verify the earlier mentioned scenarios, the frequency distribution of LE frameworks between novel and adapted framework is given in Table 5.1. Table 5.1 clearly shows that 96.77% of the frameworks were falling in the category of novel or original frameworks. The present study outcome clearly reveals good sings for the growth of LE in terms of novelty. Only 3.23% of the frameworks were published with adaption of various elements from the literature. At the same time, theory building on existing theories or verifying the existing theories or finding the shortcomings of existing theories should give equal importance. Otherwise, theory building will take place in a monopoly manner that results in development of directionless theory building in any field of LE literature.

Table 5.1 The frequency distribution of LE frameworks between novel and adapted

Novel/Adapted	**Frequency**	**Percentage**	**Framework articles** (Appendix-C)
Novel frameworks	30	96.77	1,2,3,4,5,6,7,8,9,10,12,13,14, 15,16, 17,18,19,20,21,22,23,24,25,26,27, 28,29,30,31
Adapted frameworks	1	3.23	11

5.3.2 Source of framework

Table 5.2 gives the frequency of LE frameworks published as academician, practitioners and consultants based frameworks. Table 5.2 clearly indicated that the number of frameworks developed by academicians was very less (16.67%) as compared with practitioners and consultants. The key point is that the importance of academician based frameworks is equally important as that of consultant and practitioner based frameworks. Another important observation was that practitioner and consultant based frameworks were restricted to the specific field of work area. Generally, the generic comprehensive frameworks are mostly developed by academicians. Hence the study suggests that there is a need to contribute by academicians to develop strong theory building framework in the field of LE.

Table 5.2 The frequency of frameworks published as academician, practitioners and consultant based framework

Source	**Frequency**	**Percentage**	**Framework articles** (Appendix-C)
Academician based	5	16.13	9,11,12,19,25
Consultants based	21	67.74	1,2,3,5,6,7,8,13,14,15,17,18, 20,21,22,23,24,26,28,29,30
Practitioners based	5	16.13	4,10,16,27,31,

5.3.3 Framework verification

If any researcher proposes a framework with applying expert's knowledge or other development procedure, the researcher should verify the framework applicability in real life scenario. The present study found that only around 38.7% of the frameworks were verified by applying case study verification methodology. Table 5.3 shows the frequency of frameworks that were verified in the selected literature. Table 5.3 clearly shows that around 61.3% of the frameworks were not verified in the real life scenario. The present study found that a few researchers were clearly mentioned the type of organizations, they were implemented the developed framework. Many consultants and practitioners did not present their framework implementation or verification methodology in their research. Zayko (2006) has proposed a conceptual LE framework but that study did not give clear indication of whether the proposed LE framework was verified or not. Hence the present study considered these frameworks in the category of “not verified”.

Table 5.3 The frequency of frameworks that were verified in the selected literature

Verified	**Frequency**	**Percentage**	**Framework articles** (Appendix-C)
Yes	12	38.70	3,7,8,11, 12, 16, 18,19,22,21,26,27
No	19	61.30	1,2,4,5,6,9,10,13,14,15, 17,20,23,24,25,28,29,30,31

5.3.4 Mode of Verification

There are many verification methodologies to verify any proposed framework. Hence the present study further investigated to find out what type of verification methodology used by the researchers to verify the proposed frameworks. Table 5.4 gives the frequency of modes of verification for applicability of frameworks. According to Soni and Kodali (2013), case study is most preferred methodology to verify any proposed framework. Similar results was obtained in the present study. Table 5.4 clearly shows all proposed LE frameworks verified by applying case study verification methodology. None of the researchers used any other verification methodologies to verify proposed framework.

Table 5.4 The frequency of modes of verification for applicability of frameworks

Mode of Verification	Frequency	Percentage	Framework articles (Appendix-C)
Case study	12	38.70	3,7,8,11,12, 16,18,19,21,22,26,27
Survey	0	0	
Focus study	0	0	
Delphi	0	0	
Multiple	0	0	
Not mentioned	19	61.30	1,2,6,5,4,9,10,13,14,15,17, 20,24,25,23,28,29,30,31
Total	31	100	

5.3.5 Elements of framework

In the present study, the selected sample of the frameworks deals with a wide variety of concerns. Hence it cannot be compared on the same scale, but it is important to find out:

- What type of elements is used by various researchers to develop the sample LE frameworks?
- What are the standard elements that are used to formulate the selected LE framework?

Similar kind of approach was followed by Mishra et al (2006) and Soni and Kodali (2013) to identify the best practices and to develop world class maintenance and supply chain management frameworks respectively. The present study also followed similar approach to identify best practices in the field of LE to develop a new framework. The frequency occurrence of LE elements in the sample of the frameworks has given Appendix- F. Appendix - F revealed that around, 121 unique elements are identified from a sample of LE frameworks. Some elements were utilized by various researchers with different phrases or words, but the meaning of those elements was the same. These kinds of elements were clubbed to find out the exact number of unique elements in the sample of LE frameworks. For instance, value stream mapping/ optimize value stream or value stream to the customer/ waste identification through value stream/process and value stream mapping/ process maps on display for comments/value stream alignment/value stream flow/ perform value-added activities through value stream mapping. All these elements represent value stream mapping. The present study identified 121 unique elements; however, they are not independent of each other. Majority of the elements can fall in a particular domain. If a suitable principle component analysis is performed, all these elements fall under a few independent elements. These few independent elements are very broad in nature. For example, supplier relationship, continuous improvements, customer relationship, elimination of waste etc. All these elements are representing very specific area or a set of a larger domain. Generic frameworks have broader view than the issue specific frameworks. The purpose of the present study is not to compare LE frameworks based on its strengths and weakness. The main purpose of this section is to find out availability of standard elements in the existing literature. The frequency analysis of the present study revealed that only 33 (27.27% of total LE elements) of elements were repeated more than two times and only 18 (14.87% of total LE elements) of elements were repeated more than five times. The statistical analysis clearly shows a lot of inconsistencies with respect to study of LE principles by various researchers.

There were many reasons to see incoherence in terms of LE elements in the existing LE frameworks; the main reason is the perspective of the researchers. Karlsson and Åhlström (1997) have proposed LE framework only to manage supply chain activities since the framework was proposed for implementation only in small and medium scale industries. Whereas, many researchers (Sayer and Williams, 2007; Scrimshir, 2009; Bohan and Accorti, 2008) have considered implementing LE frameworks only in various manufacturing activities.

On the other hand, some researchers (Conner, 2001) have proposed LE frameworks to implement in both manufacturing and supply chain activities. Very few researchers like Cook and Graser (2001) have proposed LE frameworks for implementation in all the activities across the whole industry. The different kinds of views about LE by the researchers, finally makes the LE attributes incoherent and display large variety of the LE elements.

The present study tries to find out a set of standard elements that make LE, the study separated the elements that are repeated more than once. Around 42 LE elements were repeated twice or more in a sample of existing LE frameworks. Another objective of the comparative analysis in the study is to identify the pillar or main elements of LE framework. It was found that some elements have relatively high frequency than other elements. Hence the study identified elements that were repeated with frequency of 0.2 or more i.e., 20% or more frameworks were considered important to achieve LE excellence in any organizations. These repetitive elements were considered as pivotal points to develop a new LE framework. The study found that around 18 elements were repeated with frequency of 0.2 or more. But these elements are also falling in some of the broad areas of LE. Now to find these board areas with the help of these eighteen elements, the study formed a twelve member team with six academicians and three each from consultants and practitioners groups. The team identified eleven broad areas of LE after thorough discussion among all team members. Similar kind of approach was followed by Mishra et al. (2006); Sharma and Kodali, (2008a), Sharma and Kodali (2008b) and Soni and Kodali (2013) to develop a framework in the field of world class maintenance, total quality management, manufacturing excellence and supply chain management respectively. According to Karlsson and Åhlström (1996), LE is combination of LM, lean supply chain management (LSCM) and lean product development (LPD). Hence, similar kind of analysis performed on LM, LSCM and LPD frameworks. With that the study also identified two more key pillars, which were playing important `to achieve LE excellence. These two pillars have identified during comparative analysis on LPD frameworks, which were concurrent engineering and knowledge management. These two pillars plays vital role to achieve excellence in LE. In total, it has revealed that thirteen pillars identified to develop LE framework that are covering all pillars identified in LM, LSCM and LPD frameworks. The study also identified 48, 39 and 38 standard elements from LM, LSCM and LPD frameworks, which were repeated more than two frameworks.

The previous chapter study has identified 106 elements after avoiding duplication in all four areas of the frameworks with the help of empirical study. Around 98.11% of these elements have matched with the standard elements identified with help of comparative analysis from LE, LM, LSCM and LPD elements. Hence, the authors were requested twelve team members to find out suitability of these elements (106 elements) to incorporate in LE framework. The team suggested 106 elements suitable to incorporate in LE framework due to its importance to achieve excellence in LE. The study used the efforts of twelve team members to fit the particular element in a particular broad area or pillar. At last, the study has proposed framework with clear identification of all elements' broad areas or pillars of LE. The pillars of LE and respective elements are given in Table 5.5.

Table 5.5 The pillars of LE and respective elements

S.No.	Pillar	Element
1	**Continuous improvement**	
CI1		Cross functional teams
CI2		Value stream mapping
CI3		PDSA cycle (Plan- Do - Study- Act cycle)
CI4		Mixed model assembly or process flexibility
CI5		Bottleneck analysis

S.No.	Pillar	Element
CI6		Product and process simplification
CI7		Use of flat hierarchy
CI8		New process and equipment
CI9		Integrate product and process development
2	**Standardization**	
ST1		Standardize materials for specific products families
ST2		Standardized products
ST3		Standardized tools and equipment
ST4		5S
ST5		Andon
ST6		Standardized work procedures
ST7		Autonomation
ST8		Group technology
ST9		Visual control boards
3	**Information technology system**	
ITS1		Use of EDI to communicate between suppliers and customers
ITS2		Enterprise resource planning system
ITS3		Information technology employed at customer base
ITS4		Effective information flow throughout supply chain
ITS5		Use of bar coding and scanner in logistics systems
ITS6		Modelling analysis and simulation tools or computer-aided system like CAD/CAE
ITS7		Rapid prototyping
4	**Total productive maintenance**	
TPM1		Maintenance of equipment and tools
TPM2		Safety improvement and ergonomics programmes
TPM3		Computer integrated maintenance system
TPM4		Overall equipment effectiveness

S.No.	Pillar	Element
TPM5		Life cycle analysis
TPM6		Maintenance practices/ procedures/ tools
TPM7		Failure evaluation/ debugging/ fault finding
TPM8		Point of use tool storage
5	**Elimination of waste**	
EW1		7 wastes
EW2		Reduction of WIP inventory
EW3		Cellular layout
EW4		Focused factory production
EW5		Storage space reduction
EW6		Synchronized of material flows and processes for simultaneous execution
EW7		Single minute exchange of die
EW8		Milk run
EW9		Production smoothing or Uniform workload production
6	**Just in time production**	
JIT1		Single piece flow
JIT2		Small lot size production
JIT3		Pull production
JIT4		Kanban
JIT5		Just in time deliveries throughout supply chain
JIT6		Plant layout
JIT7		Point of usage storage
JIT8		Super market
7	**Human resource management**	
HRM1		Multi skilled employees
HRM2		Employee involvement in every stage of organization
HRM3		Suggestion scheme
HRM4		Employee training and education.

S.No.	Pillar	Element
HRM5		Stable or long term employment
HRM6		Job rotation
HRM7		Job enrichment
HRM8		Fair rewards and recognition
8	**Supply chain management**	
SCM1		Supplier training and development activity
SCM2		Supplier evaluation and certification
SCM3		Supplier feedback
SCM4		Supplier proximity
SCM5		Single source and reliable suppliers
SCM6		Long term partnership with suppliers
SCM7		Encouraging first tier suppliers with profit sharing
9	**Management commitment and leadership**	
ML1		Lean vision and mission
ML2		Long-term business thinking
ML3		Horizontal and vertical information system
ML4		Appropriate resource allocations
ML5		Create a learning culture organization
ML6		Holistic strategy for integrating system or organizational policy deployment
ML7		Effective leadership development
ML8		Research and development activities for product development.
10	**Total quality management**	
TQM1		Quality improvement circle and teams
TQM2		Operator responsibility for quality
TQM3		Statistical process control
TQM4		Error proofing or Poka yoke
TQM5		Five whys or Root cause analysis
TQM6		Quality at the source

S.No.	Pillar	Element
TQM7		Supplier and customer involvement in quality development programmes
TQM8		Process capability analysis
11	**Customer relationship management**	
CRM1		Delivery performance improvement
CRM2		Continuous evaluation of customer feedback
CRM3		Maintain spare capacity
CRM4		Specification of value in terms customer point view
CRM5		Post sales service to customer
CRM6		Takt time
CRM7		Customer enrichment
CRM8		Quality function deployment
12	**Knowledge management**	
KM1		Developing knowledge teams
KM2		Knowledge capture and reuse
KM3		Centralized and documented engineering knowledge
KM4		Maintaining tools and techniques for knowledge storage, acquisition and decision support
KM5		Specialist career path to knowledge managers
KM6		Knowledge discovery and detection
KM7		Innovation brain storming
KM8		Knowledge sharing within and across organizations
13	**Concurrent engineering**	
CE1		Supplier and customer involvement in design
CE2		Queue management in product development processes
CE3		Design of experiments
CE4		Value analysis/ value engineering
CE5		Role of chief engineer

S.No.	Pillar	Element
CE6		Design for manufacturing and assembly
CE7		Modern stage gate model
CE8		Design structure matrix
CE9		Failure mode and effective analysis

5.4 Proposed framework for LE and salient features

Figure 5.1 presents a framework for LE. The study tries to present the salient features of the proposed framework compared with other existing LE frameworks.

- The proposed framework consists of 106 LE elements and 13 pillars or broad areas that were identified through empirical survey and a thorough literature survey respectively.
- The present study's proposed framework was constructed after consultations with academicians, practitioners and consultants, which triumphs over the shortcomings of the existing frameworks in the field of LE.
- The proposed framework were consisted more number of pillars and elements as compared with the sample frameworks considered in the study. It clearly indicated its comprehensive nature compared with other existing frameworks in the field of LE. However the study is accepting that there is a possibility of missing some of the elements in the proposed framework. According to Weick (1979), frameworks generally consist of inadequacy because it is not possible to generate a framework with the characteristics being general, simple and accurate at the same time.
- Any framework generally undergoes the process of evaluating reliability and validity of the constructs. The proposed framework also generates a requirement to evaluate

reliability and validity of elements. Hence, the framework verification and validation is indispensable.

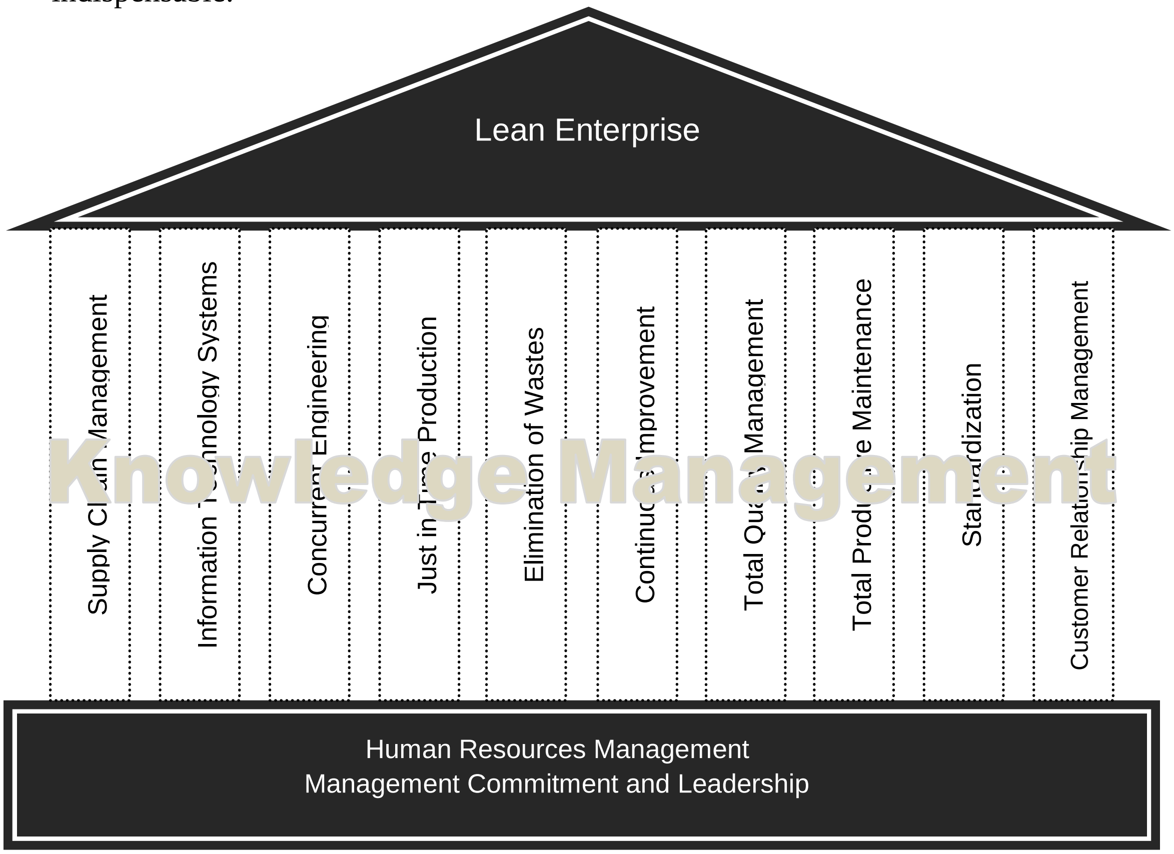

Figure 5.1: A framework for LE

5.5 Pillars of comprehensive framework of LE

The proposed framework in previous section consisted thirteen pillars. The present sub-section tries to justify why these pillars were considered integral part of LE framework and the importance of each pillar to achieve excellence in the field of LE.

Continuous improvement (CI)

According to Corbett and Rastrick, (2000) and Milakovich (1991), one of the best ways to improve the organizational output performance is CI. CI is a tool consisting of "Improvement initiatives that increase successes and reduce failures" (Juergensen, 2000). It is also a culture of sustained improvement with the elimination of failures in all systems and processes of an organization (Bhuiyan and Baghel, 2005).The main objective of the element is incremental improvement of products, processes and services over a period of time with involvement of teamwork across the organization. Due to its importance, eighteen LE frameworks (Around 59% of the frameworks) were proposed as an element in the implementation of LE frameworks. Hence the present study suggests that it is one of the key pillars for implementation of LE framework in any organization.

Total quality management (TQM)

Shah and Ward (2003) have clearly revealed that TQM is an integral part of the lean production. TQM has a very common definition reducing the poor-quality cost that is achieved with elimination of defects through various improvement procedures (Sorqvist, 1998). Generally, majority of the organizations have believed that TQM is one of the thrust areas to achieve manufacturing excellence, as TQM involves both the quality as well as productivity improvements (Sharma, 2009). Various researchers like Blockmon et al (1999), Steudel and Desruelle (1992) and Farsijani and Carruthers (1996) have proposed frameworks considered TQM as an important characteristic to be a world-class manufacturing organization. It is already proven from the literature that TQM is a very important pillar to achieve excellence in manufacturing. It was also reflected in the comparative analysis that around 23% of the frameworks were proposed TQM related elements in the sample of frameworks. Hence the present study concludes that it is one of the key pillars to implement LE framework in the organization.

Supply chain management (SCM)

In 1990s, the manufacturing organizations started to identify the impact of suppliers' role to the success of the organization. The main challenge was delivering the goods to customers at the right time, at the right place, and at the right price. It develops into a new challenge rather than producing only high quality goods. Many organizations identified that SCM is the way to carry out the goals (Chin et. al, 2004). With that approach in mind, many organizations like Digital Equipment Corporation (Arntzen et. al, 1995), Hewlett-Packard Company (Fisher, 1997) and Whirlpool (Lummus and Vokurka, 1999) have started to practice SCM approach to improve organizational performance as well as enhance competitiveness in the market place. In the present business scenario, the buyers and suppliers' dependence has increased significantly. In that point of view, the organizations have to give more importance to establishment of long - term relationship with the suppliers. Furthermore, vendors' knowledge and experience also plays a vital role while designing new products, producing higher quality products and quicker reactions to market requirements (Kanji, 1999). More than 25% of the frameworks were proposed SCM as one of the major elements for achieving LE excellence. In the present global competition, SCM performance has become an important foundation to get fruitful results over the competitors' in the market place. Hence the present study also suggested SCM as one of the pillar to achieve excellence in LE.

Customer relationship management (CRM)

The success story of any successful organization is delivering products and services while surpassing customer expectations (Boydell et. al, 1991). According to Robson (1986), customers for any successful organizations are not only the people to whom the organization's product is sold to. These organizations have given equal importance to both external and internal customers. The only difference is that the internal customers are a part of the organization as compared with the external customers. Many organizations identify top 20% of the customers (the 80:20 rules), conduct analysis on the specific needs of the customers, and take advantage of flexible manufacturing and deliver the products with special discounts, service arrangement and warranties to maintain the long term relationship with these customers (Grant and Schlesinger, 1995). Around 26% of the researchers were considered CRM related elements in the proposed frameworks. Hence CRM is used as one of the pillars in the proposed framework.

Total productive maintenance (TPM)

Many organizations have opinion that maintenance is considered as a cost spending centre, not a profit creation centre, so it is considered as an evil, but necessary to the organizations. But the successful organizations should have followed and adopted the best maintenance practices in the manufacturing procedures (Sharma, 2009). According to Mishra et al (2006), maintenance activity should be performed without any waste, where waste can be described as the gap between the way things are and the way things could be. Maintenance has been changed drastically from traditional maintenance to TPM (Mishra et al., 2006). Blann (2003) reported that TPM implemented organizations will have the following characteristics: the functioning of operations will be efficient in every stage, the equipment data streaming will be helping to maintain excellent computerized maintenance management, operations and maintenance teams are working as partners continuously and such organizations will also have excellent process management and organized systems. All these factors have forced to use TPM as pillar to build a LE organization. Around 39% of the frameworks were proposed TPM as an element in the LE frameworks. Hence the study also proposed TPM as a pillar of LE framework to achieve excellence in the organization.

Human resource management (HRM)

HRM is the backbone of any organization. The success of the organization depends on tools, culture and technologies adopted in the operational procedures. But the implementation of tools, technologies and to maintain the culture totally depends on employees of the organization. Hence many researchers were proposed HRM as an important element to implement LE framework. The organizational employee commitment is one of the major factors to implement any change management concept in the organization. The employee relationship and management is based on change implementation, with all the employees acting as team to make the change process as any kind of success (Fransis, 2003). Before anticipating contribution from the employees, the organization management should invest a considerable capital budget in all steps of the planning and execution of employee development. It includes job design, knowledge training programmes, financial benefits and recognition initiatives that encourage employees to contribute effectively to attain the organizational vision and mission (Clark, 1994; Chow, 2004). All these factors also play a very vital role in LE implementation in organization and around 26% of the existing LE frameworks were proposed HRM as an element. Hence the study proposed HRM as a one of the pillar in LE framework.

Management commitment and leadership (ML)

According to Roth et al (1992), the main focus of ML is about guiding and influencing employees of the organization to attain the organization’s aspirations, developing a vision and mission of the organization, and ensuring that the organizational stakeholders including employees, customers and suppliers understand the values and vision. The effective leadership includes developing strategies required to implement changes, creating a trusting environment, creating an enthusiasm and motivation in the employees, initiate the vision across the organization, conducting training programmes and also encouraging continuous learning and development (Kouzes and Posner, 1995). These factors have influenced to include it as one of the pillars in any advanced manufacturing philosophy implementation procedure. The study also revealed 23% of the existing frameworks proposed ML as an element. The present research also proposed ML as a foundation of the framework.

Concurrent engineering (CE)

In the present scenario, the factors that influenced the success of any modern organization are: how many numbers of new products released and how many products were successful in the market place (Cooper and Kleinschmidt, 2000). Product development is a set of actions that begins from a customer need, subsequently design the product to fulfill the customer requirements, complete the production and release the product to the market place (Ulrich, 1995). In the present globalization environment, Gupta and Wilemon, (1990) and Thomke and Fujimoto, (2000) have discussed that a good product development process tries to address the time to market as a critical parameter. Generally, the traditional product development processes were used to find out any one of the best idea and develop a complete solution on the basis of the selected idea to achieve the final solution (Ward et al., 1995). It clearly indicates that traditional product development is restricted by the initial idea only. Whereas, concurrent engineering process broadly collects all the possible set of solutions and progressively converge suitable multiple solutions to get an ultimate final solution (Clark and Fujimoto, 1989). Many researchers would think that it leads to too much of information gathering to find out the final solution. But the entire information is maintained in database to reuse for future requirements. It is proved that CE is providing the best possible solutions with less time to market compared with other product development processes. Hence CE is considered as a pillar in the proposed LE framework.

Knowledge management (KM)

Many researchers have highlighted the importance of organizational resources in terms of information and explicit knowledge and how these resources help to develop a learning organization. Many researchers (Kluge et al, 2000) in the case studies' research have brought out the importance of KM to maintain business successfully. The organizational learning methodology is also an important key factor for its effectiveness, to generate innovative ideas and also for growth (Garavan, 1997). The success of the organizations not only depends on concentrating on creating and sustaining market position but also depends on key resources and capabilities of the organizations. However, very few researchers have considered knowledge management as one of the elements for achieving LE excellence. The present study has also conducted analysis on LPD frameworks to cross check all the pillars of LE, which clearly indicated that KM is one of the pillars to achieve excellence in product development process. Hence the present study proposed KM as one of the pillars to achieve excellence in the LE organization.

Standardization

The main purpose of standardization is the use of common products, processes and components to fulfill the heterogeneous requirements. Tarondeau (1998) discussed that the process of standardization helps to improve the productivity, reduce the number of managing reference points, decrease the stock level, and drastically reduce the complexity of a manufacturing system. According to Thoteman and Brandeau (2000), any optimal standardization of internal products will not create any change in characteristics of the end product from the customer's point of view. The same study also reported that standardization may have also resulted in an optimal design in terms of cost (Pahl and Beitz, 1998). Around 52% of the frameworks were considered in the present sample, standardization as an important element to achieve excellence in LE. Hence the present study also proposed standardization as one of the key pillars in the LE framework.

Elimination of waste

Toyota engineers tried to reduce setup time and defects from the production line. In that process, they have focused to identify unnecessary wastes and activities that the customers are not ready to pay for. According to Ohno, the waste can be classified into seven wastes: over production (resulted due to surplus capacity), inventory (resulted due to uncertainties in system, suppliers etc.), motion (resulted due to poor work design practices) over-processing (resulted due to avoidable and redundant processing activities), defects, transportation and waiting (Monden, 1993; Womack et al, 1990; Imai, 1997; Taylor and Brunt, 2001; Liker, 2004). All these wastes could have been avoided by applying common sense instead of depending on sophisticated technology and automation. Around 70% of the frameworks were proposed elimination of waste related elements considered in the sample of existing frameworks. Hence the present study also proposes elimination of wastes as one of the pillars to implement LE framework in the organization.

Just in time (JIT) production

The main objective of JIT is to "*produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased materials just in time to be transformed into fabricated parts*"(Schonberger,1982). In short form, Kimura and Terada (1981), JIT is a concept that produces a required volume, required product and at the required time. Many researchers proved that JIT helps to reduce inventory in all levels of the organizations, improves the quality and productivity of the organization, improves supplier and customer relationship, increases inventory turnover and workspace reduction (Mehra and Inman 1992; Markham and McCart 1995; Yasin and Wafa 1996; Sriparavastu and Gupta, 1997; Imai 1997). Around 30% of the frameworks were proposed JIT as an element of LE framework. Hence the present study also proposed JIT as pillar to achieve excellence in LE.

Information technology management (ITM)

In the present scenario, the information flow plays vital role to fulfill complex manufacturing systems as well as supply chain activities. Tan et al. (2002) have revealed the importance of information technology tools to control information flow within organization as well as across supply chain activities. To survive in the present dynamic markets conditions, the firms have started to work as group instead of single independent entity (Christopher, 1992; Lambert and Cooper, 2000). The information technology helps to provide the essential prerequisite to build and control multi level networks as well as to improve communication effectiveness in supply chain activities (Lee and Billington, 1992; White and Pearson, 2001). It is also helpful in the field of product design and development. Hence the present study proposed to include ITM as one of the important pillars to implement LE framework in the organization.

5.6 Conclusion

Many researchers have proposed frameworks for LE to implement in organizations across the world. However, the present study did not find any review article existing in the literature. Hence, the study has taken up the issue and conducted a literature review to identify inconsistencies as well as inadequacies observed in the existing LE framework. To find out inconsistencies in the LE frameworks, the present study raised a few research questions. The present study felt that answer to these questions may lead to identifying the inconsistencies in the sample of LE frameworks. It also found that academicians and practitioners' contribution was very less compared to consultants' contribution to develop existing LE frameworks. The review also noticed use of case study verification methodology by researchers to verify the proposed LE frameworks. The study also aimed to find out the elements used by researchers to propose a framework and also the degree of standardization of LE elements. It is identified that a huge dissimilar number of elements were used by researchers indicating the divergence and incoherence of the field of LE frameworks. Many researchers proposed LE framework to utilize in a specific environmental of the organization, which made it difficult to find the standard elements in the field of LE. Hence the present study has proposed a LE framework to give a coherent set of elements with the help of empirical study as well as comparative analysis. The study has proposed LE framework with the help of academicians, professionals and consultants' team. Hence, the study hopes that the proposed LE framework will overcome all the limitation of existing LE frameworks. The study requires to validate the proposed LE framework in Indian manufacturing industries.

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Chapter 6

An empirical investigation on proposed lean enterprise framework in Indian Industry

6.1 Introduction

A framework for lean enterprise (LE) was developed in the fifth chapter. The study has proposed thirteen main pillars, along with the various elements identified with the help of empirical study under each pillar. An exploratory study was conducted to check the reliability, validity and applicability of the proposed LE framework. To fulfill requirements, the study performs a nationwide survey in the second phase of the empirical study. The study also attempted to establish the directional relationships among thirteen pillars of LE, i.e. dependencies and inter-dependencies by using Interpretive structural modelling (ISM), which was subjected to statistical testing for model fit by using SEM. Details regarding the same are presented in the subsequent sections.

6.2 Methodology for empirical investigation

The different stages of the systematic approach for the empirical research were implemented in Chapter 4 to find suitable LE frameworks to Indian manufacturing industries. The same method is followed to verify the proposed LE framework in the second phase of empirical study. A brief description about the same methodology is presented below:

6.2.1 Theory verification

The first step in the systematic approach is theory verification. Accordingly, the second exploratory study was aimed to performing an empirical investigation on proposed LE framework in Indian manufacturing industries.

6.2.2 Selecting a research design

To do the empirical investigation on proposed LE framework in Indian industries, a cross sectional survey is used. The study was applied similar kind of approach in chapter 4.

6.2.3 Select a data collection method

The questionnaire survey has used to collect data, as per the research methodology discussed in detail in the chapter 4. The questionnaire was prepared and it was also administered to the same 753 industries professional (identified through CII directory, 2011), to whom the first questionnaire was sent.

6.2.4 Implementation

Although this exploratory study was conducted on the same population of 753 industries identified in the previous exploratory survey, the questionnaires were sent as a soft copy attachment through e-mails and post to various industries. The survey instrument was constructed with the elements under main pillars of the framework for LE after refinement. The questionnaire was constructed for evaluating the implementation and level of contribution of various elements under each pillar. In addition to this, general questions were also incorporated to understand the industry profile in terms of worker strength, development, client potency, etc.

The questionnaire contained two sections A and B. The intend of the section A is to construct a profile of the respondent and the experience of the respondent in manufacturing organization and the mission, vision of the company etc; identify the status of competitive strategies followed by them and other appropriate information. Section B is a prearranged questionnaire built on a five point Likert scale (the details of which are given in Appendix-G) for evaluating the level of significance of each element under 13 pillars of LE framework developed. A covering letter was drafted, in which the general information about the research work, purpose of the study and how to apply the instrument were discussed. The study was assured the respondents regarding the privacy of the information and welcome to share any other information they had, regarding the concept of LE in the Indian industry. Respondents were requested to consider each pillar as a means for achieving LE with each element in it as a milestone to direct the organization wanting to implement/assess the status of that particular pillar in their organization. The respondents were requested to allocate a level based on: how vital is each element under various pillars of the proposed framework to the organization. In the questionnaire the language is very simple and can effortlessly be understood. However, the respondents/participants were appealed to revert to the researchers through e-mail, postal mail or phone in case of any discrepancy in understanding point of view. In totality, 753 questionnaires were sent by e-mail and post. Subsequently, more than 215 e-mail reminders were sent. Apart from this, some people were communicated personally over telephone and personally. A structured questionnaire was developed using the five-point Likert scale. The scale ranged from 1 to 5, where (1) means not important, (2) means less important, (3) means important, (4) means more important, and (5) means most important. The complete details of questionnaire are given in Appendix-G. Respondents were requested to rate the degree or extent of practice of each element with reference to the five point response scale. In this study, the response rate was slightly improved and out of the 753 questionnaires, 207 responses were received and seven questionnaires were incomplete or invalid. The two hundred valid responses were received, included 76 from the automobile sector, 34 from the machines and equipment industry, 33 from electronics and components, 33 from the process industry and 24 from the textile units. The overall response rate was 26.56 % which can be considered good in Indian conditions. Statistics of sector wise responses are shown in the Table 6.1.

Table 6.1 Statistics of sector wise responses

Industry	No. of responses received by post	No. of responses received by email	Total No. of responses received	Sample size	Response rate
Automobile	33	43	76	202	37.62
Machinery equipment	17	17	34	152	22.36
Electrical and electronics	13	20	33	190	17.36
Process	14	19	33	150	20.00
Textile	8	16	24	59	40.67
Total	85	115	200	753	26.56

On an average experience the respondents were twelve years. Majority of the respondents were from the top management having designation such as general manager, associate vice president etc.

6.2.5 Overview of data analysis techniques

The various data analysis techniques that were used are:

Descriptive statistics: Descriptive statistics are intended to provide information regarding the distribution of variables. It is useful to measure tendency (Mean, Median, and Mode), measures of variability around the mean (standard deviation and variance), information concerning the spread of distribution (maximum, minimum and range) and information about the stability or sampling error of certain measures. This is used for computing overall statistics for various issues. The overall statistics for various measures is as shown in various tables in Appendix-E.

Correlation analysis: Correlation analysis is carried out to evaluate relationship among two variables. It is designated as "r" and varies between +1 to – 1. It measures the strength of relationship between interrelated variables. It gives the strength of relationship through identification of variance which generally lies between 0 to 1. It is performed to estimate relationship among various elements within the pillars. The Pearson correlation coefficient (r) is calculated, which illustrates the extent to which an increase or decrease in one variable is accompanied by a subsequent increase and decrease in the other (Sharma, 1996). The results are shown in Appendix-E.

Reliability analysis: Reliability analysis addresses the concern that whether the survey instrument will generate the identical result every instance it is administered to the same person under same situations in spite of who administers them. It is conducted for each element considered in the questionnaire to check the scale reliability of each pillar. Inter-item analysis is used to check the scales for internal consistency or reliability. Several measures of reliability can be evaluated in order to establish the reliability of a measuring instrument. These include test retest method, equivalent forms, split-halves methods and internal consistency method. Among all methods, the internal consistency method needs only one administration and accordingly, is supposed to be the most common and efficient method (Sureshchandar et. al., 2001). In this method reliability is operationalized as internal consistency, which is the degree of inter-correlation amongst the items that constitute a scale (Nunnally, 1988). Internal consistency is estimated using a reliability coefficient called Cronbach's alpha. Hence, Cronbach's alpha is evaluated for each pillar as suggested for empirical research in operations management. (Flynn et al., 1990; Malhotra and Grover, 1998).

The smallest general adequate value of Cronbach's alpha is 0.70. The results are shown in Appendix-E.

Factor analysis: Factor analysis is used to recognize a small number of factors that might be used to represent association among sets of interrelated variables. Its main usefulness is to take a large number of evident instances to measure an unobservable element or elements. The purpose of factor extraction is to extract factors i.e. the underlying constructs that describe a set of variables. It is used to uncover the latent structure (dimensions) of a set of variables. It reduces attribute space from a larger number of variables to a smaller number of factors. The results are shown in Appendix-E.

The details of the data analysis are discussed from the next section onwards.

6.3 Reliability analysis

Prior to evaluating the internal consistency of the measures (Cronbach's alpha, α), an inter item correlation matrix was built for each measure to examine the extent to which some common trait was present in the items. Low inter item correlations designate that the associated items are probably should avoid from the group elements (Nunnaly, 1988). Even an item correlation of 0.2 is considered enough to be incorporated in the list for further principle component analysis. None of the elements has shown correlation value less than 0.2. The mean item correlation of these pillars came as more than 0.4. Hence, they were considered satisfactory. Table 6.2 shows the Reliability analysis for LE pillars.

For all the pillars the alpha value is quite high and hence all the elements within various pillars can be considered for further analysis. Although, dropping some items from scales would improve some alpha values, no items were deleted to improve the alpha values, as they were already high and meet the criterion of exceeding 0.7 for all the scales. Also, this was done in order to ensure the content validity of each measurement scale. The reliability analysis for all constructs showed α value of more than 0.82. As already said α value of 0.70 or above is considered to be the criterion for demonstrating internal consistency of established scales (Nunnaly, 1988). The range of α value from 0.821 to 0.935 indicates that some pillars are more reliable than the others. It is noted that usually more number of items in a scale tended to show higher reliability and it is yet to be seen if validity of the constructs demonstrates such robustness too. Since the measurements used in this study are developed, based on extensive literature review and practitioner/expert inputs, the values found are considered to be highly adequate.

Table 6.2 Reliability analysis for LE pillars

S.No.	Pillar	No. of items*	Item means for scale	Means of inter item correlation	Cronbach alpha (α)	Standardized item alpha(α)
1	Management commitment and leadership	8 (1-8)	3.928	0.575	0.915	0.882
2	Human resource management	8 (9-16)	3.667	0.415	0.843	0.935
3	Customer relationship management	8 (17-24)	3.85	0.502	0.89	0.889
4	Supply chain management	7 (25-31)	4.071	0.486	0.866	0.871
5	Total quality management	8 (32-39)	3.75	0.495	0.889	0.876
6	Total productive maintenance	8 (40-47)	3.892	0.474	0.875	0.854
7	Continuous improvement	9 (48-56)	3.778	0.658	0.945	0.821
8	Standardization	9 (57-65)	3.689	0.528	0.909	0.870
9	Information technology system	7 (66-72)	3.527	0.491	0.870	0.921
10	Elimination of waste	9 (73-81)	3.887	0.510	0.902	0.911
11	Just-in-time production	8 (82-89)	4.075	0.555	0.908	0.856
12	Knowledge management	8 (90-97)	3.892	0.474	0.875	0.816
13	Concurrent engineering	8 (98-105)	4.075	0.555	0.908	0.873

6.4 Validity analysis

Prior to performing the principal component analysis, the data matrix was examined to ensure that it had sufficient correlations to justify the application of factor analysis. One of the measures to quantify the degree of inter-correlations among the variables and the appropriateness of factor analysis is the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. A small value of KMO means each variable cannot be predicted or explained by the other variables without significant error; hence factor analysis may not be appropriate. As a rule, KMO values in the 0.90s are measured as marvelous; 0.80s are meritorious; 0.70s are middling; 0.60s are ordinary; 0.50s are miserable; and below 0.50s are undesirable (Hair et al., 1996). Hence, the research study has considered individual variables that have KMO values lower than 0.50 should not be included. Table 6.3 shows the overall KMO measure of sampling adequacy for LE pillars. From Table 6.3 it is clear that for all the pillars KMO value is more than 0.7. A large number of constructs like management commitment and leadership, human resource management, customer relationship management, total quality management, total productive maintenance, continuous improvement, standardization, elimination of waste, just in time production, knowledge management, and concurrent engineering were considered meritorious, while the pillars supply chain management, information technology system are middling, which was above the suggested middling standard of 0.7 required for performing factor analysis (Hair et al., 1996; Norusis, 1994). Hence, based on the above tests, it concluded that all thirteen pillars were suitable for pertaining principle component analysis. In addition to this, the methodology suggested by Meyer and Collier (2001) were followed to find out the Factor analysis statistics. The percent of variance explained by the first principal component of each measurement scale was considered as vital. One criterion is that the first component of each scale explains more than 40% of the variance in the items. The second criteria is that the factor loadings for items should be greater than 0.30. Hence this study considered items whose factor loadings are greater than 0.40. The two remaining criteria considered were: a large eigen-value for the first component and small, fairly equal eigen-values for subsequent components for subsequent components. The values are verified with the parallel analysis.

Table 6.3 The overall KMO measure of sampling adequacy for LE pillars

Pillar	No. of items	Items deleted (by number)	KMO
Management commitment and leadership	8 (1-8)	None	0.826
Human resource management	8 (9-16)	None	0.811
Customer relationship management	8 (17-24)	None	0.811
Supply chain management	7 (25-31)	None	0.727
Total quality management	8 (32-39)	None	0.858
Total productive maintenance	8 (40-47)	None	0.821
Continuous improvement	9 (48-56)	None	0.891
Standardization	9 (57-65)	None	0.852
Information technology system	7 (66-72)	None	0.769
Elimination of waste	9 (73-81)	None	0.810
Just-in-time production	8 (82-89)	None	0.846
Knowledge management	8 (90-97)	None	0.878
Concurrent engineering	8 (98-105)	None	0.862

Validity analysis measures that the item or scale measure what it has been designed to measure and nothing else. Normally validity analysis is done using three measures:

- Content validity: It is judgment by experts, of the extent to which a summated scale truly measures the concept that it intended to measure, based on the content of the items. It can be determined using qualitative technique. It is not possible to measure by using any quantitative techniques. It can be determined by the help of experts (Flynn et. al., 1990). To assess the content validity of the questionnaire, the initial draft of the questionnaire was administered to the same group of twelve members to whom the previous questionnaire was administered. At the same time the questionnaire was also sent to two senior level executives in reputed automotive manufacturing organizations. The questionnaire was also administered to eight students of mechanical engineering group of Birla Institute of Technology and Sciences, Pilani. These students were doing their practice school (industry Internship) in various organizations and hence the opinions from these individual students were also considered. Finally, the questionnaire has modified as per feedback received from the experts and the final version of the questionnaire was sent to the CEO’s or top management and managers of the same group of 753 companies identified earlier.
- Criterion-related validity: The basic idea of criterion-related validity is to check the performance of the measure against some criterion. Traditionally, it is evaluated by examining the correlations of the different constructs with one or the more measures of business or manufacturing performance (Saraph et. al., 1989). This investigates the empirical relationship between the scores on a test instrument (predictor) i.e. framework elements and an objective outcome (the criterion) i.e. the

various pillars. The most important of measure for checking the criterion related validity is simple correlation, for testing a scale or elements for a single outcome. The bivariate correlation matrices between LE pillars are shown in Table 6.4, and it can be seen that for both the relevant criterion the correlation is high for all the pillars.

- Construct validity: it measures whether a scale is an appropriate operational definition of an outcome - i.e., the LE. Since the construct cannot be directly assessed indirect inference about the construct validity can be made through empirical investigations. Principle component analysis conducted on a single scale will show whether all the dimensions (elements) within a summated scale will load a single or same construct or whether the summated scale measure more than one construct - i.e., it checks the unidimensionality of the scales towards a single construct. The principle component analysis was conducted within each main pillar with the means of all elements taken as the loading on each pillar.

The results of validity analysis have clearly showed that the complete pillars were loaded on single pillar. The complete sets of elements under each pillar were also loaded on single element or construct. Hence, the proposed framework of LE has fulfilled the requirements of validity and reliability analysis and also is suitable to fulfill the requirements of Indian manufacturing industries.

Table 6.4 Bivariate correlation matrices

	Mean	Std. D	ML	HRM	CRM	SCM	TQM	TPM	CI	ST	ITS	EW	JIT	KM	CE
ML	3.928	0.882	1	.596**	.495**	.449**	.545**	.430**	.523**	.504**	.546**	.416**	.357**	.416**	.547**
HRM	3.667	0.935	.596**	1	.436**	.459**	.430**	.514**	.462**	.432**	.406**	.645**	.281**	.342**	.462**
CRM	3.85	0.889	.495**	.436**	1	.612**	.338**	.476**	.448**	.504**	.493**	.575**	.622**	.543**	.469**
SCM	4.071	0.871	.449**	.459**	.612**	1	.521**	.606**	.491**	.537**	.510**	.427**	.422**	.432**	.335**
TQM	3.75	0.876	.545**	.430**	.338**	.521**	1	.367**	.348**	.497**	.428**	.355**	.409**	.358**	.457**
TPM	3.892	0.854	.430**	.514**	.476**	.606**	.367**	1	.600**	.577**	.377**	.533**	.308**	.305**	.423**
CI	3.778	0.821	.523**	.462**	.448**	.491**	.348**	.600**	1	.694**	.692**	.593**	.294**	.208**	.473**
ST	3.689	0.870	.504**	.432**	.504**	.537**	.497**	.577**	.694**	1	.681**	.714**	.341**	.427**	.469**
ITS	3.527	0.921	.546**	.406**	.493**	.510**	.428**	.377**	.692**	.681**	1	.634**	.395**	.447**	.563**
EW	3.887	0.911	.416**	.645**	.575**	.427**	.355**	.533**	.593**	.714**	.634**	1	.339**	.377**	.461**
JIT	4.075	0.856	.357**	.281**	.622**	.422**	.409**	.308**	.294**	.341**	.395**	.339**	1	.791**	.582**
KM	3.892	0.816	.416**	.342**	.543**	.432**	.358**	.305**	.208**	.427**	.447**	.377**	.791**	1	.674**
CE	4.075	0.873	.547**	.462**	.469**	.335**	.457**	.423**	.473**	.469**	.563**	.461**	.582**	.674**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Legend: MCL- Management commitment and Leadership; HRM- Human Resource Management; CRM- Customer Relationship Management; SCM- Supply Chain Management; TQM- Total Quality Management; TPM- Total Productive Maintenance; CI- Continuous Improvements; ST- Standardization; ITS- Information Technology System; EW- Elimination of Waste; JIT- Just-in-time Production; KM- Knowledge Management; CE- Concurrent Engineering.

6.5 Path analysis for LE framework

The relationships among pillars were not established while checking the validity of the constructs. The importance of establishing relationship among pillars is very significant from implementation point of view. Successful deployment of first level of pillars is needed for successful implementation of second level of pillars and so on. Hence the study made an attempt to create a mental model derived from these thirteen pillars to establish the directional relationships among the pillars of LE. It also includes dependencies and inter-dependencies by using interpretive structural modelling (ISM). Later, it is subjected to statistical testing for model fit by using structural equation modelling (SEM).

6.6 Research methodology applied for path analysis

The objective of the present section of study is to develop and validate the proposed framework of LE in Indian manufacturing industry using ISM and SEM.

6.6.1 Interpretive structural modeling (ISM) method

To develop the framework for LE, one should facilitate an enhanced understanding of the pillars and elements as well as their inter-relationship. The present section of research is premised on the recognition of underlying relationships between cause and effect that can lead to new conclusions and empirical verification. ISM methodology fulfils this requirement as it essentially analyses the drivers, the inter-relationship between pillars, hierarchy of their importance and classification of intervention levels. Hence, the present section of study is developed ISM for LE model.Warfield was introduced ISM that is an algebraic technique for system representation. It is used to reduce complex system interactions to a logically oriented graph (Hsiao and Liu, 2005).

It has been applied in various research fields to find out the relationship among the elements like energy management (Saxena et al., 1992), information technology (Kanungo, 2009), manufacturing strategy (Singh et al, 2007), organization behaviour (Jyoti et al, 2008), performance management (Manoharan et al, 2010), project management (Iyer and Sagheer, 2010), risk management (Jha and Devaya, 2010), supply chain management (Ravi and Shankar,2005), strategic management (Bolanos et al., 2005), total quality management (Sahney et al, 2006), vendor selection (Mandal and Deshmukh, 1994) and waste management (Sharma et al., 1995). In LE research, ISM has been applied to discuss the various issues. Kumar et al (2013) has applied ISM approach successively to identify the exterior drivers of lean manufacturing elements.

In the present research work, ISM is utilized to develop a structural relationship between the pillars, which were established in the previous chapter. The study has considered two cases for developing the ISM models, which are large scale automotive industry (LSAI) and another one is small and medium scale automotive industry (SMSAI). Two organizations are practising lean principles more than ten years in their respective organizations.Both the organizations have shown keen interest in finding the association between pillars of LE.

Large scale automobile industry (LSAI)

LSAI organization is actively participating in implementation of LE principles across organizational activities. The employees of LSAI organization are also involving in continuous rigorous training programme conducting in their advance learning centre. The organization is manufacturing different automobile components like crank shaft and forged components.

Small and medium scale automotive industry (SMSAI)

SMSAI case organization is a leading global supplier of automotive components and systems, including piston and piston rings. The organization provides customers with incomparable manufacturing reach and ability. The organization claims that their approach in implementation of lean principles is exceptional.

6.6.2 Development of interpretive structural modelling (ISM) for proposed cases

In this section ISM method is explained to both the proposed cases side by side.

The various steps involved in ISM technique are as follows:

Step 1. All the thirteen elements identified from the previous chapter were arranged in a matrix, with the elements arranged so that the experts can give their opinion while the items in the matrix are being compared. The thirteen pillars are: management commitment and leadership (ML), human resource management (HRM), customer relationship management (CRM), total quality management (TQM), total productive maintenance (TPM), continuous improvement (CI), standardization (ST), elimination of waste (EW), just in time production (JIT), knowledge management (KM), concurrent engineering (CE), supply chain management (SCM), information technology system (ITS). The letters shown in the parenthesis refers to the pillar legends.

Step 2. Establishing a contextual relationship between pillars with respect to which pairs of elements will be analysed.

Step 3. Developing a self-interaction matrix (SSIM) of pillars to display pair-wise relationship between pillars under consideration. The data to fill in the matrix was collected by interacting with the six experts from industry and academics. The six experts from industry were managers from both the organizations, CEO of the SMSAI and Brand manager from LSAI. The six academic experts belong to leading institutions from India. All the experts were requested to identify the relationships among thirteen pillars of LE under the light of their elements and general understanding. Each expert was given a worksheet which had structural self-interaction matrix (SSIM) to fill. To develop contextual relationship among pillars of LE model and their elements the experts were asked to respond on a worksheet by indicating 'V', 'A', 'X' and 'O' in each cell of the matrix, where:

V: pillar or construct i will affect pillar or sub-construct j;

A: pillar or construct j will affect pillar or sub-construct i;

X: pillar or construct i and j affect each other equally;

O: pillar or construct i and j will have no relationship.

Each expert was briefed about the pillars and elements of LE model in the worksheet provided to record their responses. After clarifying the research objectives and clear their queries completely, each expert was requested to respond on the worksheet. All the responses were collected and a check was performed. If the relationship between $i^{th}$and j^{th}element is unanimous then corresponding letter was allocated in the respective cell. However if the responses in a particular cell were of varied opinions among the experts, all the experts were again consulted for that particular relationship and requested to rethink on the relationship to probably enhances the concurrency of the responses. In this manner after several interactions the final SSIM of the two LE model pillars was formed. The SSIM for LSAI and SMSAI are shown in Table 6.5 and Table 6.6, respectively.

Table 6.5 The SSIM of LSAI

	ML	JIT	CE	KM	CRM	CI	TQM	SRM	TPM	ITS	ST	EW	HRM
HRM	A	V	V	X	X	V	V	X	V	V	V	V	X
EW	A	X	A	O	O	V	X	A	V	A	X	X	
ST	A	V	A	A	A	V	X	A	V	A	X		
ITS	A	V	O	A	A	V	V	A	V	X			
TPM	A	A	A	A	A	V	A	A	X				
SRM	A	V	A	X	X	V	V	X					
TQM	A	V	A	A	A	A	X						
CI	A	A	A	A	A	X							
CRM	A	V	V	X	X								
KM	A	V	V	X									
CE	A	V	X										
JIT	A	X											
ML	X												

Table 6.6 The SSIM of SMSAI

	ML	JIT	CE	KM	CRM	CI	TQM	SRM	TPM	ITS	ST	EW	HRM
HRM	X	V	V	X	X	V	V	V	V	X	V	V	X
EW	A	X	X	A	A	V	X	A	V	A	X	X	
ST	A	V	A	A	A	V	X	A	V	A	X		
ITS	A	X	V	A	A	O	V	X	A	X			
TPM	A	X	A	A	O	V	X	A	X				
SRM	A	X	A	X	X	V	V	X					
TQM	A	V	A	A	A	X	X						
CI	A	A	A	A	X	X							
CRM	A	V	V	X	X								
KM	A	V	V	X									
CE	A	V	X										
JIT	A	X											
ML	X												

Step 4. The SSIM has to be changed into a binary matrix, called the reachability matrix by replacement X, A, V and O by 1 and 0. The rules for substituting 1's and 0's are given as follows:

a) If the entry in cell (i,j) of SSIM is V then entry in the (i,j) cell of reachability matrix must be replaced with 1 and in cell (j,i) must be replaced with 0.

b) If the entry in cell (i,j) of SSIM is A then entry in the (i,j) cell of reachability matrix must be replaced with 0 and in cell (j,i) must be replaced with 0.

c) If the entry in cell (i,j) of SSIM is X then entry in the (i,j) cell of reachability matrix must be replaced with 1 and in cell (j,i) must also be replaced with 1.

d) If the entry in cell (i,j) of SSIM is O then entry in the (i,j) cell of reachability matrix must be replaced with 0 and in cell (j,i) must also be replaced with 0.

e) After making the reachability matrix its transitivity is checked. If element *i* lead to element *j* and element *j* leads to element *k*, then element *i* should lead to element *k*. By transitivity embedding, the modified reachability matrix is obtained. Table 6.7 and Table 6.8 shows final reachability matrix for LSAI and SMSAI organizations.

Step 5. Table 6.7 and Table 6.8 display the driving power and dependence of each LE model pillar. The driving power of a particular LE model pillar is the total numbers of pillars (including it) which may help to achieve or establish. These driving power and dependencies will be used further in MICMAC analysis, which involves classification of elements into four groups of autonomous, dependent, linkage, and independent (driver) LE model elements.

Table 6.7 Final reachability matrix of LSAI organization

	HRM	EW	ST	ITS	TPM	SRM	TQM	CI	CRM	KM	CE	JIT	ML	Driver power
HRM	1	1	1	1	1	1	1	1	1	1	1	1	0	12
EW	0	1	1	0	1	0	1	1	0	0	0	1	0	6
ST	0	1	1	0	1	0	1	1	0	0	0	1	0	6
ITS	0	1	1	1	1	0	1	1	0	0	0	1	0	7
TPM	0	0	0	0	1	0	1	1	0	0	0	1	0	4
SRM	1	1	1	1	1	1	1	1	1	1	0	1	0	11
TQM	0	1	1	0	1	0	1	1	0	0	0	1	0	6
CI	0	0	0	0	0	0	0	1	0	0	0	0	0	1
CRM	1	1	1	1	1	1	1	1	1	1	1	1	0	11
KM	1	1	1	1	1	1	1	1	1	1	1	1	0	11
CE	0	1	1	1	1	1	1	1	0	0	1	1	0	9
JIT	0	1	1	0	1	0	0	1	0	0	0	1	0	4
ML	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Dependence	5	11	11	7	12	6	11	13	5	5	5	12	1	

Table 6.8 Final reachability matrix of SMSAI organization

	HRM	EW	ST	ITS	TPM	SRM	TQM	CI	CRM	KM	CE	JIT	ML	Driver power
HRM	1	1	1	1	1	1	1	1	1	1	1	1	1	13
EW	0	1	1	0	1	0	1	1	0	0	1	1	0	7
ST	0	1	1	0	1	0	1	1	0	0	0	1	0	6
ITS	1	1	1	1	1	0	1	0	0	0	1	1	0	8
TPM	0	0	0	0	1	0	1	1	0	0	0	1	0	4
SRM	0	1	1	1	1	1	1	1	1	1	O	1	0	10
TQM	0	1	1	0	1	0	1	1	0	0	0	1	0	6
CI	0	0	0	0	0	0	1	1	0	0	0	0	0	2
CRM	1	1	1	1	0	1	1	1	1	1	0	0	0	9
KM	1	1	1	1	1	1	1	1	1	1	1	1	0	12
CE	0	0	1	0	1	1	1	1	0	0	1	1	0	7
JIT	0	1	0	1	1	1	0	1	0	0	0	1	0	6
ML	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Dependence	5	10	10	7	11	7	12	12	5	5	6	11	2	

Step 6. From the reachability matrix, the reachability set and antecedent set for each criterion is found. The reachability set consists of the pillar itself and other pillar to which it may reach, whereas the antecedent set consists of the pillar itself and the other pillar which may reach to it. Then the intersection of these sets is derived for all pillars. The pillar for which the reachability and intersection sets are the same is the top-level pillar. Physically, the top pillars of the hierarchy will not reach to any other pillar above their own level. Once the top-level pillar is identified, it is separated out from the other pillar. Then, by the same process, the next level of pillars is found. The levels of partition of the pillars for LSAI and SMSAI are shown in Table 6.9 and Table 6.10.

Table 6.9 Levels of partition of the pillars for LSAI organization

Pillars	Reachability Set	Antecedent Set	Interaction Set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12	1,6,9,10,13	1,6,9,10	II
2	2,3,5,7,8,12	1,2,3,4,6,7,9,10,11,12,13	2,3,7,12	VII
3	2,3,5,7,8,12	1,2,3,4,6,7,9,10,11,12,13	2,3,7,12	VII
4	2,3,4,5,7,8,12	1,4,6,9,10,13	4	III
5	5,7,8,12	1,2,3,4,5,6,7,9,10,11,12,13	5,7,12	V
6	1,2,3,4,5,5,6,7,8,9,10,12	1,6,9,10,11,13	1,6,9,10	II
7	2,3,5,7,8,12	1,2,4,5,6,7,9,10,11,13	2,5,7	VI
8	8	1,2,3,4,5,6,7,8,9,10,11,12,13	8	VIII
9	1,2,3,4,5,6,7,8,9,10,11,12	1,6,9,10,13	1,6,9,10	II
10	1,2,3,4,5,6,7,8,9,10,11,13	1,6,9,10,13	1,6,9,11	II
11	2,3,5,6,7,8,11,12	1,6,9,10,11,13	6,11	IV
12	2,3,5,7,12	1,2,3,4,6,7,9,10,11,12,13	2,3,7,12	VII
13	1,2,3,4,5,6,7,8,9,10,11,12,13,	13	13	I

Table 6.10 Levels of partition of the pillars for SMSAI

Pillars	Reachability Set	Antecedent Set	Interaction Set	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13	1,4,9,10,13	1,4,9,10,13	II
2	2,3,5,7,8,12	1,2,3,4,6,7,9,10,11,12,13	2,3,7,12	VII
3	2,3,5,7,8,12	1,2,3,4,6,7,9,10,11,12,13	2,3,7,12	VII
4	1,2,3,4,5,7,11,12	1,4,6,9,10,13	1,4	V
5	5,7,8,12	1,2,3,4,5,6,7,10,11,12,13	5,7,12	VIII
6	2,3,4,5,6,7,8,9,10,12	1,6,9,10,11,12,13	6,9,10,12	IV
7	2,3,5,7,8,12	1,2,3,4,5,6,7,8,9,10,11,13	2,3,5,7,8	IX
8	7,8	1,2,3,4,5,6,7,8,9,10,11,12,13	7,8	X
9	1,2,3,4,6,7,8,9,	1,6,10,13	1,6,10	VI
10	1,2,3,4,5,6,7,8,9,10,11,12	1,6,10,13	1,6,10	VI
11	3,5,6,7,8,11,12	1,2,4,10,11,13	11	III
12	2,5,6,8,12	1,2,3,4,6,7,10,11,12,13	2,5,6,12	X
13	1,2,3,4,5,6,7,8,9,10,11,12,13,	1,13	1,13	I

Step 7. Once all the transitivities are removed, the diagraph is finally converted into ISM model. The ISM model of LASI and SMSAI organizations are as shown in Figure 6.1 and Figure 6.2 respectively.

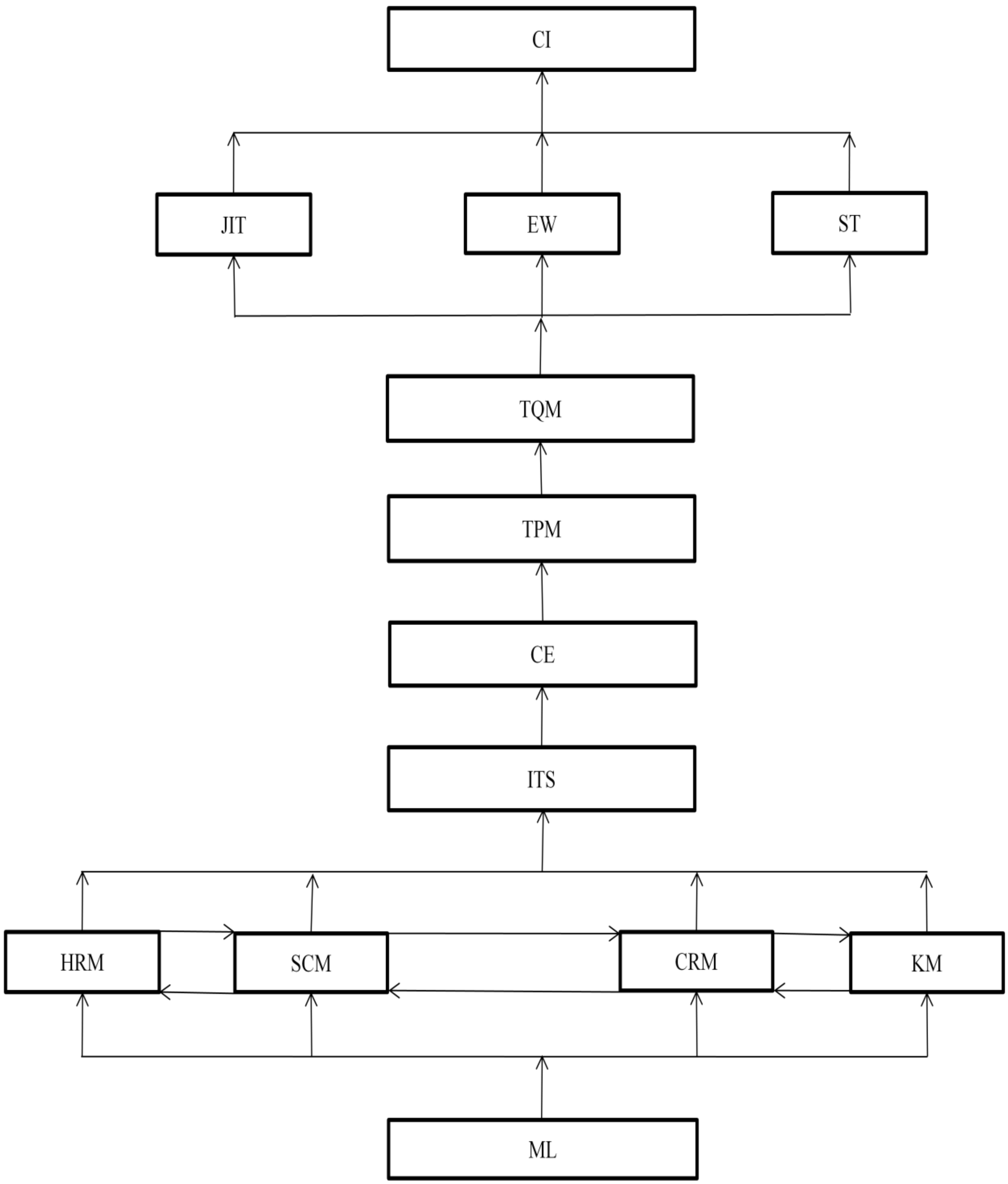

Figure 6.1: ISM of LSAI

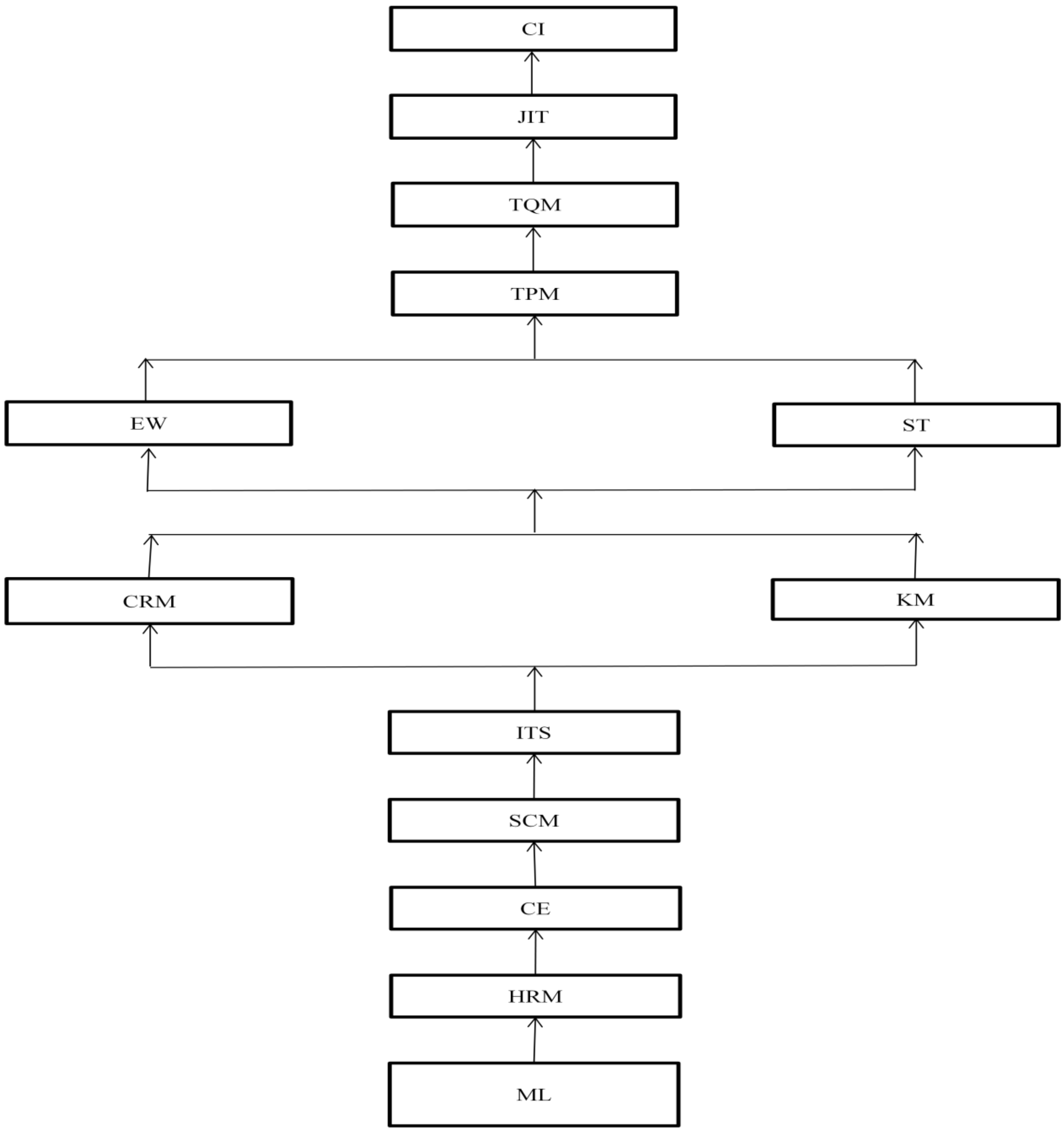

Figure 6.2: ISM of SMSAI

LEGENDS: ML- Management commitment and Leadership; HRM- Human Resource Management; CE- Concurrent Engineering; SCM- Supply Chain Management; ITS- Information Technology System; KM- Knowledge Management; CRM- Customer Relationship Management; ST-Standardization; EW- Elimination of Waste; TPM- Total Productive Maintenance; TQM- Total Quality Management; JIT- Just-In-Time Production; CI- Continuous Improvement.

Figure 6.1 and Figure 6.2 represent the structural linkages between pillars that form part of the process that helps explain the role of different pillars in the context of LE process. Finally the ISM's are checked for conceptual inconsistency, and in case of any inconsistency necessary modifications are carried out.

6.6.3 Analysis of ISM models

While there are similarities across both diagrams, there is a conspicuous difference in terms of a particular pillar appearing at a particular level in the respective LE model. These differences finally account for the structures of the two LE models being different. It was found that a total of six elements, like CI, EW, ST, ML, HRM and JIT pillars are similar hierarchical in both the models. This shows that both the organizations are following some kind of sequential process to achieve excellence in organizational activities. ML is having direct influence on HRM in both models. The roles of other seven elements (ITS, CE, SCM KM, TQM, CRM and TPM) shows significant difference in both the models. For LSAI organization, ML is observed to form the highest level which drives HRM, SCM, CRM, and KM whereas in SMSAI organization only ML was observed at the top and impacted only HRM. In LSAI organization, TQM directly effects on EW, ST along with JIT. However in the SMSAI, EW and ST are driving TQM. In both the cases, TPM directly contributes to TQM. In both cases, CI was driven by EW and ST, whereas LSAI organization JIT also included. Hence, it is observed that both organizations have some similarity, however, at critical points, it is observed that there is a significant difference appearing.

6.6.4 Development of SEM for statistical testing

In order to verify the proposed ISM for two organizations, structural equation modelling (SEM) using AMOS 18.0v was performed to check the statistical fit. The inputs for this analysis are respondents data (200 responses) collected from the previous section of study. The averages of responses for the elements under each pillar were used and the directional relationships among pillars established using ISM method so as to check the goodness of fit. The model fit parameter values of SEM for LSAI and SMSAI ISM's are given in Table 6.11. It was found that SMSAI ISM complies to the range of model fit parameters while LSAI ISM fit is very much under permissible range of model fit parameter values. It can thus be proposed here that LSAI ISM presents a statistically valid LE practices model.

Table 6.11 Model fit parameter values of SEM for SMSAI and LSAI ISM's

Model parameters	SMSAI ISM	LSAI ISM	Permissible range
χ^2	7867.7	3212.317	-
df	1292	1596	-
χ^2/df	6.08	2.01	≤3
GFI	0.856	0.934	≥0.90
AGFI	0.835	0.845	≥0.80
RMSEA	0.021	0.019	≤0.10
CFI	0.668	0.934	≥0.90
RMR	0.165	0.117	≤0.14

6.6.5 MICMAC analysis for ISM's of cases

The MICMAC analysis is used for analyzing the driver power and the dependence power of the developed ISM's. In this, the pillars are classified into four groups based on the driving power and dependence power. The MICMAC analysis principle is based on the multiplication properties of matrices. If element 'i' directly influences element 'k' and if element 'k' directly influences element ‘j’, any change affecting element ‘i’ have repercussions on element ‘j’. This is because there is an indirect connection between elements ‘i’ and ‘k’. Table 6.7 and Table 6.8 show the final reachability matrix with an additional row and a column. The names of pillars are listed in the first column while the first row contains pillar numbers only. The last column is labelled ‘driver’ and the last row is labelled ‘dependence’. The number under the driver column indicates the number of nodes (or pillars) that pillar can reach (directly and indirectly). The dependence metric tells us how many nodes can reach a particular node (or pillars). For example, in LSAI organization shown in Table 6.7 for element 1 (HRM) the driver value is 12 and the dependence value is 5. This means that element number reaches twelve other elements (in this context ‘influences’ twelve other elements) and is reached (or ‘influenced’) by only five elements. X-Y charts are plotted for each element based on its driver and dependence scores. Figure 6.3 and Figure 6.4 show driver dependence diagram for LSAI and SMSAI respectively.

These plotted pillars can be categorized into certain types based on the quadrant or position they occupy on the driver dependence plot as shown in Figure 6.3 and Figure 6.4. The four regions in the Figure 6.3 and Figure 6.4 are divided into 4 sectors namely: I-Autonomous; II-Dependent; III-Relay; IV-Independent (Driver). Independent or driver pillars do not depend on other pillars. They tend to be located in the top left quadrant of the driver dependence chart. These pillars tend to be crucial because they form a set of key factors either contributing to inertia or to movement. These pillars are also considered as entry variables in the system. Relay pillars appear on the top right of the driver dependence chart. Relay elements are, by nature, factors of instability since any action on them has consequences on the other pillars, in case certain conditions on other influential variables are met.

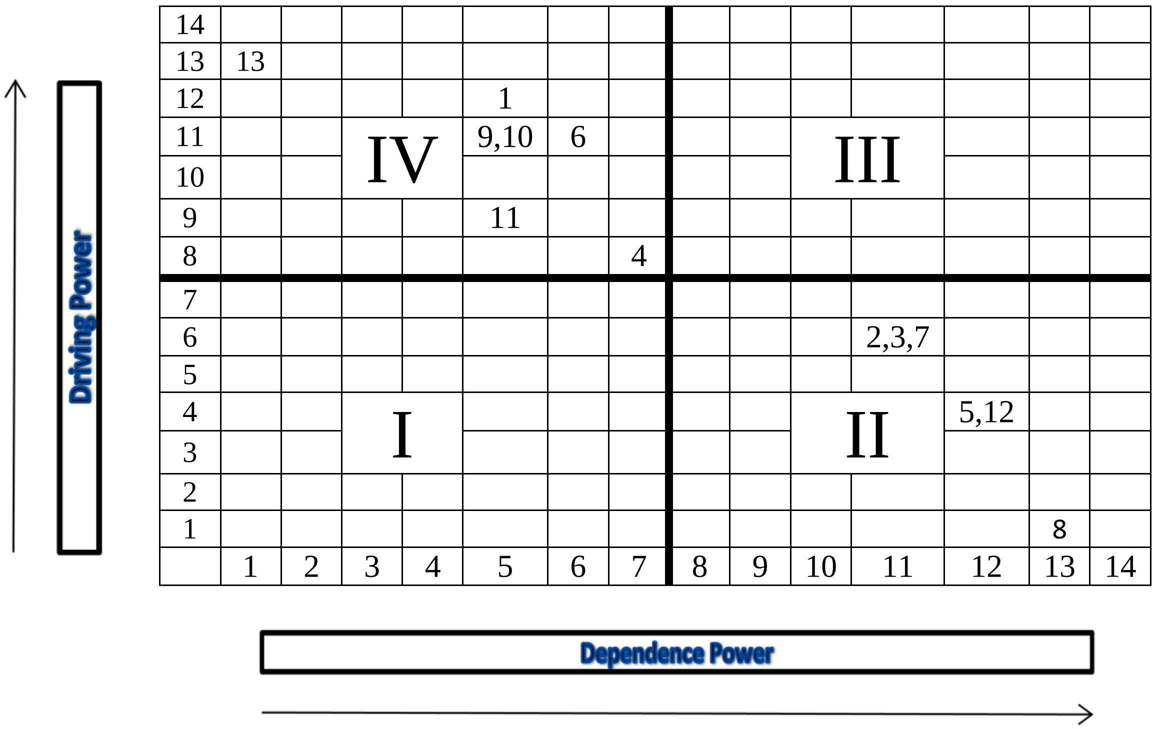

Figure 6.3: Driver dependence diagram for LSAI

Depended pillars can be considered as the result variables. These pillars are located at the bottom right quadrant of the driver dependence chart .From a practical standpoint, depended pillars are used to judge the effectiveness of managerial inputs. In other words, a business or a process is evaluated based on the quality of the outcomes and how the business processes were (or are expected to be) used to leverage the inputs to produce the outcomes. Autonomous variables are pillars or factors that have relatively few connections in the system. These elements are situated in the bottom left quadrant.

Independent/driver elements

MICMAC analysis revealed that for both the organizations, the driver elements were HRM (1), ML (13), ITS (4), SCM (6), CRM (9), KM (10) and CE (4) in both ISM models. In general, such drivers have high influence on the system that is being studied and cannot be changed or manipulated easily.

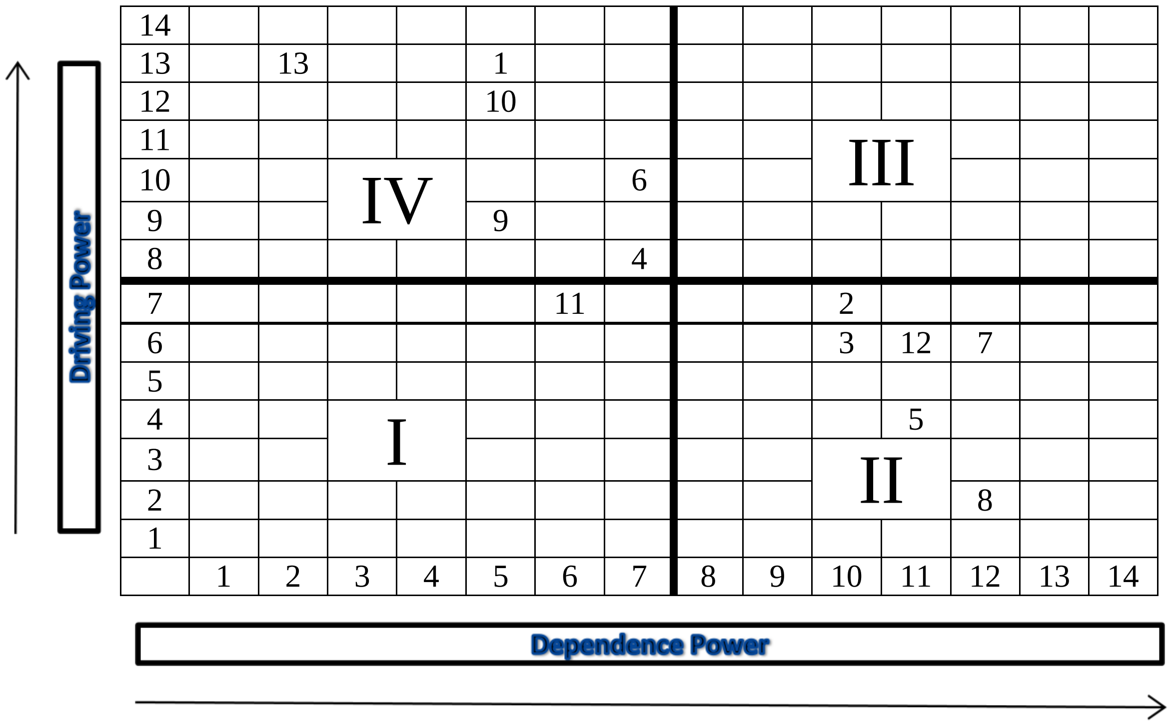

Figure 6.4: Driver dependence diagram for SMSAI organization

ML practices focuses more on leadership/senior management's role in building the organizational structure, administrative processes, and enabling the human resources towards LE culture. Hence, it is imperative that ML was a crucial driver for both the LE models. HRM was another driver which was commonly found in the organizations as they focus to improve skill of the organizational employees. It observed in the ISM structure that HRM was driven by ML but HRM emerged as a driver for both the organizations. This contradiction is possible because of the importance given to HRM by both the organizations. In any organization, HRM describes the objectives and positioning of new techniques introduced in the organization like cost reduction, cycle time reduction, competitive advantage, first mover advantage etc. The LE success is mostly dependent on ML and HRM practices in organization.

Relay element

EW (2) is identified as the relay element in SMSAI organizations. EW is often referred as an important pillar in the implementation LE framework in the organization. EW, by nature has pillar of instability since any action on it has a consequence on the other pillars, in case certain conditions on other influential pillars are met.

Dependent elements

It was observed that total five elements i.e. ST (3), TPM (5), TQM (7), CI (8) and JIT (12), were in the dependent element category from both ISM models. EW was also included in dependent element in SMSAI ISM model. From a practical standpoint, these pillars were used to judge the effectiveness of driver pillars input. All these five pillars were observed as variables due to the fact that these pillars help in execution part of LE which highly depends on other independent variables. For example, the pillar like TQM focuses on the various quality improvement programmes which support the LE to enhance processes quality and performance of processes.

Autonomous elements

It can be observed from the Figure 6.3 and Figure 6.4 that both LSAI and SMSAI doesn't have any autonomous variables in its system.

Similarity in both organizations

It was observed that both the organizations recognize the almost same pillars as driver and independent pillars but their levels of influence like driver power and dependency power are different. Both LSAI and SMSAI do not have any autonomous variables in their system. Despite the similarity between two LE models, LSAI model was found to have higher statistically fit and hence has been considered to be representative of LE practices framework in Indian manufacturing industry.

6.7 Discussion

The initial part of the chapter has performed validity and reliability analysis on a proposed LE framework in Indian manufacturing industries. The sample data collected from two hundred Indian manufacturing industries. The study performed correlation analysis to find out the relationship among pillars and elements within the pillars also. The study revealed high inter item correlation mean value among elements and pillars also. It clearly indicated that all the pillars and elements were played major role in the implementation of LE principles in the organizations. The study also revealed overall mean of each pillar was more than 3.5, which indicated all the elements under each pillar plays very important role in successful implementation of LE principles in the organizations. The study also revealed all the pillars have high Cronbach's alpha value, which was more than 0.8. It is clearly demonstrated high internal consistency shown among the elements and pillars also. Hence, the study clearly indicated that LE framework fulfils the requirement of reliability analysis.

The study has performed validity analysis on the proposed LE framework with the same sample data. The study has performed content, criterion-related as well as construct validity analysis. The content validity analysis was performed with the help of twelve team members. They were suggested minor corrections to improve questionnaire to improve the format of the questionnaire. The criterion-related validity analysis revealed bivariante correlation among pillars were high, which was 0.3 and above. It clearly indicates all the elements in the proposed LE framework plays important role. The study also performed construct validity analysis.The objective of the construct validity is to check whether it measures the concept or the theoretical construct it was anticipated or designed to measure. The validity analysis can be performed on any scale, but the scale should satisfy two conditions: One is unidimenasionality of the scale (Gerbing and Anderson, 1988). Unidimensionality is used to check whether all elements are concentrated towards the main target of the measurement (Gerbing and Anderson, 1988; Pierce et al., 1989). Secondly, the scale should fulfill the reliability conditions as well (Ahire et al, 1996). The study revealed all elements were shown uni-dimensionality towards pillars of the framework. Similarly, all the pillars were shown uni-dimensionality towards LE. The study has already performed reliability analysis, which was shown high cronbach's alpha value. The proposed LE framework has fulfilled the requirements of validity and reliability analysis. Hence, the study concluded the proposed LE framework can useful to implement in Indian manufacturing industry.

The chapter also presents a research methodology to perform ISM methodology for proposed framework of LE in Indian manufacturing industry by using two automotive organization cases. The ISM was performed on two exemplary cases of LE organizations in Indian manufacturing industry. These cases (LSAI and SMSAI) were selected on the basis of capital scale of the organization. From the discussion presented in the research work, it is clear as to how the framework for LE practices in Indian manufacturing industry works. So far as managerial implications of this framework are concerned, the study provides guidelines for achieving standardization in all the functions involved in developing a LE organization. It also helps a manager to understand cause and effect relationship among various important pillars in LE process. Such relationships can be used to diagnose any form of malfunctioning that may exist in LE practices. From researcher's point of view, the framework provides a definitive set of pillars which in totality present the overall picture of LE and which overcomes the deficiency that exists in standard theory of integrating various field of LE practices together. The framework highlights the importance of various relationships and interrelationships between pillars of LE practices in Indian manufacturing industry. However, there are some shortcomings of the present study. Firstly, the case study focused only on the automotive sector. However, in India, several other sectors of manufacturing industry like apparel, process, machinery sectors are also growing and LE practices are very prevalent in them. Therefore several more studies can be conducted to test the applicability of the given LE practices framework in these sectors too. Secondly, the pillars of LE practices are solely based on existing literature (although respondents in the survey are practitioners), hence more pillars in consultation with practitioners can be added to increase the robustness and comprehensiveness of LE practices framework. In the end, authors would like to suggest to the researchers to deliberate on the proposed framework and make efforts to enhance the applicability of this framework so that all the sectors of manufacturing industry not only in India but in other countries too, can also benefit from adopting the proposed LE practices.

6.8 Conclusion

In this chapter survey responses were analyzed for various issues of LE. Various statistical tools like the descriptive statistics; reliability analysis, principle component analysis, structure evaluation modelling, and correlation analysis are being used. The data was analyzed using SPSS (version 18.0 V). The proposed framework for LE was tested on the basis of 200 responses received from Indian manufacturing industries. The study was found Pearson's one tailed correlation coefficient value. It is revealed that a strong correlation exists among pillars and elements under pillars also in the proposed framework. The study also performed reliability analysis to find out the reliability of the pillars and its respective elements, which revealed all pillars and its elements have high cronbach's alpha value. The study also performed unidimensionality of the pillars as well as elements under the pillars, which revealed that all the pillars were unidimensional towards LE and all the elements were unidimentional towards respective pillars of the framework.

The ISM model based on expert opinions were formed which enabled comparison of the structural model from the different pillars of LE practices. The ISM was developed for two automobile component manufacturing organizations as test cases. The two manufacturing organizations selected from the automobile sector, which were LSAI and SMSAI.The relationships among pillars of LE framework were obtained from ISM, and later were subjected to statistical testing for model fit by using SEM. The input to SEM was the respondent’s (200 responses) data used in previous study in the present chapter. The major findings revealed that ISM of LSAI organization statistically fits for LE framework, and finally MICMAC analysis was conducted to find the driving and dependency power of each element of the statistically fit LE practices framework. Finally, the study concludes the proposed LE framework is suitable to implement in Indian manufacturing industries.

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Chapter 7

Conclusion

Manufacturing industries in India face a great deal of competition from global market. In order to be competitive globally, Indian manufacturing industries have to work most efficiently and improve their productivity. Under such circumstances, many industries are implementing various change management programmes such as total quality management, total productive maintenance, six-sigma, lean enterprise (LE) systems, etc. Among such programmes, LE has attracted by the industry professional significantly, which is reflected in the number of case studies and participating organization in the surveys that are reported in the literature related to LE. However, many organizations are failing in their attempts to implement LE effectively. Although many publications and books are available that discuss LE, it is ironical to hear about such failures. It is happening because there is an improper understanding of LE among the professionals. Many researchers have discussed that implementation of LE requires a thorough understanding about the 'LE elements', 'steps to implement LE', and 'relationship between LE elements'. Although there is a vast literature of almost 25 years behind LE, it seems to be highly incoherent with respect to use of elements and inconsistent in strategy formulation. Hence, there is a need to study the LE practices in Indian manufacturing industry and also find out a definitive set of pillars (or practices) of LE that can lead to LE excellence framework.

The present research is aimed at examining some of the fundamental concerns in field of LE. Therefore, the main objective of the research is to identify and investigate these issues and suggest appropriate solutions by carrying out the following:

In chapter 2, a review of the extant literature on content oriented classification and empirical research in LE is presented. It provided a comprehensive assessment of research methodology and content of LE in 499 research articles in LE published between 1990 and 2009. Twenty seven journals were short listed out of 173 journals for the purpose. From the view point of LE content, a systematic classification and a critical analysis is carried out so as to identify research gaps in content of LE as well as to recommend directions for future research. Similarly, the study filtered all empirical related articles to perform review on empirical research methodology in LE and also recommend future direction to improve quality of research. The research revealed that most of the articles were conceptual in nature and empirical articles were increasing at aggressive rate than in the past. The review also revealed that less research work was performed on LE and lean product development research streams. The review also revealed that organizations concentrated to remove a few types of wastes instead of removing the complete set of LE wastes. It is reflected in usage various LE elements. The review also revealed very few popular LE elements discussed by various research articles. The chapter also reviewed a set of 178 empirical research articles in LE research with respect to empirical research methodology and its related aspects using empirical research approach given by Flynn et al. (1990). The present status of empirical research methodology in LE was demonstrated in this chapter. From complete analysis it concluded that empirical research in LE is increasing at a faster rate than ever but at the same time researchers should break the monotony in their research purpose for theory building and start focusing on various realms of theory verification as well. The researchers were also left various aspects of empirical research unexplored such as significance of triangulation of data, alternate research designs other than survey and case studies, longitudinal data collection and larger sample sizes. Although there were a couple of literature reviews in LE, none of them focused exclusively on empirical research methodology in LE. Also the sample size of chapters with respect to number of chapters (449 chapters) as well as number of journals (27 journals) is larger than ever considered for literature review in LE. This study spans a longer time period of 20years (1990-2009).

Chapter 3, the research study is used to find out implementation status of LE principles across Indian manufacturing organizations through the empirical survey methodology. The questionnaire has been used to collect data from Indian manufacturing industry. The research has collected 180 samples and performed descriptive statistical analysis. It reveals that many manufacturing organizations were in initial transition stage and concentrating mostly in-plant operations instead of collaboration in all levels of business with suppliers and customers. It also found that drivers for implementation of LE were customer satisfaction and organizational continuous improvement programme. It also reveals that barriers to implement LE principles were employee resistance, implementing a few elements of LE principles instead of the complete package of LE framework, budget constraints and lack of understanding of LE principles to shop floor managers. Finally, it concludes that Indian manufacturing organizations have to conduct continuous learning programmes to improve understanding of LE principles as well as maintain their motivation level in apex point. It also suggested that a systematic LM framework is needs to Indian manufacturing organizations, which will act as clear cut guiding torch to the organization managers to implement LE principles across organization.

In chapter 4, the study described the various steps undertaken to perform study on the concept of LE by researchers/ consultants and certain frameworks as given by various academicians /

researchers / consultants were identified. Reliability and validity analysis of these existing frameworks for LE performed done through extensive survey of Indian manufacturing industry. The results of this survey was discussed in this chapter, and the results show that although majority of the frameworks were displaying high level of reliability, very few frameworks displayed unidimensionality with respect to the construct i.e. LE it measures. Apart from this, it also found that none of the existing frameworks were considered critical elements such as knowledge management, customer relationship management, total productive maintenance etc. Hence, the study concluded that none of the existing frameworks can be used in their present form and therefore, a new LE framework is required to address all these gaps. At the end of this survey it suggested that there is a requirement for an appropriate framework for assessing manufacturing, supply chain and product development in the Indian changed scenario which suits the Indian milieu and provides strategic directions for the Indian industry. This new framework could be to some extent also being a combination of existing frameworks, which may provide a better model for the Indian context. Similar kind of analysis was performed on lean manufacturing, lean supply chain management and lean product development framework also. These empirical studies helps to find out a set of 44, 44, 46, and 42 lean elements from LE, lean manufacturing, lean supply chain and lean product development framework respectively with the help of frequency distribution analysis.

In chapter 5, a critical review of LE frameworks is discussed. In this chapter an attempt was made to highlight the inconsistencies present in existing LE frameworks. Many authors from around the globe were proposed frameworks for LE. However, no review was reported till date that critically assesses the inconsistencies and inadequacies present in these frameworks. Thus, 31 frameworks in LE published in various journals, books and Google portals were critically reviewed. The main objective of review is to identify the inconsistencies in LE frameworks by examining selected frameworks under the light of some basic research questions. The answer to these questions highlighted the inconsistencies present in existing frameworks and inadequacy in development of framework for LE. It was also established that case study research design dominates among possible modes of verifying the frameworks. The review also aimed to find out what elements were used for making frameworks and the degree of standardization of these elements in LE domain. It observed that plethora of elements were used to make frameworks which were highly scattered in various bodies of knowledge such as 'operations management', 'product develop', 'supply chain', 'strategic management', ' human resources', 'best practices' and a few others. In such scenario majority of frameworks were composed by novelty basis hence there did not exist any standard set of elements. Based on the results of reviewing these articles, an attempt is made here to propose a framework that possibly suggests a way to achieve coherency in use of LE frameworks. The proposed framework pillars were identified with the help of comparative analysis and elements were identified with the help of empirical investigation performed in chapter 4 and twelve team members. Hence, the research hopes the proposed framework helps researchers in reducing the inconsistencies that may occur in future LE frameworks. Finally, the present study has proposed LE framework with 13 pillars and 106 elements under those pillars.

In chapter 6, firstly, an extensive survey of Indian industries was performed for empirical investigation for the usefulness and comprehensiveness of the developed framework of LE for the Indian Industry. This chapter discussed the observations and analysis of the second questionnaire which were sent to the same industries as in the fourth chapter. The second questionnaire was developed to check the reliability and validity of the developed framework.

The developed framework for the LE was validated. Secondly, a path analysis for proposed framework of LE in Indian manufacturing industry using interpretive structural modelling (ISM) and structural equation modelling (SEM) was performed. The ISM is done using two LE principles practicing Indian manufacturing industry. The study has identified two organizations, one of the organizations is practicing aggressively LE principles and another organization is also implemented effectively, but lacking in LE implementation as compared with first organization due to its limitations. Based two organizations practices, ISM model were developed. The relationships among pillars of LE framework were obtained from ISM, and later were subjected to statistical testing of model fit by using SEM. The input to SEM was the respondent's (200 responses) data used in previous study. The major findings revealed that ISM based on organization, is statistically fit for LE framework.

Summary of contributions of the research

The contribution of this research may be summarized in the following manner:

- Extensive review of the literature related to LE performed and it also revealed 31 existing LE frameworks apart from identifying the various research gaps.
- Validity and reliability of the 31 existing LE frameworks were carried out using an exploratory survey. In addition, it was found none of the frameworks was suitable in existing form for Indian manufacturing scenario.
- A structured framework for LE was proposed. This framework can be helpful the managers to identify the various initiatives they have to consider to progress towards being the finest or excellent manufacturer.
- The managerial implications of LE framework can be vastly felt. Majority of companies in India are new on LE implementations. The present study thus provides

managers an insight as to what are the pillars of LE and what constitutes these pillars. The thirteen pillars also span all the areas of business right from product development to customer relationship management. Indian managers can use these pillars within a framework to achieve excellence in LE implementation. The main benefit of the study is that the thirteen pillars proposed with the help of conceptual analysis as well as group of experts belonging to academicians, professionals and consultants. The elements of the study are derived with the assist of empirical study from Indian manufacturing sector.

- The proposed framework was validated using one more exploratory survey and path analysis. Various statistical analyses were used, which confirmed that the developed framework is legitimate in the Indian scenario. Finally, the applicability of the proposed framework for LE is verified in two organizations with the assistance of ISM model as well as reliability and validity analysis.
- Researchers must focus on verifying already existing theories in LE instead of proposing new theories. It is observed that a huge amount of literature on theory building is built up and must get examined. It is also emphasized that large body of LE requires further standardized terminology and elements.
- It would be better theory development taken place if researchers focus on developing countries also. In our review too same truth is discovered that very less empirical studies in LE are published for developing and underdeveloped countries. It is right time for the researchers to start focusing on these avenues of cost reduction and profit making.
- There exists a huge gap between theory building and theory verification, if we consider total number of articles considered in this present study. The rate at which theory building is progressing is ahead of theory verification. A discipline can only reach

maturity phase if rate of theory building and verification is same. Hence to bring the discipline to maturity phase, researchers must concentrate for theory verification as well.

- Research designs like case study and survey are highly encouraged by researchers. LE being strategic in nature should be supported by other research design like panel study and focus group as well. Such research designs are used of qualitative data based on respondents' experience. However, many researchers have pointed out that there exists a huge gap between theory and practice in LE research. Panel study and focus group research design are helpful to bridge this gap.
- There is a plight of use of longitudinal data collection in LE empirical research. Since longitudinal studies span a longer period of research, they can provide clear image of the system and its dynamic nature as compared with cross sectional data based study.
- Authors communicating empirical studies should report several characteristics of respondents like industry, work experience of respondents, designation etc. Such characteristics help the reader to judge the quality and reliability of the reported facts and theories. Although getting complete demographic data is not an easy task but researchers may take help of survey professionals in order to overcome this problem.
- Size of the samples especially in survey research is very much restricted. The fact is highlighted by the figure that 88% of research articles were based on sample size of 300. In that too 70% still falls below 100 samples, which is quiet an eye opener. Researcher should try to use larger sample size along with an effort to achieve higher response rates in survey research.
- In quantitative data analysis techniques (DAT's), descriptive statistics takes the highest position in comparison to other DAT's. Descriptive statistics are important but for establishing a theory, inferential statistics (hypothesis testing) is even more essential. It is

thus imperative for researchers to adopt higher forms of DAT's along with descriptive statistics. Although mutli-variate DAT's like structural equation modelling are being used in LE empirical research but the amount does not seem to be sufficient enough. Researchers give more attention to mutil-variate DAT's as well and should not neglect univariate/bivariate DAT's at the same time.

- Researchers should explore the opportunity of triangulation as it is established to be appropriate for theory verification. It also enhances the judgmental correctness of the researcher.
- The proposed framework for LE requesting the researchers to volunteer in checking reliability and validity so as to establish a refined and coherent set of LE pillars and constructs so that the divergence of LE discipline can be restricted.
- The research implications of the study are far reaching as it has already been highlighted earlier that huge literature on LE lacks standardization. These pillars of LE can be used as standard or as coherent set of elements for future research purposes as these pillars and elements are derived from extant literature and empirical study from Indian manufacturing industry.
- The proposed LE framework provides a definitive set of elemnents which present overall picture of LE and overcomes the deficiency of standard in theory of LE.

Recommendations for Future Work

The work presented in thesis addresses several issues related to LE in empirical research literature, Indian manufacturing industry and theory. However there are several issues that remained unaddressed due to limitation on the scope of work. Hence avenues for further research are suggested, which are given as follows:

- Empirical research literature in LE is not limited only in four publications but rather its presence is felt in publications all around the world, hence aiming researchers may validate the findings of present literature review in publications which were not considered for article selection. For example: Omega-international journal of management science be included in the sample meant for reviewing the articles.
- Only five sectors across the Indian manufacturing scenario were included in the study and the response rate was reasonably good as compared with the present empirical research works. However, this study can promote various other sectors and the reliability / validity of the proposed framework in other sectors can also be tested.
- The five sectors taken by for study can further be refined to various classification within each sector like for process industries cement, pharmacy, chemical, etc. and their level of LE identified.
- Each LE framework pillar can be developed further by identifying their implementation elements individually.
- This questionnaire can be further enhanced so that it can be used for a global survey also. It is also possible that comparison can be made between the Indian companies and their global counterparts.
- Relationships amongst various pillars of LE were identified using bivariate correlation (Pearson's Correlation) which indicated positive correlations among the 13 pillars. This relationship can be further analyzed using other methods.

Appendix - A: List of papers reviewed in chapter 2

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Appendix - B: Survey questionnaire

An empirical survey for implementation of lean principles in Indian manufacturing industry

Objective of the study: The objective of the study is to analyze the implementation of lean principles in Indian manufacturing industry.

- To identify the popular lean elements used across Indian manufacturing organizations.
- To identify the driving force to implement lean principles across Indian manufacturing organizations.
- To identify the main obstacles to implement lean principles across Indian manufacturing organizations.
- To identify the benefits of implementation of lean principles in Indian manufacturing industries and etc.

Structure of the survey questionnaire: The Questionnaire consists of two parts: Part A consists of organization information and competitiveness, whereas Part B consists of various aspects of implementation of lean principles.

Confidentiality: The responses given are confidential and organization information will not be disclosed at any time. Your input is critical for providing Indian manufacturing industry with valuable information regarding lean implementation practices and potential for improvement.

Part A: Organization Information

1. **Organization Name:**

2. **Name of respondent (optional):**

3. **Manufacturing plant location:**

4. **Major products:**

5. **Total turnover:**

6. **What is the vision and mission statement of your organization**?

7. **Is your company a single facility or multi facility operation?**

(a) Single Facility (b) Multi Facility

8. **Indicate ownership type of your company**

(a) India owned (b) Foreign owned (c) Joint venture

9. **Please indicate your area of work**

(a) Corporate or operating Management (b) Engineering and Design
(c) Production Management (d) Marketing and sales
(e) Administration and human resources (f) Other________________

10. **Do you count your company as a _________ (choose one)?**

(a) Small and Medium Scale enterprise (b) Large Scale enterprise.

11. **Compared to three years ago, the total annual sales of your organization in 2012 is:**
(a) Smaller (b) Same (c) Larger

12. **Does your organization follow a lean manufacturing strategy? If not, please specify your philosophy or practices**

(a) Yes
(b) No (Please write practice your organization implementing ______________)

13. **How long did your organization following the lean principles?**
(Please 'Tick' mark).

(a) More than one month and less than 1 year (b) More than1 year and less than 5Years
(c) More than 5 and less than10 Years (d) More than 10Years

14. **Area of lean principles applied in your organization**

(a) Human resources (b) Product development
(c) Manufacturing (d) Supply chain functions.
(e) Whole organization

15. **Which part of the organization lean principles can implemented to get maximum benefits?**

(a) Human resource (b) Product development
(c) Manufacturing (d) Supply chain functions
(e) Whole organization

16. **The type of manufacturing Industry, which you are working**

(a) Automobile industry
(b) Machine Equipment industry
(c) Process industry
(d) Electronics Industry
(e) Textile industry

17. **What kind of external support is utilizing by your organization to implement lean principles? Please tick as many options as relevant**

(a) Customers
(b) Further/ Higher Education
(c) Local Enterprise Centre
(d) Specialist Consultancy
(e) Suppliers
(f) None

Other (Please specify): ___________________________________.

Part B: Various of aspects of Implementation of lean principles

18. **What is your understanding of lean manufacturing?**

S.No.	Understanding of lean principles	Tick mark
1	Waste reduction	
2	Continuous improvement	
3	Tools and techniques to improve operations	
4	Headcount reduction	
5	A system to organizing and managing product development, supplier and customer relations	
6	Toyota production system	
7	A fully integrated management philosophy	
8	A way of life	

19. **What are the drive forces to implement lean principles in your organization? (1-less drive force to 5-more drive force)**

S.No.	Drive force to implement lean principles	1	2	3	4	5
1	To increase market share					
2	To increase flexibility					
3	The need for survival from internal constraints					
4	Development of key performance indicators					
5	Part of the organisation's continuous programme					
6	Drive to focus on customers					
7	Desire to employ world best practice					

20. **What is the level of implementation of lean manufacturing principles in below given key areas of your organization? (1-No Implementation to 5-complete implementation)**

S.No.	Key area of implementation	1	2	3	4	5
1	Scheduling					
2	Inventory					
3	Material handling					
4	Equipment					
5	Work processes					
6	Quality					

S.No.	Key area of implementation	1	2	3	4	5
7	Employees					
8	Layout					
9	Suppliers					
10	Customers					
11	Safety and ergonomics					
12	Product design					
13	Management and culture					
14	Tools and techniques					

21. **What are obstacles of implementing lean principles in your organization?**
    (1-low obstacle to 5-more obstacle)

S.No.	Obstacles	1	2	3	4	5
1	Lack of top management support					
2	Failure of past lean projects					
3	Financial benefits not recognized					
4	Does not practice what is preached					
5	Lack of time to implement					
6	Systematic lean approach missing or lack of know- how to implement					
7	Company culture or national culture					
8.	Budget constraints					
9.	Employee resistance					
10	Backsliding to the old ways of working					
11	Lack of communication					
12	Lack of manufacturing facility					
13	Lack of support from suppliers					
14	Frequent design changes					
15	The customer orders are highly fluctuating/varying					
16	Lower volume of demand					

22. **What kind lean waste your organization has able to remove from manufacturing process industry with help of lean principles.**
    (1-not able to remove to 5-Completely able to remove)

S.No.	Type of waste	1	2	3	4	5
1	Over production					
2	Waiting					
3	Unnecessary motion					
4	Transportation					
5	Inventory					
6	Inappropriate processing					
7	Defects					

23. **What are the benefits your organization received from lean principles implementation? (1-less benefit to 5-highest benefit)**

S.No.	Benefits	1	2	3	4	5
1	Improved flexibility					
2	Improved response time					
3	Improved quality					
4	Increased profit					
5	Decreased inventory					
6	Reduced waste or scrap					
7	Improved productivity					
8	Reduced cost					

24. **Which of the following elements of lean have you heard or aware of before? (1-Not aware to 5-Completely aware)**

S.No.	Tools/ Elements/ Constructs	1	2	3	4	5
1	Cross functional team working					
2	Multi skilled workforce					
3	Kanban system					
4	Pull production					
5	One piece flow					
6	Pokayoke or Mistake proofing or Defect prevention					
7	Statistical process control					
8	Just-in-time delivery (from suppliers and within workstations)					
9	Small lot production					
10	Takt time or takt calculations					
11	Value stream mapping					
12	Successive checking					
13	Defects at source (Self inspection)					
14	Multi functional training					
15	Elimination of waste					
16	Single minute exchange of dies					
17	Commonization and standardization of parts					
18	Layout change or U-shaped cell					
19	Workload or Line balancing					
20	Order based production					
21	WIP reduction					
22	Design for manufacturing					
23	Continuous improvements					
24	Work standardization					
25	Use of problem solving tools					
26	Total productive maintenance					

S.No.	Tools/ Elements/ Constructs	1	2	3	4	5
27	Visual control					
28	Cycle time and lead time reduction					
29	Use of EDI with suppliers					
30	Sole sourcing or supplier reduction					
31	Rewards and recognition					
32	Standardized containers					
33	Information sharing with suppliers					
34	Production smoothing or Load levelling					
35	Synchronization					
36	Maintain spare capacity					
37	Quality circles					
38	Supplier proximity					
39	Supplier involvement in design					
40	Total quality management					
41	Cellular manufacturing					
42	Group technology					
43	Computer integrated manufacturing (CAD/CAM/CAE)					
44	Supplier training and development					
45	Use of multiple small machines					
46	Process sharing					
47	Andon (Warning lights)					
48	Jidoka (Autonomation)					
49	Long term supplier relationship					
50	Product and process simplification					
51	Flat organisation structure					
52	Storage space reduction					
53	Long term employment					
54	Automation					
55	Quality certification (suppliers and manufacturers)					
56	New process or Equipment technologies					
57	Suggestion schemes					
58	Mixed model manufacturing / scheduling					
59	Elimination of buffers					
60	Communication between employees					
61	Employee empowerment					
62	Employee participation					
63	Job rotation or Flexible job responsibilities					
64	Job enlargement or Nagara system					

S.No.	Tools/ Elements/ Constructs	1	2	3	4	5
65	Safety improvement programs					
66	Housekeeping (5S)					
67	Focused factory production					
68	Rolling production plans					
69	Concurrent engineering					

25. **Please indicate the implementation status lean tools in your organization?**
(1- not implemented to 5- completely implemented)

S.No	Group/category	Lean elements	1	2	3	4	5
1	Process & equipment						
1.1		Statistical process control					
1.2		Pokayoke					
1.3		Work standardization					
1.4		Value stream mapping					
1.5		Single minute exchange of dies					
1.6		One piece flow					
1.7		Takt time					
1.8		Successive checking					
1.9		Commonization and standardization of parts					
1.10		Standardized containers					
1.11		Continuous improvements					
1.12		Use of problem solving tools					
1.13		Design for manufacturing					
1.14		Layout change or U-shaped cell					
1.15		Maintain spare capacity					
1.16		Defects at source (Self inspection)					
1.17		Total productive maintenance					
1.18		Total quality management					
1.19		Synchronization					
1.20		Cellular manufacturing					
1.21		Group technology					
1.22		Computer integrated manufacturing (CAD/CAM/CAE)					
1.23		Andon (Warning lights)					
1.24		Use of multiple small machines					
1.25		Process sharing					
1.26		Housekeeping (5S)					

S.No	Group/category	Lean elements	1	2	3	4	5
1.27		New process or Equipment technologies					
1.28		Automation					
1.29		Product and process simplification					
1.30		Focused factory production					
1.31		Concurrent engineering					
2	Manufacturing planning and control						
2.1		Kanban system					
2.2		Small lot production					
2.3		Pull production					
2.4		Workload or Line balancing					
2.5		Visual control					
2.6		Production smoothing or Load leveling					
2.7		Order based production					
2.8		Elimination of waste					
2.9		WIP reduction					
2.10		Cycle time and Lead time reduction					
2.11		Jidoka (Autonomation)					
2.12		Rolling production plans					
2.13		Mixed model manufacturing/ scheduling					
3	Human resource management						
3.1		Cross functional team working					
3.2		Multi skilled workforce					
3.3		Rewards and recognition					
3.4		Multi functional training					
3.5		Quality circles					
3.6		Suggestion schemes					
3.7		Safety improvement programs					
3.8		Communication between employees					
3.9		Flat organisation structure					
3.10		Long term employment					
3.11		Employee participation					
3.12		Job enlargement or Nagara system					
3.13		Employee empowerment					
3.14		Job rotation or Flexible job responsibilities					

S.No	Group/category	Lean elements	1	2	3	4	5
4	Supply chain management						
4.1		Sole sourcing or Supplier reduction					
4.2		Information sharing with suppliers					
4.3		Just-in-time delivery (from suppliers and within workstations)					
4.4		Use of EDI with suppliers					
4.5		Supplier proximity					
4.6		Supplier involvement in design					
4.7		Supplier training and development					
4.8		Quality certification (suppliers and manufacturers)					
4.9		Elimination of buffers					
4.10		Storage space reduction					
4.11		Long term supplier relationship					

21. Which of the following lean elements have been used in avoiding familiar lean wastes in your organization?

S.No.	Tools and Techniques	Over production	Waiting	Unnecessary motion	Transportation	Inventory	Inappropriate processing	Defects
1	Kanban system							
2	Single minute exchange of dies							
3	Pull production							
4	Small lot production							
5	Cross functional teams							
6	Continuous improvement program or Kaizen							
7	One piece flow							
8	Multi skilled workforce							
9	Total productive maintenance							
10	Statistical process control							
11	Total quality management							

S.No.	Tools and Techniques	Over production	Waiting	Unnecessary motion	Transportation	Inventory	Inappropriate processing	Defects
12	Multi functional training							
13	Defects at source (Self inspection)							
14	Just-in-time delivery (from suppliers and within workstations)							
15	Visual control							
16	Work standardization							
17	Cycle time and Lead time reduction							
18	Sole sourcing or Supplier reduction							
19	Long term supplier relationship							
20	Suggestion schemes							
21	Quality circles							
22	Pokayoke or Mistake proofing or Defect prevention							
23	Housekeeping (5S)							
24	Focused factory production							
25	Communication between employees							
26	Production smoothing or Load levelling							
27	Job rotation or Flexible job responsibilities							
28	Use of problem solving tools							
29	Job enlargement or Nagara system							
30	Flat organisation structure							
31	Value stream mapping							
32	Mixed model manufacturing/sche							

S.No.	Tools and Techniques	Over production	Waiting	Unnecessary motion	Transportation	Inventory	Inappropriate processing	Defects
	duling							
33	New process equipment/technologies							
34	Product and process simplification							
35	Quality certification (suppliers and manufacturers)							
36	Elimination of buffers							
37	Design for manufacturing							
38	Storage space reduction							
39	Information sharing with suppliers							
40	Layout change or U-shaped cell							
41	Workload or Line balancing							
42	Automation							
43	Use of EDI with suppliers							
44	Safety improvement programs							
45	Process sharing							
46	Commonization and standardization of parts							
47	Supplier involvement in design							
48	Supplier training and development							
49	Rewards and recognition							
50	Computer integrated manufacturing							
51	Links with customer for quality							
52	Synchronization							
53	Takt time or takt							

S.No.	Tools and Techniques	Over production	Waiting	Unnecessary motion	Transportation	Inventory	Inappropriate processing	Defects
	calculations							
54	WIP reduction							
55	Standardized containers							
56	Long term employment							
57	Rolling production plans							
58	Use of multiple small machines							
59	Successive checking							
60	Andon (Warning lights)							
61	Jidoka (Autonomation)							
62	Employee empowerment							
63	Employee participation							
64	Cellular manufacturing							
65	Group technology							
66	Order based production							
67	Concurrent engineering							
68	Maintain spare capacity							
69	Supplier proximity							

Appendix - C: List of LE related framework papers reviewed in Chapter 4 and Chapter 5

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Appendix - D: Survey questionnaires

Survey questionnaire for empirical study of "Lean Enterprise Frameworks" in Indian manufacturing industry

Introduction: Academic researchers/ Consultants/ Organizations have proposed various frameworks for Lean Enterprise, which are available in literature. The frameworks for Lean Enterprise are identified from existing literature. The frameworks and its elements are presented in this questionnaire. The Questionnaire consists of two parts: Part A consists of organization profile and competitiveness, whereas Part B consists of lean enterprise frameworks and its elements. The aim of the study is given below:

Aim: An empirical analysis of lean enterprise frameworks in Indian manufacturing industry

PART A: Organization Profile

1. **Name of Organization:**

2. **Name of respondent and designation (optional):**

3. **Total years of experience:**

4. **Plant location:**

5. **What are the major products of the organization?**

6. **Total turnover of the organization:**

7. **What is the vision statement of your organization?**

8. **What is the mission statement of your organization?**

9. **Please indicate the number of employees in your organization.**

(a) 0-50 (b) 51-499 (c) 500-2000

(d) 2001-4999 (e) Over 5000

10. **Do you consider your organization as a?**

(a) Small enterprise (b) Medium enterprise (c) Large enterprise

11. **Does your organization following lean activities / tools?**

(a) Yes (b) No

12. **If yes, how long did your organization following the lean activities / tools?**

(a) Less than 1 year (b) 1 Year (c) 2 Years

(d) More than 2 Years

13. **Where the lean activities/ tools are implemented in your organization?**

(a) Whole organization/ enterprise (product development, manufacturing and distribution)

(b) Product development

(c) Manufacturing

(d) Physical distribution system (Supply chain management)

(e) Other (Please specify)

14. **Indicate the growth of the organization in terms of revenue in the last 3 years:**

(a) Over 20% (b) Between 10-20% (c) Less than10% (d) Negative growth

15. **Indicate the growth of organization in terms of profit in the last 3 years:**

(a) Over 20% (b) Between 10-20% (c) Less than 10% (d) Loss

16. **Please indicate your organization's performance over the last 3 years compared to your competitors:**

(a) Excellent

(b) Good

(c) Average

(d) Below Average

(e) Poor

17. **Please indicate the rank of priority for the objectives of your organization (1 for highest and 6 for lowest). Please add any additional objective and its rank of priority if not included below:**

Organization objectives	**Rank**	**Organization objectives**	**Rank**
Profit		Global focus	
Growth		Maintain competitive advantage	
Survival		Social responsibility	
Other (please specify)		Other (please specify)	

18. **Please indicate the rank for the competitive priorities of your organization (1 for highest and 10 for lowest). Please add any additional competitive priority and its rank if not included below:**

Competitive priority	**Rank**	**Competitive priority**	**Rank**
Cost		Delivery/Availability	
Flexibility		Morale	
Environmental consciousness		Customer relations	
Quality and reliability		Productivity	
Innovation		Sustainability	
Global focus		Other (please specify)	

PART B

Guidelines for filling the questionnaire:

Please consider each framework in isolation/ individually to achieve Lean Enterprise Excellence.
Please read the framework and its elements carefully and indicate/assign the actual level of importance of the elements of the framework mentioned as per your expertise in your organization.
The level of importance is given from 1 to 5 wherein: 1: Unimportant 2: Ordinary Important 3: Important 4:Very Important 5: Absolutely Important

Framework 1: Cynthia R. Cook and John C. Graser						
S.No.	Constructs / Elements / Tools	1	2	3	4	5
1.1	Design and development					
1.2	Manufacturing					
1.3	Purchasing & suppliers					
1.4	Human resources					

Framework 2: CTRM Aero Composites						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
2.1	Just in time					
2.2	Jidoka or Autonomous					
2.3	Standardized work					
2.4	Total productive maintenance					
2.5	Six sigma					
2.6	Single minute exchange of die					
2.7	Andon					
2.8	Key performance indicator scorecard					
2.9	Kanban					
2.10	Employee involvement					
2.11	Kaizen					
2.12	Heijuka					
2.13	Employee empowerment					
2.14	Leadership					
2.15	Team work					
2.16	Customer focus culture					

Framework 3: Lean Breakthru Consulting Group						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
3.1	Lean design system					
3.2	Lean production system					
3.3	Value chain synchronization					
3.4	Daily persistent improvement					

Framework 4: J.E. Boyer Company, Inc.						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
4.1	Cellular manufacturing					
4.2	5S housekeeping and workplace organization					
4.3	Setup reduction					
4.4	Pull Systems					
4.5	Kanban					
4.6	Kitting					
4.7	Parallel design					
4.8	Fast quoting					
4.9	Standard components					
4.10	Focus on value in your design					

Framework 5: Michael G. Beason						
S.No.	Constructs/Elements/Tools	1	2	3	5	5
5.1	Operational excellence					
5.2	Workforce development					
5.3	Leadership and culture					

Framework 6: Conner G						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
6.1	Total Quality Management					
6.2	Lean Manufacturing Techniques					
6.3	Sales , Production and Inventory					
6.4	Total Organization buy in					
6.5	Vision					

Framework 7: Christer Karlsson and Pär Åhlström						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
7.1	Lean procurement					
7.2	Partners					
7.3	Lean distribution					

Framework 8: Unlimited Possibilities Consulting LLC						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
8.1	People / Systems					
8.2	Lean office					
8.3	Lean operations					

Framework 9: Fraunhofer IPA Slovakia						
S.No.	Constructs/ Elements/ Tools	1	2	3	4	5
9.1	Productivity audit					
9.2	Value stream mapping					
9.3	Time economy					
9.4	Ergonomics					
9.5	Elimination of wasting - kaizen, workshops, projects – DMAIC					
9.6	Work standardization					
9.7	Quality at source					
9.8	Manufacturing cells					
9.9	Teamwork					
9.10	Visualization					
9.11	Low-cost automation					
9.12	Kanban, Drum-buffer-rope, continuous flows					
9.13	Total productive maintenance					
9.14	Setup time reduction					
9.15	Lean layout and lean logistics					
9.16	Lean administration					
9.17	Lean development and ramp up					
9.18	Value innovations					

Framework 10: The MIT Lean Aerospace Initiative						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
10.1	Leverage lean capability for business growth					
10.2	Optimize the capability and utilization of assets					
10.3	Provide capability to manage risk, cost, schedule, and performance					
10.4	Resource and empower program development efforts					
10.5	Establish a requirements definition process to optimize life-cycle value					
10.6	Utilize data from the extended enterprise to optimize future requirement definitions					

Framework 10: The MIT Lean Aerospace Initiative						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
10.7	Incorporate customer value into design of products and processes					
10.8	Incorporate downstream stakeholder values into products and processes					
10.9	Integrate product and process development					
10.10	Define and develop supplier network					
10.11	Optimize network-wide performance					
10.12	Foster innovation and knowledge-sharing throughout the supplier network					
10.13	Utilize production knowledge and capabilities competitive advantage					
10.14	Establish and maintain a lean production system					
10.15	Align sales and marketing to production					
10.16	Distribute product in lean fashion					
10.17	Enhance value of delivered products and services to customers					
10.18	Provide post delivery service, support, and sustainability					

Framework 11: James Crawford						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
11.1	Lean product development					
11.2	Lean customer management					
11.3	Lean partner and supplier management					
11.4	Information and capital flow					
11.5	The end to end process					
11.6	Value stream to the customer					
11.7	Lean enterprise management					

Framework 12: Natalie J. Sayer and Bruce Williams						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
12.1	Ensure personal safety					
12.2	Continuous growth and learning					
12.3	Celebrate wins					
12.4	Engaged-challenged employees					
12.5	Effective communication					
12.6	Standardized work					
12.7	Continuous flow-pull					
12.8	Just in time					

Framework 12: Natalie J. Sayer and Bruce Williams						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
12.10	Perform value-added activities					
12.11	Elimination of waste					
12.12	Employee security					

Framework 13: Hank Czarnecki and Nicholas Loyd						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
13.1	One piece flow					
13.2	Cellular/takt time					
13.3	Visual steam mapping					
13.4	Total productive Maintenance					
13.5	kanban/pull system					
13.6	Kaizen					
13.7	Quick change over					
13.8	Quality at source					
13.9	7 wastes					
13.10	Cross functional teams					
13.11	Standardized work					
13.12	5S/ workplace organization					
13.13	Visual factory					
13.14	Point of use storage					

Framework 14: David Scrimshire						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
14.1	Job standardization					
14.2	Visual controls					
14.3	Kanban					
14.4	Set time reduction					
14.5	5S					
14.6	7 wastes					
14.7	Statistical process control / quality tools					

Framework 15: Louis Columbus						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
15.1	Seamless information flow					
15.2	Integrated product and process capability					
15.3	Make decisions at the lowest levels					

Framework 15: Louis Columbus						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
15.4	Maturation, identify and optimize enterprise flow					
15.5	Vision, relationship based on mutual trust and commitment across the extended enterprise					
15.6	Maintain stability in changing environment					
15.7	Align and involve all stakeholders to achieve lean vision					
15.8	Optimize capability and utilization of people					
15.9	Focus on external and internal environment					
15.10	Nurture a learning environment					
15.11	Stakeholder value (effectiveness)					
15.12	Overall efficiency					
15.13	System availability					
15.14	System-level flexibility					

Framework 16: Unisa Strategic Partnerships						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
16.1	Cellular & workflow layout					
16.2	Just in time & kanban pull systems					
16.3	Quick changeover or Single minute exchange of die					
16.4	Corrective action					
16.5	Stop & fix					
16.6	Person & machine separation					
16.7	Andon					
16.8	Visual predictable quality					
16.9	Quick response					
16.10	Mistake proofing					
16.11	Statistical process control					
16.12	Six sigma					
16.13	Work leveling / work balance					
16.14	Takt & pitch time					
16.15	Engagement of work force team work					
16.16	Continuous improvement (Kaizen)					
16.17	Reduction of waste					
16.18	Visual management					
16.19	Performance measurement					
16.20	Total productive maintenance					
16.21	Overall equipment efficiency					

Framework 16: Unisa Strategic Partnerships						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
16.22	5S					
16.23	Standardized work & process control planning					
16.24	Quality fundamentals					
16.25	Process & value stream mapping					
16.26	Root cause analysis					

Framework 17: Industrial Solutions, Inc						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
17.1	Workplace order and cleanliness					
17.2	Just-in-time production					
17.3	Six-sigma quality					
17.4	Visual management					
17.5	Empowered teams					
17.6	Continuous pursuit of perfection					

Framework 18: Patrick Lucansky , Robert Burke and Lee Durchame						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
18.1	Positive, clear communication					
18.2	Ensure no blame culture					
18.3	Work through cross functional teams					
18.4	Staff involvement at every stage					
18.5	Process maps on display for comments					
18.6	Remove non value added steps, hand offs, rework loops					
18.7	Agree design principle with all					
18.8	Fix the root cuase not synptoms					
18.9	Ensure solution supports department interfaces					
18.10	Continuous Improvement					

Framework 19: Wyrick Enterprises						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
19.1	Customer focus					
19.2	Empower people					
19.3	Lean leadership					
19.4	Reduced batch size					
19.5	Quick set ups					
19.6	5S+ safety					

Framework 19: Wyrick Enterprises						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
19.7	Visual work force					
19.8	Standard work					
19.9	Point of use storage					
19.10	Production leveling					
19.11	Total productive maintenance					
19.12	Process capability					
19.13	Lead time reduction					
19.14	Optimize value stream					
19.15	Optimize decision levels					
19.16	Value creation					
19.17	Lean business management					
19.18	Integrated sourcing					
19.19	Integrated enterprise solutions					
19.20	Common processes					

Framework 20: Karen Martin & Associates						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
20.1	Performance metrics					
20.2	Value stream alignment					
20.3	Setup/ Batch size reduction					
20.4	Pull system					
20.5	Work balancing/ Level loading					
20.6	Multifunctional workers					
20.7	Co-location/ cells					
20.8	Quality at the source					
20.9	Standard work					
20.10	Visual management / 5S					
20.11	Root cause analysis					
20.12	Metrics based process mapping					
20.13	Motivated workforce					
20.14	Value stream/waste identification					
20.15	Customer definded value					
20.16	Daily kaizen/Kaizen events					

Framework 21: Matt Zayko						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
21.1	Managing the factory & supply chain					
21.2	Designing the process					
21.3	Designing the product					
21.4	Product development					
21.5	People development					
21.6	Lean enterprise management & leadership					

Framework 22: Archfield Consulting Group						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
22.1	5S					
22.2	Visula management					
22.3	Pull production					
22.4	Waste elimination					
22.5	Standard work					
22.6	Zero defects					
22.7	Work force empowerment					
22.8	Continuous improvement (Kaizens)					

Framework 23: Productivity Inc						
S.No.	Constructs/Elements/Tools	1	2	3	4	5
23.1	Supply chain					
23.2	Production flow					
23.3	Total productive maintenance					
23.4	Six sigma					
23.5	Lean six sigma in administration					
23.6	Workplace organization					
23.7	Leadership development					
23.8	Continuous improvement management					
23.9	People empowerment and team Work					
23.10	Policy deployment					

Framework 24: Rick Bohan and Pete Accorti						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
24.1	Lean metrics					
24.2	5S throughout the plant					
24.3	Visual factory					

Framework 24: Rick Bohan and Pete Accorti						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
24.4	Standardized work					
24.5	Total productive maintenance					
24.6	Quick die change					
24.7	Value stream mapping					
24.8	Structured team problem solving					

Framework 25: Moffitt Associates Consultants						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
25.1	Time based competition					
25.2	Value adding management					
25.3	Just in time operations					
25.4	Total quality management					
25.5	Employee involvement					
25.6	5S					
25.7	5 Whys					
25.8	Visual control					
25.9	Single minute exchange of die					
25.10	Andon					
25.11	Pull					
25.12	Mistake proofing					
25.13	Standard work					
25.14	Physical layout					
25.15	Quality at source					
25.16	Takt time					
25.17	Jidoka					
25.18	Multi skilled work force					
25.19	Kanban					
25.20	Total productive maintenance					
25.21	Continuous improvement					
25.22	Policy deployment					
25.23	Six sigma					
25.24	Process measures					
25.25	Supermarket					
25.26	Line stop					
25.27	Supplier partnership					
25.28	Adjustment elimination					

Framework 25: Moffitt Associates Consultants						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
25.29	Right Sizing (Batch size reduction)					
25.30	Material resource specialist					
25.31	Hanadashi					
25.32	Voice of customer					

Framework 26: Jochen Czabke						
S.No.	Constructs/ Elements/ Tools	1	2	3	4	5
26.1	Just in time					
26.2	Total productive maintenance					
26.3	Total quality management					
26.4	New product development					
26.5	Marketing					
26.6	Partnering with suppliers /customers					
26.7	Environmental practices and support functions					
26.8	Team work					
26.9	People and partner					
26.10	Continuous improvement & learning					
26.11	Supply chain management					
26.12	Customer relationship management					
26.13	Waste reduction					

Framework 27: Lean Enterprise LLC.						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
27.1	Value Stream managers					
27.2	Lean daily management					
27.3	Root cause problem solving					
27.4	Knowing if we are winning or losing					
27.5	Associate standard work play book					
27.6	Leader standard work					
27.7	Engineer standard work					
27.8	Takt time					
27.9	Hour by hour boards					
27.10	Set up wheel board / schedule					
27.11	Volume levers					
27.12	Material pull maintenance					
27.13	5S/Visual management reviews					

Framework 27: Lean Enterprise LLC.						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
27.14	Total productive maintenance					
27.15	Total predictive maintenance					

Framework 28: Broadsight Analysis Lean Enterprise						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
28.1	Just in time					
28.2	Kanban					
28.3	Kaizen					
28.4	Reduce waste					
28.5	Standard components					
28.6	Smooth flow					
28.7	Cell operations					
28.8	Quality circles					
28.9	Lean culture					

Framework 29: Canford Consultants						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
29.1	Standardized work					
29.2	Kaizen					
29.3	Just in time					
29.4	Total productive maintenance					
29.5	Heijunka					
29.6	Jidoka (Autonomation)					
29.7	Management deployment systems					
29.8	Kaizen event					
29.9	Continuous improvement					
29.10	Customer focus					
29.11	Smooth operation flow					

Framework 30: Just- in-Time Enterprise Institute						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
30.1	Just in time logistics					
30.2	Business flow kaizen					
30.3	Value stream management					
30.4	Professional development					
30.5	Lean training					
30.6	Value stream flow and kaizen					

Framework 31: Doug Howardell						
S.No.	Constructs/ Elements/Tools	1	2	3	4	5
31.1	Value stream mapping					
31.2	The 5S					
31.3	Kaizen events					
31.4	Kanban					
31.5	Error-proofing					
31.6	Line balancing					
31.7	Six sigma quality					
31.8	Visual management					
31.9	Cellular manufacturing					
31.10	Single piece flow					
31.11	Self-inspection					

Appendix - E: Selected results from chapter 4 and chapter 6

Component Matrix[a]

	Component
	1
F1.1	.805
F1.2	.690
F1.3	.821
F1.4	.818

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component		
	1	2	3
F2.1	.358	.554	.463
F2.2	.396	.548	.602
F2.3	.323	.276	.744
F2.4	.703	-.452	.093
F2.5	.742	.130	-.226
F2.6	.790	.232	-.306
F2.7	.640	.333	-.360
F2.8	.681	.424	-.354
F2.9	.733	.352	-.299
F2.10	.754	-.028	.089
F2.11	.701	-.059	-.070
F2.12	.786	.014	-.092
F2.13	.733	-.232	.258
F2.14	.658	-.491	.136
F2.15	.647	-.562	.053
F2.16	.593	-.536	.220

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F2.1	.253	-.041	.764
F2.2	.202	.023	.882
F2.3	-.051	.204	.831
F2.4	.238	.807	.023
F2.5	.705	.338	.089
F2.6	.828	.276	.093
F2.7	.799	.092	.063
F2.8	.866	.057	.127
F2.9	.839	.156	.147
F2.10	.470	.537	.260
F2.11	.505	.485	.102
F2.12	.610	.482	.146
F2.13	.269	.711	.280
F2.14	.165	.816	.024
F2.15	.170	.837	-.083
F2.16	.053	.826	.050

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

Component Matrix[a]

	Component
	1
F3.1	.814
F3.2	.821
F3.3	.770
F3.4	.726

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component	
	1	2
F4.1	.577	.031
F4.2	.649	-.344
F4.3	.716	-.185
F4.4	.774	.336
F4.5	.739	.589
F4.6	.646	.609
F4.7	.807	-.215
F4.8	.840	-.112
F4.9	.767	-.314
F4.10	.698	-.349

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F4.1	.441	.374
F4.2	.725	.120
F4.3	.682	.287
F4.4	.412	.737
F4.5	.231	.917
F4.6	.145	.876
F4.7	.772	.318
F4.8	.736	.420
F4.9	.800	.215
F4.10	.767	.145

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component
	1
F5.1	.893
F5.2	.848
F5.3	.933

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component
	1
F6.1	.876
F6.2	.836
F6.3	.849
F6.4	.904
F6.5	.556

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component
	1
F7.1	.618
F7.2	.938
F7.3	.840

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component
	1
F8.1	.845
F8.2	.880
F8.3	.799

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component		
	1	2	3
F9.1	.633	.464	.117
F9.2	.674	.310	.330
F9.3	.720	.261	.487
F9.4	.684	.278	-.114
F9.5	.730	-.052	-.014
F9.6	.627	-.254	.240
F9.7	.798	-.238	.247
F9.8	.615	-.483	.037
F9.9	.665	-.418	.060
F9.10	.644	-.385	.429
F9.11	.751	.236	.279
F9.12	.613	.524	-.144
F9.13	.764	.128	-.394
F9.14	.667	.130	-.257
F9.15	.791	.037	-.215
F9.16	.775	-.177	-.441
F9.17	.752	-.217	-.408
F9.18	.777	-.106	-.098

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F9.1	.299	.083	.730
F9.2	.157	.308	.735
F9.3	.063	.438	.793
F9.4	.513	.139	.525
F9.5	.463	.439	.358
F9.6	.200	.636	.266
F9.7	.301	.724	.374
F9.8	.352	.699	.009
F9.9	.365	.692	.092
F9.10	.062	.821	.263
F9.11	.246	.381	.702
F9.12	.491	-.086	.649
F9.13	.783	.165	.341
F9.14	.614	.170	.349
F9.15	.659	.323	.368
F9.16	.826	.363	.109
F9.17	.787	.393	.082
F9.18	.558	.467	.309

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

Component Matrix[a]

	Component			
	1	2	3	4
F10.1	.622	.447	.158	.234
F10.2	.600	.476	.242	-.202
F10.3	.677	.313	.144	-.432
F10.4	.656	-.014	.330	-.374
F10.5	.712	-.049	.304	.050
F10.6	.550	-.030	.408	.280
F10.7	.598	-.247	.268	-.238
F10.8	.789	.106	-.157	-.229
F10.9	.747	.158	-.350	.223
F10.10	.786	.128	-.283	-.088
F10.11	.692	.234	-.376	.021
F10.12	.753	-.137	-.281	-.217
F10.13	.737	-.135	-.314	.104
F10.14	.696	-.349	-.250	.122
F10.15	.695	-.372	-.062	.013
F10.16	.703	-.514	.095	-.045
F10.17	.667	-.273	.380	.330
F10.18	.660	.326	.075	.514

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

Rotated Component Matrix[a]

	Component			
	1	2	3	4
F10.1	.272	.051	.367	.675
F10.2	.182	.040	.703	.397
F10.3	.300	.156	.791	.152
F10.4	.141	.470	.655	.094
F10.5	.206	.527	.359	.393
F10.6	.030	.478	.171	.539
F10.7	.156	.596	.408	.038
F10.8	.609	.255	.504	.142
F10.9	.745	.128	.130	.410
F10.10	.709	.190	.372	.211
F10.11	.727	.027	.272	.270
F10.12	.683	.370	.329	-.019
F10.13	.706	.357	.087	.194
F10.14	.630	.523	-.019	.112
F10.15	.479	.613	.109	.086
F10.16	.360	.787	.141	.034
F10.17	.124	.711	.068	.497
F10.18	.365	.137	.106	.805

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 17 iterations.

Component Matrix[a]

	Component	
	1	2
F11.1	.539	.641
F11.2	.703	.395
F11.3	.701	.160
F11.4	.666	-.557
F11.5	.826	-.337
F11.6	.804	-.349
F11.7	.670	.291

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F11.1	-.037	.837
F11.2	.251	.767
F11.3	.408	.592
F11.4	.867	.041
F11.5	.836	.310
F11.6	.828	.287
F11.7	.297	.667

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component	
	1	2
F12.1	.586	.641
F12.2	.562	.703
F12.3	.694	.359
F12.4	.776	.069
F12.5	.722	-.034
F12.6	.719	-.220
F12.7	.633	-.467
F12.8	.768	-.345
F12.9	.812	-.255
F12.10	.791	-.090
F12.11	.752	.030
F12.12	.707	-.105

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F12.1	.145	.856
F12.2	.092	.896
F12.3	.389	.678
F12.4	.615	.478
F12.5	.625	.362
F12.6	.724	.204
F12.7	.785	-.050
F12.8	.833	.126
F12.9	.821	.226
F12.10	.714	.353
F12.11	.616	.432
F12.12	.651	.295

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component		
	1	2	3
F13.1	.759	.331	.256
F13.2	.658	.470	.290
F13.3	.609	.378	-.004
F13.4	.556	-.125	.549
F13.5	.700	.004	.425
F13.6	.705	-.314	.160
F13.7	.699	-.494	.170
F13.8	.761	-.363	-.102
F13.9	.716	-.332	-.224
F13.10	.651	-.145	-.469
F13.11	.773	-.137	-.135
F13.12	.680	-.074	-.302
F13.13	.729	.412	-.291
F13.14	.624	.492	-.241

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F13.1	.183	.663	.526
F13.2	.024	.714	.476
F13.3	.195	.653	.224
F13.4	.146	.137	.765
F13.5	.234	.340	.706
F13.6	.550	.122	.551
F13.7	.639	-.030	.594
F13.8	.750	.149	.369
F13.9	.768	.166	.237
F13.10	.751	.315	-.039
F13.11	.653	.345	.301
F13.12	.643	.367	.101
F13.13	.405	.788	.035
F13.14	.266	.787	.008

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Component Matrix[a]

	Component	
	1	2
F14.1	.838	-.070
F14.2	.833	-.378
F14.3	.693	.594
F14.4	.771	.338
F14.5	.752	-.275
F14.6	.672	-.472
F14.7	.505	.446

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F14.1	.694	.474
F14.2	.884	.233
F14.3	.163	.898
F14.4	.385	.749
F14.5	.757	.262
F14.6	.820	.058
F14.7	.110	.665

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component		
	1	2	3
F15.1	.739	-.207	-.031
F15.2	.816	-.061	-.077
F15.3	.730	-.326	-.082
F15.4	.801	-.318	-.286
F15.5	.725	-.124	-.338
F15.6	.682	.213	-.502
F15.7	.800	.407	-.147
F15.8	.710	.525	.094
F15.9	.639	.614	.124
F15.10	.714	.161	.325
F15.11	.647	-.133	.238
F15.12	.729	-.186	.512
F15.13	.677	-.215	.381
F15.14	.779	-.252	-.109

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F15.1	.583	.459	.197
F15.2	.610	.417	.361
F15.3	.656	.456	.089
F15.4	.833	.339	.129
F15.5	.744	.191	.255
F15.6	.697	-.074	.521
F15.7	.469	.194	.754
F15.8	.208	.286	.814
F15.9	.108	.238	.856
F15.10	.197	.588	.507
F15.11	.320	.586	.218
F15.12	.215	.857	.219
F15.13	.277	.739	.165
F15.14	.678	.438	.176

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Component Matrix[a]

	Component				
	1	2	3	4	5
F16.1	.706	-.006	-.402	-.173	-.077
F16.2	.647	.498	-.036	-.075	.186
F16.3	.673	.326	-.158	-.128	-.104
F16.4	.586	.223	-.155	-.320	.415
F16.5	.698	.071	-.413	-.049	.231
F16.6	.665	-.092	.063	.313	.108
F16.7	.690	-.097	-.002	.458	-.010
F16.8	.756	.009	.072	.079	.098
F16.9	.802	-.152	-.053	.143	-.001
F16.10	.794	.019	.068	.113	-.129
F16.11	.674	.175	.223	.353	-.250
F16.12	.615	.425	.412	-.193	-.216
F16.13	.547	.515	.226	.068	.209
F16.14	.487	.516	-.142	.100	.122
F16.15	.593	.564	.009	.281	-.075
F16.16	.653	-.131	.491	-.356	.076
F16.17	.676	-.468	.085	-.041	.183
F16.18	.640	-.475	.033	.236	.316
F16.19	.644	-.402	.104	.257	.177
F16.20	.665	-.203	.360	-.309	.229
F16.21	.710	-.080	.083	-.184	-.350
F16.22	.729	-.351	-.144	-.166	-.216
F16.23	.716	-.271	-.365	-.007	-.260
F16.24	.785	-.068	-.235	-.343	-.073
F16.25	.716	.049	-.292	.039	-.097
F16.26	.732	-.152	.301	-.049	-.255

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
F16.1	.731	.277	.210	.100	.175
F16.2	.245	.733	.105	.203	.244
F16.3	.503	.556	.067	.202	.062
F16.4	.308	.435	.133	.240	.577
F16.5	.554	.395	.338	-.016	.378
F16.6	.208	.331	.625	.140	-.034
F16.7	.269	.357	.679	.034	-.181
F16.8	.310	.407	.485	.301	.070
F16.9	.464	.294	.582	.222	-.005
F16.10	.419	.419	.444	.315	-.132
F16.11	.207	.540	.417	.238	-.395
F16.12	.164	.610	-.026	.620	-.167
F16.13	-.030	.743	.163	.267	.115
F16.14	.194	.698	.080	-.030	.130
F16.15	.200	.818	.168	.032	-.156
F16.16	.153	.158	.288	.818	.126
F16.17	.336	-.049	.645	.391	.184
F16.18	.211	.000	.827	.175	.179
F16.19	.209	.057	.767	.219	.033
F16.20	.176	.123	.394	.697	.270
F16.21	.560	.209	.207	.487	-.188
F16.22	.696	-.001	.385	.341	-.020
F16.23	.785	.082	.390	.085	-.068
F16.24	.730	.233	.205	.352	.214
F16.25	.604	.378	.315	.061	.028
F16.26	.367	.208	.389	.577	-.233

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 12 iterations.

Component Matrix[a]

	Component
	1
F17.1	.711
F17.2	.721
F17.3	.761
F17.4	.796
F17.5	.771
F17.6	.785

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Component Matrix[a]

	Component	
	1	2
F18.1	.638	.427
F18.2	.601	.656
F18.3	.676	.441
F18.4	.688	.103
F18.5	.735	-.138
F18.6	.784	-.380
F18.7	.803	-.390
F18.8	.801	-.343
F18.9	.798	-.062
F18.10	.735	.000

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F18.1	.262	.722
F18.2	.097	.884
F18.3	.285	.755
F18.4	.494	.490
F18.5	.675	.323
F18.6	.857	.158
F18.7	.878	.160
F18.8	.848	.197
F18.9	.680	.422
F18.10	.593	.435

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component			
	1	2	3	4
F19.1	.580	.509	.425	.027
F19.2	.748	-.003	.431	-.117
F19.3	.768	.154	.243	-.005
F19.4	.678	.289	-.252	.168
F19.5	.647	.540	-.157	.026
F19.6	.647	.273	-.080	-.484
F19.7	.724	-.134	-.281	-.263
F19.8	.734	.021	-.158	-.438
F19.9	.631	-.288	-.007	.058
F19.10	.742	-.332	.142	-.206
F19.11	.677	-.158	.454	-.129
F19.12	.622	-.179	.472	.216
F19.13	.626	.039	.220	.546
F19.14	.737	-.116	-.319	.239
F19.15	.808	-.136	-.166	.098
F19.16	.630	.326	-.332	.356
F19.17	.704	.354	-.021	-.127
F19.18	.799	-.337	-.156	-.077
F19.19	.823	-.268	-.215	.069
F19.20	.603	-.330	-.094	.187

Extraction Method: Principal Component Analysis. a. 4 components extracted.

Rotated Component Matrix[a]

	Component			
	1	2	3	4
F19.1	-.130	.665	.494	.273
F19.2	.297	.729	.148	.343
F19.3	.286	.589	.377	.318
F19.4	.341	.133	.667	.235
F19.5	.095	.192	.732	.393
F19.6	.167	.208	.289	.761
F19.7	.598	.084	.208	.532
F19.8	.427	.183	.200	.708
F19.9	.601	.301	.118	.138
F19.10	.604	.461	-.030	.381
F19.11	.349	.710	-.005	.283
F19.12	.378	.729	.108	-.046
F19.13	.375	.546	.492	-.242
F19.14	.689	.101	.467	.110
F19.15	.670	.257	.373	.235
F19.16	.345	.057	.783	.073
F19.17	.184	.322	.515	.484
F19.18	.769	.241	.146	.334
F19.19	.781	.216	.291	.242
F19.20	.663	.223	.163	.017

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 11 iterations.

Component Matrix[a]

	Component		
	1	2	3
F20.1	.549	.625	-.119
F20.2	.620	.339	-.029
F20.3	.723	.280	-.126
F20.4	.749	-.181	-.345
F20.5	.694	-.322	-.404
F20.6	.667	-.415	.323
F20.7	.618	-.490	-.024
F20.8	.771	-.244	.073
F20.9	.657	-.079	-.020
F20.10	.669	.137	.398
F20.11	.629	.018	.530
F20.12	.695	.475	-.205
F20.13	.667	.378	.023
F20.14	.733	.019	.417
F20.15	.704	-.203	-.184
F20.16	.726	-.181	-.245

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F20.1	.052	.832	.105
F20.2	.220	.622	.254
F20.3	.370	.652	.233
F20.4	.761	.345	.120
F20.5	.837	.214	.060
F20.6	.518	-.035	.672
F20.7	.699	-.047	.363
F20.8	.609	.215	.493
F20.9	.483	.305	.333
F20.10	.163	.394	.666
F20.11	.141	.247	.771
F20.12	.277	.812	.126
F20.13	.203	.667	.317
F20.14	.263	.330	.730
F20.15	.667	.267	.236
F20.16	.698	.310	.192

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Component Matrix[a]

	Component
	1
F21.1	.778
F21.2	.855
F21.3	.874
F21.4	.861
F21.5	.817
F21.6	.733

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component
	1
F22.1	.724
F22.2	.763
F22.3	.609
F22.4	.741
F22.5	.807
F22.6	.861
F22.7	.796
F22.8	.800

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Component Matrix[a]

	Component		
	1	2	3
F23.1	.703	-.392	.379
F23.2	.728	-.383	.424
F23.3	.764	-.303	.095
F23.4	.765	-.360	-.343
F23.5	.760	-.270	-.452
F23.6	.714	.191	-.433
F23.7	.717	.420	-.170
F23.8	.727	.489	-.114
F23.9	.755	.223	.304
F23.10	.561	.544	.433

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F23.1	.853	.192	.164
F23.2	.888	.170	.196
F23.3	.674	.435	.205
F23.4	.454	.789	.060
F23.5	.337	.855	.104
F23.6	.057	.726	.452
F23.7	.079	.478	.696
F23.8	.078	.426	.770
F23.9	.489	.165	.669
F23.10	.267	-.111	.845

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Component Matrix[a]

	Component
	1
F24.1	.592
F24.2	.721
F24.3	.732
F24.4	.774
F24.5	.686
F24.6	.708
F24.7	.762
F24.8	.728

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
F25.1	.564	.524	-.096	.071	-.138	-.135	-.061
F25.2	.704	.406	-.247	.259	.193	-.091	.031
F25.3	.794	.218	-.108	.043	-.129	-.345	-.150
F25.4	.715	.236	.232	-.237	-.119	-.355	-.002
F25.5	.598	.076	.398	-.293	-.234	-.273	.232
F25.6	.558	-.204	.362	.387	.289	-.018	-.109
F25.7	.635	-.198	.181	.242	-.032	-.204	.021
F25.8	.668	-.147	.083	.437	-.234	.018	-.101
F25.9	.773	-.217	-.050	-.081	-.070	.226	-.200
F25.10	.651	-.250	-.095	-.048	.330	-.160	-.003
F25.11	.781	-.114	-.153	-.134	.145	.052	-.070
F25.12	.589	.418	-.017	-.226	.098	.333	.176
F25.13	.570	.177	.226	-.002	-.060	.454	.331
F25.14	.592	.476	-.040	.260	.334	.034	.163
F25.15	.660	.223	.290	.119	-.059	-.158	.068
F25.16	.740	-.218	-.139	-.009	-.188	.127	-.194
F25.17	.654	-.384	.128	-.143	-.289	.012	-.098
F25.18	.641	-.036	.337	.198	.144	.040	-.358
F25.19	.694	-.218	.020	-.288	.178	.086	-.319
F25.20	.695	-.153	.524	-.085	.156	.169	-.036
F25.21	.545	-.115	.568	-.005	-.062	.220	.232
F25.22	.650	.051	-.008	.407	.193	-.111	.240
F25.23	.671	.289	.168	-.347	.135	-.003	-.326
F25.24	.724	.494	-.169	-.166	.035	.068	-.061
F25.25	.681	.409	-.162	-.360	-.111	-.010	.091
F25.26	.655	-.028	-.512	.122	.146	.218	-.066
F25.27	.787	-.059	-.285	.104	-.193	-.010	.041
F25.28	.780	-.104	-.313	.117	-.271	.161	-.050
F25.29	.716	-.146	-.131	.210	-.403	.116	.141
F25.30	.704	-.424	-.281	-.033	.006	-.199	.161
F25.31	.552	-.480	-.245	-.321	.254	-.075	.199
F25.32	.601	-.467	-.094	-.200	.187	-.130	.336

Extraction Method: Principal Component Analysis.

a. 7 components extracted.

Rotated Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
F25.1	.679	.260	-.104	.086	.304	.096	-.009
F25.2	.813	.239	.171	.292	.040	.024	-.009
F25.3	.566	.417	.185	.246	.440	.197	-.164
F25.4	.411	.155	.181	.187	.697	.254	.075
F25.5	.160	.130	.205	.133	.769	.101	.296
F25.6	.093	.136	.195	.788	.035	.151	.140
F25.7	.126	.350	.272	.524	.294	.023	.049
F25.8	.166	.634	.056	.522	.132	.026	.086
F25.9	.181	.552	.333	.208	.070	.441	.228
F25.10	.243	.157	.616	.331	.085	.230	-.017
F25.11	.361	.354	.493	.185	.088	.369	.128
F25.12	.609	.097	.118	-.065	.091	.247	.506
F25.13	.327	.240	.063	.143	.099	.054	.724
F25.14	.779	.009	.103	.353	-.004	-.023	.206
F25.15	.401	.199	.050	.410	.447	.073	.201
F25.16	.179	.645	.292	.174	.102	.347	.099
F25.17	-.105	.553	.320	.189	.347	.313	.176
F25.18	.192	.232	.039	.636	.130	.437	.108
F25.19	.151	.262	.425	.210	.110	.646	.097
F25.20	.061	.123	.245	.520	.278	.421	.488
F25.21	-.022	.162	.120	.409	.333	.117	.637
F25.22	.471	.236	.303	.522	.071	-.187	.129
F25.23	.457	.059	.107	.147	.336	.657	.131
F25.24	.767	.233	.103	-.013	.202	.333	.167
F25.25	.643	.239	.198	-.199	.380	.264	.212
F25.26	.507	.490	.397	.084	-.290	.187	.026
F25.27	.408	.647	.344	.140	.150	.072	.062
F25.28	.347	.767	.271	.103	.042	.155	.119
F25.29	.218	.763	.205	.172	.178	-.059	.233
F25.30	.143	.479	.716	.164	.169	.026	-.032
F25.31	.042	.184	.854	.013	.060	.179	.086
F25.32	.035	.207	.808	.158	.177	.017	.174

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 16 iterations.

Component Matrix[a]

	Component		
	1	2	3
F26.1	.584	.142	.544
F26.2	.655	-.474	.441
F26.3	.623	-.408	.452
F26.4	.756	.329	.244
F26.5	.615	.598	.084
F26.6	.740	.418	.046
F26.7	.683	.347	-.036
F26.8	.757	-.077	-.298
F26.9	.778	-.036	-.259
F26.10	.765	-.340	-.200
F26.11	.768	.026	-.266
F26.12	.711	-.055	-.352
F26.13	.702	-.449	-.163

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

	Component		
	1	2	3
F26.1	.006	.572	.574
F26.2	.319	.107	.858
F26.3	.268	.143	.816
F26.4	.259	.750	.331
F26.5	.179	.843	.011
F26.6	.347	.765	.133
F26.7	.384	.658	.086
F26.8	.741	.309	.154
F26.9	.717	.362	.169
F26.10	.755	.133	.383
F26.11	.694	.403	.127
F26.12	.737	.287	.083
F26.13	.735	.016	.425

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 8 iterations.

Component Matrix[a]

	Component		
	1	2	3
F27.1	.643	-.344	-.256
F27.2	.781	-.261	-.251
F27.3	.635	-.482	-.174
F27.4	.794	-.266	.065
F27.5	.713	-.137	-.166
F27.6	.761	.160	-.223
F27.7	.696	.288	-.375
F27.8	.609	.493	-.096
F27.9	.570	.637	.013
F27.10	.746	.408	.014
F27.11	.723	.307	.307
F27.12	.733	.196	.281
F27.13	.719	-.305	-.031
F27.14	.714	-.400	.298
F27.15	.642	-.174	.608

Extraction Method: Principal Component Analysis

Rotated Component Matrix[a]

	Component		
	1	2	3
F27.1	.749	.154	.110
F27.2	.791	.301	.161
F27.3	.790	.028	.202
F27.4	.662	.258	.447
F27.5	.633	.345	.186
F27.6	.514	.616	.107
F27.7	.461	.700	-.078
F27.8	.158	.768	.097
F27.9	-.003	.841	.153
F27.10	.252	.767	.268
F27.11	.167	.631	.535
F27.12	.251	.553	.534
F27.13	.677	.197	.336
F27.14	.586	.072	.641
F27.15	.266	.160	.846

Component Matrix[a]

	Component	
	1	2
F28.1	.647	.411
F28.2	.825	.332
F28.3	.799	.364
F28.4	.755	.239
F28.5	.779	.205
F28.6	.799	-.257
F28.7	.730	-.350
F28.8	.790	-.427
F28.9	.753	-.496

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F28.1	.753	.143
F28.2	.829	.323
F28.3	.832	.281
F28.4	.714	.342
F28.5	.708	.384
F28.6	.407	.734
F28.7	.293	.755
F28.8	.284	.851
F28.9	.210	.877

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component	
	1	2
F29.1	.641	-.264
F29.2	.761	-.284
F29.3	.690	-.361
F29.4	.782	-.238
F29.5	.726	-.467
F29.6	.765	-.312
F29.7	.700	.336
F29.8	.775	.395
F29.9	.752	.284
F29.10	.652	.545
F29.11	.787	.367

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F29.1	.650	.243
F29.2	.751	.310
F29.3	.752	.205
F29.4	.735	.357
F29.5	.850	.151
F29.6	.773	.291
F29.7	.284	.723
F29.8	.299	.816
F29.9	.358	.720
F29.10	.107	.843
F29.11	.327	.804

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Component Matrix[a]

	Component
	1
F30.1	.743
F30.2	.877
F30.3	.853
F30.4	.825
F30.5	.791
F30.6	.651

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Component Matrix[a]

	Component	
	1	2
F31.1	.693	.545
F31.2	.696	.555
F31.3	.817	.305
F31.4	.863	-.058
F31.5	.845	.150
F31.6	.794	-.178
F31.7	.795	-.263
F31.8	.745	-.029
F31.9	.777	-.398
F31.10	.837	-.247
F31.11	.784	-.258

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Rotated Component Matrix[a]

	Component	
	1	2
F31.1	.220	.854
F31.2	.217	.864
F31.3	.465	.738
F31.4	.721	.478
F31.5	.580	.632
F31.6	.739	.341
F31.7	.792	.274
F31.8	.609	.429
F31.9	.859	.155
F31.10	.815	.312
F31.11	.779	.271

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Item Statistics

	Mean	Std. Deviation	N
ML 1	3.5667	.68829	200
ML 2	36000	.74444	200
ML 3	4.0222	.83201	200
ML 4	4.1778	.79913	200
ML 5	4.0889	.75701	200
ML 6	3.9778	.77644	200
ML 7	4.0889	.66256	200
ML 8	4.0000	.73233	200

Component Matrix[a]

	Component
	1
ML 1	.708
ML 2	.577
ML 3	.850
ML 4	.857
ML 5	.830
ML 6	.815
ML 7	.888
ML 8	.806

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlations

	ML 1	ML 2	ML 3	ML 4	ML 5	ML 6	ML 7	ML 8
ML 1	1	.541**	.528**	.458**	.477**	.479**	.546**	.576**
ML 2	.541**	1	.483**	.346**	.539**	.255**	.390**	.328**
ML 3	.528**	.483**	1	.834**	.706**	.554**	.767**	.477**
ML 4	.458**	.346**	.834**	1	.749**	.655**	.730**	.573**
ML 5	.477**	.539**	.706**	.749**	1	.574**	.608**	.605**
ML 6	.479**	.255**	.554**	.655**	.574**	1	.786**	.786**
ML 7	.546**	.390**	.767**	.730**	.608**	.786**	1	.737**
ML 8	.576**	.328**	.477**	.573**	.605**	.786**	.737**	1

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

Item Statistics

	Mean	Std. Deviation	N
HRM 1	3.8556	1.06819	200
HRM 2	3.7500	.75395	200
HRM 3	3.6389	.85066	200
HRM 4	3.5556	.88578	200
HRM 5	3.6667	.81877	200
HRM 6	3.5333	.93594	200
HRM 7	3.6444	.87563	200
HRM 8	3.6944	1.03080	200

Component Matrix[a]

	Component
	1
HRM 1	.433
HRM 2	.609
HRM 3	.635
HRM 4	.824
HRM 5	.828
HRM 6	.847
HRM 7	.787
HRM 8	.605

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlations

	HRM 1	HRM 2	HRM 3	HRM 4	HRM 5	HRM 6	HRM 7	HRM 8
HRM 1	1	.284*	.348**	.251**	.245**	.290**	.184*	.295**
HRM 2	.284*	1	.311**	.410**	.416**	.538**	.372**	.225**
HRM 3	.348**	.311**	1	.431**	.356**	.391**	.494**	.351**
HRM 4	.251**	.410**	.431**	1	.596**	.692**	.688**	.401**
HRM 5	.245**	.416**	.356**	.596**	1	.729**	.644**	.507**
HRM 6	.290**	.538**	.391**	.692**	.729**	1	.560**	.413**
HRM 7	.184*	.372**	.494**	.688**	.644**	.560**	1	.312**
HRM 8	.295**	.225**	.351**	.401**	.507**	.413**	.312**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**.Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
CRM 1	3.9167	.82472	200
CRM 2	3.8167	.86828	200
CRM 3	3.6000	.84298	200
CRM 4	3.8500	.87469	200
CRM 5	4.0333	.79734	200
CRM 6	3.9500	.80692	200
CRM 7	3.8167	.90606	200
CRM 8	3.8167	.95995	200

Component Matrix[a]

	Component
	1
CRM 1	.561
CRM 2	.724
CRM 3	.650
CRM 4	.823
CRM 5	.774
CRM 6	.851
CRM 7	.840
CRM 8	.781

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlations

	CRM 1	CRM 2	CRM 3	CRM 4	CRM 5	CRM 6	CRM 7	CRM 8
CRM 1	1	.517**	.221**	.285**	.412**	.548**	.338**	.319**
CRM 2	.517**	1	.563**	.449**	.517**	.537**	.468**	.402**
CRM 3	.221**	.563**	1	.555**	.494**	.389**	.430**	.406**
CRM 4	.285**	.449**	.555**	1	.608**	.702**	.663**	.606**
CRM 5	.412**	.517**	.494**	.608**	1	.654**	.542**	.424**
CRM 6	.548**	.537**	.389**	.702**	.654**	1	.652**	.594**
CRM 7	.338**	.468**	.430**	.663**	.542**	.652**	1	.867**
CRM 8	.319**	.402**	.406**	.606**	.424**	.594**	.867**	1

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

Item Statistics

	Mean	Std. Deviation	N
SCM 1	3.9500	.67082	200
SCM 2	4.0500	.59114	200
SCM 3	4.2000	.60167	200
SCM 4	4.2500	.83147	200
SCM 5	4.1000	.62624	200
SCM 6	4.0000	.63422	200
SCM 7	3.9500	.74200	200

Component Matrix[a]

	Component
	1
SCM 1	.915
SCM 2	.883
SCM 3	.698
SCM 4	.723
SCM 5	.480
SCM 6	.671
SCM 7	.851

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlation

	SCM 1	SCM 2	SCM 3	SCM 4	SCM 5	SCM 6	SCM 7
SCM 1	1	.352**	.334**	.356**	.259**	.420**	.365**
SCM 2	.352**	1	.405**	.448**	.379**	.387**	.416**
SCM 3	.334**	.405**	1	.618**	.436**	.463**	.467**
SCM 4	.356**	.448**	.618**	1	.547**	.601**	.760**
SCM 5	.259**	.379**	.436**	.547**	1	.750**	.740**
SCM 6	.420**	.387**	.463**	.601**	.750**	1	.590**
SCM7	.365**	.416**	.467**	.760**	.740**	.590**	1

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
TQM 1	3.8167	.86828	200
TQM 2	3.8833	.79997	200
TQM 3	3.6833	.86828	200
TQM 4	3.7000	.88375	200
TQM 5	3.6333	1.01882	200
TQM 6	3.7667	.94011	200
TQM 7	3.7667	.97511	200
TQM 8	3.7500	.92679	200

Component Matrix[a]

	Component
	1
TQM 1	.593
TQM 2	.645
TQM 3	.690
TQM 4	.767
TQM 5	.815
TQM 6	.841
TQM 7	.832
TQM 8	.786

Extraction Method: Principal Component Analysis.

Correlations

	TQM 1	TQM 2	TQM 3	TQM 4	TQM 5	TQM 6	TQM 7	TQM 8
TQM 1	1	.452**	.434**	.256**	.359**	.420**	.365**	.443**
TQM 2	.452**	1	.405**	.448**	.379**	.387**	.416**	.503**
TQM 3	.434**	.405**	1	.618**	.436**	.463**	.467**	.380**
TQM 4	.256**	.448**	.618**	1	.547**	.601**	.560**	.522**
TQM 5	.359**	.379**	.436**	.547**	1	.750**	.740**	.559**
TQM 6	.420**	.387**	.463**	.601**	.750**	1	.690**	.625**
TQM 7	.365**	.416**	.467**	.560**	.740**	.690**	1	.640**
TQM 8	.443**	.503**	.380**	.522**	.559**	.625**	.640**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
TPM 1	3.8000	.89318	200
TPM 2	3.8667	.76516	200
TPM 3	3.7000	.82489	200
TPM 4	3.6833	.88737	200
TPM 5	3.7000	.88375	200
TPM 6	4.1667	.88121	200
TPM 7	4.0167	.92438	200
TPM 8	4.2000	.91175	200

Component Matrix[a]

	Component
	1
TPM 1	.778
TPM 2	.871
TPM 3	.759
TPM 4	.819
TPM 5	.853
TPM 6	.723
TPM 7	.699
TPM 8	.353

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlations

	TPM 1	TPM 2	TPM 3	TPM 4	TPM 5	TPM 6	TPM 7	TPM 8
TPM 1	1	.696**	.487**	.575**	.624**	.468**	.430**	.235**
TPM 2	.696**	1	.680**	.678**	.634**	.530**	.548**	.303**
TPM 3	.487**	.680**	1	.648**	.589**	.415**	.380**	.292**
TPM 4	.575**	.678**	.648**	1	.776**	.432**	.395**	.282**
TPM 5	.624**	.634**	.589**	.776**	1	.517**	.540**	.262**
TPM 6	.468**	.530**	.415**	.432**	.517**	1	.696**	.250**
TPM 7	.430**	.548**	.380**	.395**	.540**	.696**	1	.254**
TPM 8	.235**	.303**	.292**	.282**	.262**	.250**	.254**	1

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

*. Correlation is significant at the 0.05 level (2-tailed).

Item Statistics

	Mean	Std. Deviation	N
CI 1	3.6444	.70610	200
CI 2	3.5778	.71657	200
CI 3	3.6444	.76678	200
CI 4	3.7778	.91880	200
CI 5	3.9556	.81756	200
CI 6	3.9333	.90683	200
CI 7	3.8889	.87733	200
CI 8	3.8889	.76872	200
CI 9	3.6889	.78597	200

Component Matrix[a]

	Component
	1
CI 1	.711
CI 2	.863
CI 3	.852
CI 4	.908
CI 5	.932
CI 6	.813
CI 7	.811
CI 8	.797
CI 9	.819

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Correlations

	CI 1	CI 2	CI 3	CI 4	CI 5	CI 6	CI 7	CI 8	CI 9
CI 1	1	.629**	.632**	.635**	.631**	.451**	.513**	.380**	.524**
CI 2	.629**	1	.701**	.705**	.731**	.713**	.600**	.685**	.718**
CI 3	.632**	.701**	1	.839**	.759**	.608**	.639**	.653**	.557**
CI 4	.635**	.705**	.839**	1	.849**	.706**	.690**	.724**	.646**
CI 5	.631**	.731**	.759**	.849**	1	.750**	.741**	.739**	.778**
CI 6	.451**	.713**	.608**	.706**	.750**	1	.637**	.566**	.660**
CI 7	.513**	.600**	.639**	.690**	.741**	.637**	1	.611**	.663**
CI 8	.380**	.685**	.653**	.724**	.739**	.566**	.611**	1	.608**
CI 9	.524**	.718**	.557**	.646**	.778**	.660**	.663**	.608**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
ST 1	3.9833	.86828	200
ST 2	3.6500	.96575	200
ST 3	3.7500	.83147	200
ST 4	3.6167	.95294	200
ST 5	3.6833	.90606	200
ST 6	3.6667	.98025	200
ST 7	3.6167	.89863	200
ST 8	3.5500	.94115	200
ST 9	3.6833	.90606	200

Component Matrix[a]

	Component
	1
ST 1	.680
ST 2	.775
ST 3	.831
ST 4	.752
ST 5	.841
ST 6	.756
ST 7	.731
ST 8	.789
ST 9	.699

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Correlations

	ST 1	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9
ST 1	1	.613**	.575**	.458**	.526**	.387**	.357**	.380**	.419**
ST 2	.613**	1	.621**	.600**	.639**	.549**	.424**	.416**	.447**
ST 3	.575**	.621**	1	.598**	.651**	.535**	.544**	.626**	.517**
ST 4	.458**	.600**	.598**	1	.713**	.455**	.434**	.442**	.441**
ST 5	.526**	.639**	.651**	.713**	1	.692**	.550**	.559**	.388**
ST 6	.387**	.549**	.535**	.455**	.692**	1	.577**	.563**	.409**
ST 7	.357**	.424**	.544**	.434**	.550**	.577**	1	.667**	.468**
ST 8	.380**	.416**	.626**	.442**	.559**	.563**	.667**	1	.756**
ST 9	.419**	.447**	.517**	.441**	.388**	.409**	.468**	.756**	1

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

Item Statistics

	Mean	Std. Deviation	N
ITS 1	3.4444	.83380	200
ITS 2	3.2444	.82301	200
ITS 3	3.5778	.95692	200
ITS 4	3.8000	.86134	200
ITS 5	3.7333	.82962	200
ITS 6	3.7111	.86191	200
ITS 7	3.1778	.92848	200

Component Matrix[a]

	Component
	1
ITS 1	.791
ITS 2	.639
ITS 3	.819
ITS 4	.807
ITS 5	.879
ITS 6	.750
ITS 7	.666

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Correlations

	ITS 1	ITS 2	ITS 3	ITS 4	ITS 5	ITS 6	ITS 7
ITS 1	1	.622**	.629**	.467**	.560**	.397**	.532**
ITS 2	.622**	1	.359**	.290**	.489**	.478**	.206**
ITS 3	.629**	.359**	1	.656**	.730**	.447**	.412**
ITS 4	.467**	.290**	.656**	1	.738**	.674**	.324**
ITS 5	.560**	.489**	.730**	.738**	1	.642**	.381**
ITS 6	.397**	.478**	.447**	.674**	.642**	1	.288**
ITS 7	.532**	.206**	.412**	.324**	.381**	.288**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
EW 1	3.7833	.79997	200
EW 2	3.8333	.91846	200
EW 3	3.8667	.97683	200
EW 4	3.9833	.84876	200
EW 5	3.9667	.79734	200
EW 6	3.8333	.88121	200
EW 7	3.7833	.84082	200
EW 8	4.1500	.72832	200
EW 9	3.7833	.84082	200

Component Matrix[a]

	Component
	1
EW 1	.681
EW 2	.705
EW 3	.729
EW 4	.833
EW 5	.818
EW 6	.827
EW 7	.727
EW 8	.777
EW 9	.662

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Correlations

	EW 1	EW 2	EW 3	EW 4	EW 5	EW 6	EW 7	EW 8	EW 9
EW 1	1	.544**	.413**	.513**	.540**	.400**	.378**	.459**	.428**
EW 2	.544**	1	.386**	.491**	.381**	.628**	.409**	.564**	.409**
EW 3	.413**	.386**	1	.644**	.532**	.578**	.434**	.570**	.352**
EW 4	.513**	.491**	.644**	1	.668**	.646**	.535**	.601**	.488**
EW 5	.540**	.381**	.532**	.668**	1	.708**	.614**	.528**	.514**
EW 6	.400**	.628**	.578**	.646**	.708**	1	.675**	.483**	.426**
EW 7	.378**	.409**	.434**	.535**	.614**	.675**	1	.491**	.360**
EW 8	.459**	.564**	.570**	.601**	.528**	.483**	.491**	1	.573**
EW 9	.428**	.409**	.352**	.488**	.514**	.426**	.360**	.573**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
JIT 1	3.8667	.90560	200
JIT 2	4.1333	.82827	200
JIT 3	4.1333	.88690	200
JIT 4	4.0500	.88611	200
JIT 5	4.0167	1.01097	200
JIT 6	4.2167	.84082	200
JIT 7	4.0667	.91297	200
JIT 8	4.1167	.84082	200

Component Matrix[a]

	Component
	1
JIT 1	.457
JIT 2	.853
JIT 3	.730
JIT 4	.877
JIT 5	.854
JIT 6	.801
JIT 7	.830
JIT 8	.836

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlations

	JIT 1	JIT 2	JIT 3	JIT 4	JIT 5	JIT 6	JIT 7	JIT 8
JIT 1	1	.448**	.314**	.343**	.350**	.258**	.274**	.219**
JIT 2	.448**	1	.592**	.790**	.638**	.608**	.631**	.627**
JIT 3	.314**	.592**	1	.695**	.558**	.366**	.527**	.541**
JIT 4	.343**	.790**	.695**	1	.673**	.705**	.638**	.599**
JIT 5	.350**	.638**	.558**	.673**	1	.666**	.671**	.747**
JIT 6	.258**	.608**	.366**	.705**	.666**	1	.658**	.675**
JIT 7	.274**	.631**	.527**	.638**	.671**	.658**	1	.732**
JIT 8	.219**	.627**	.541**	.599**	.747**	.675**	.732**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
KM 1	3.8333	.84232	200
KM 2	3.8333	.84232	200
KM 3	3.8667	.92392	200
KM 4	3.8833	.91709	200
KM 5	3.7833	.87979	200
KM 6	3.6500	.89365	200
KM 7	4.0167	.88737	200
KM 8	3.8500	.85532	200
KM 9	4.0833	.78303	200

Component Matrix[a]

	Component
	1
KM 1	.803
KM 2	.782
KM 3	.732
KM 4	.713
KM 5	.760
KM 6	.677
KM 7	.743
KM 8	.757
KM 9	.784

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Correlation

	KM 1	KM 2	KM 3	KM 4	KM 5	KM 6	KM 7	KM 8
KM 1	1	.717**	.617**	.517**	.471**	.568**	.452**	.523**
KM 2	.717**	1	.596**	.495**	.449**	.545**	.430**	.523**
KM 3	.617**	.596**	1	.436**	.459**	.430**	.514**	.462**
KM 4	.517**	.495**	.436**	1	.612**	.338**	.476**	.448**
KM 5	.471**	.449**	.459**	.612**	1	.521**	.606**	.491**
KM 6	.568**	.545**	.430**	.338**	.521**	1	.367**	.348**
KM 7	.452**	.430**	.514**	.476**	.606**	.367**	1	.600**
KM 8	.523**	.523**	.462**	.448**	.491**	.348**	.600**	1

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

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
CE 1	3.6667	.90929	200
CE 2	3.8000	.89318	200
CE 3	3.7333	.94898	200
CE 4	3.9167	.99088	200
CE 5	3.9833	.80830	200
CE 6	3.7500	.83147	200
CE 7	3.7500	.74650	200
CE 8	3.8730	.77560	200
CE 9	3.768	0.8112	200

Component Matrix[a]

	Component
	1
CE 1	.753
CE 2	.764
CE 3	.721
CE 4	.756
CE 5	.695
CE 6	.868
CE 7	.628
CE 8	.762
CE 9	.823

Extraction Method: Principal Component Analysis. a. 1 components extracted.

Correlations

	CE 1	CE 2	CE 3	CE 4	CE 5	CE 6	CE 7	CE 8	CE 9
CE 1	1	.681**	.518**	.434**	.357**	.532**	.370**	.675**	.711**
CE 2	.681**	1	.411**	.530**	.413**	.587**	.302**	.665**	.417**
CE 3	.518**	.411**	1	.582**	.366**	.552**	.308**	.582**	.513**
CE 4	.434**	.530**	.582**	1	.417**	.585**	.357**	.612	.614**
CE 5	.357**	.413**	.366**	.417**	1	.642**	.437**	.417**	.428**
CE 6	.532**	.587**	.552**	.585**	.642**	1	.574**	.512**	.634**
CE 7	.370**	.302**	.308**	.357**	.437**	.574**	1	.257**	.671**
CE 8	.675**	.665**	.582**	.612**	.417**	.512**	.257**	1	.649**
CE 9	.711**	.417**	.513**	.614**	.428**	.634**	.671**	.649**	1

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

Appendix - F: List of elements identified from LE frameworks

Framework → / Elements ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Continuous improvement		11	4									2	6			16	6	10		16		8	8		21	10		3	2,8,9	2	3	18	0.58
Standard components/Standard work		3		9					6			6	11	1		23			8	9		5		4	13		6, 7	5	1			16	0.52
5S/ Workplace Organization/Workplace order and cleanliness				2									12	5		22	1		6			1	6	2	6		13				2	12	0.39
Total productive maintenance		4							13				4			20			11				3	5	20	2	14, 15		4			12	0.39
Single minute exchange of die/Setup time reduction		6		3					14				7	4		3			5, 13	3				6	9		10					12	0.39
Value stream mapping									2		6	10				25		5	14	2, 14				7						6	1	11	0.35
Elimination of waste									5			11	9	6		17		6				4			28	13		4				10	0.32
Visual controls/Visual management									10				13	2		18	4			10		2		3	8						8	10	0.32
Just in time operations		1						3				8				2	2								3	1		1	3			9	0.29
Employee empowerment		10, 13															5	4	2			7	9		5							8	0.26
Jidoka/Autonomation/Andon/Line stop/ stop and fix		2,7														5, 7									10,17, 26				6			8	0.26

Framework → / Elements ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Supplier partnership / Lean partner and supplier management / Supply chain management	3									10	3										1		1		27	6, 11						8	0.26
Cellular manufacturing / Cellular and workflow layout	2			1					8				2			1									14			7			9	8	0.26
Kanban/kanban and pull system		9		5									5	3											19			2			4	7	0.23
Leadership /Leadership and culture		14			3						7								3, 17		6		7									7	0.23
Production leveling/Heijunka/Work balancing		12														13			10	5			2						5		6	7	0.23
Six sigma/Lean six sigma in administration		5														12	3						4,5		23						7	7	0.23
Single piece flow / One piece flow/Continuous flow									12			7	1															6	11		10	6	0.19
Customer focus/Voice of customer		16																	1	15					32				10			5	0.16
Just in time logistics/Lean procurement/Lean distribution/Dist							1,2		15	16																				1		5	0.16

Framework → **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
ribute product in lean fashion/Lean layout and lean logistics																																	
Pull production/Material pull maintenance				4																4		3			11		12					5	0.16
Quality at source									7			9	8							8					15							5	0.16
Root cause analysis /Root cause problem solving / Fix the root cause not symptoms/5 Whys																26		8		11					7		3					5	0.16
Total Quality Management/Quality Circles/Quality fundamentals						1										24									4	3		8				5	0.16
Workforce development/People development/Visual work force/Engaged-challenged employees/Motivated workforce					2							4							7	13	5											5	0.16
Effective communication/ Positive, clear communication/											4	5			1			1														4	0.13

Framework → / **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Seamless information flow																																	
Lean product development			1						17		1										4											4	0.13
Process capability/Process measures/Statistical process control														7		11			12						24							4	0.13
Team work		15							9							15										8						4	0.13
Error-proofing/Mistake proofing																10									12						5	3	0.10
Lean production system			2			2				14																						3	0.10
Takt & pitch time																14									16		8					3	0.10
Value adding management/Value stream management																									2		1			3		3	0.10
Cross functional teams													10					3														2	0.06
Customer relationship management											2															12						2	0.06
Design and development/Designing the product	1																				3											2	0.06
Incorporate customer value into design of										7, 8																						2	0.06

Framework → / **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
products and processes																																	
Integrate product and process development										9					2																	2	0.06
Lean culture/Ensure no blame culture																		2										9				2	0.06
Multi functional workers/Multi skilled work force																				6					18							2	0.06
Optimize capability and utilization of people /Optimize the capability and utilization of assets										2					8																	2	0.06
Overall equipment efficiency															12	21																2	0.06
People and Systems/People and partner								1																		9						2	0.06
Performance measurement/Performance metrics																19				1												2	0.06
Point of use storage													14						9													2	0.06
Policy deployment																							10		22							2	0.06

Framework → / **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Batch size reduction																			4						29							2	0.06
Stakeholder value Align and involve all stakeholders to achieve lean vision															7, 11																	2	0.06
System availability/System-level flexibility															13, 14																	2	0.06
Value creation/Value innovations									18										16													2	0.06
Vision, relationship based on mutual trust and commitment across the extended enterprise						5									5																	2	0.06
Agree design principle with all																		7														1	0.03
Align sales and marketing to production										15																						1	0.03
Associate standard work play book																											5					1	0.03
Celebrate wins												3																				1	0.03
Co-location and cells																				7												1	0.03

Framework → **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Common processes																			20													1	0.03
Corrective action																4																1	0.03
Designing the process																					2											1	0.03
Employee security												12																				1	0.03
Enhance value of delivered products and services to customers										17																						1	0.03
Ensure personal safety												1																				1	0.03
Ensure solution supports department interfaces																		9														1	0.03
Envinormental practices and support functions																										7						1	0.03
Ergonomics									4																							1	0.03
Establish a requirements definition process to optimize life-cycle value										5																						1	0.03
Fast quoting				8																												1	0.03
Focus on external and internal															9																	1	0.03

Framework → / **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
environment																																	
Focus on value in your design				10																												1	0.03
Foster innovation and knowledge-sharing throughout the supplier network										12																						1	0.03
Hanadashi																									31							1	0.03
Hour by hour boards																											9					1	0.03
Human resources	4																															1	0.03
Integrated enterprise solutions																			19													1	0.03
Integrated sourcing																			18													1	0.03
Key performance indicator scorecard		8																														1	0.03
Kitting				6																												1	0.03
Knowing if we are winning or losing																											4					1	0.03
Lean administration									16																							1	0.03
Lean daily management																											2					1	0.03
Lean metrics																								1								1	0.03
Lean office								2																								1	0.03
Lean training																														5		1	0.03

Framework → / Elements ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Leverage lean capability for business growth										1																						1	0.03
Low-cost automation									11																							1	0.03
Maintain stability in changing environment															6																	1	0.03
Make decisions at the lowest levels															3																	1	0.03
Management deployment systems																													7			1	0.03
Marketing																										5						1	0.03
Material resource specialist																									30							1	0.03
Maturation, identify and optimize enterprise flow															4																	1	0.03
Metrics based process mapping																				12												1	0.03
New product development																										4						1	0.03
Nurture a learning environment															10																	1	0.03
Operational excellence					1																											1	0.03
Optimize decesion levels																			15													1	0.03

Framework → **Elements** ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
Optimize network-wide performance										11																						1	0.03
Parallel design				7																												1	0.03
Partners							3																									1	0.03
Person & machine separation																6																1	0.03
Productivity audit									1																							1	0.03
Professional development																														4		1	0.03
Provide capability to manage risk, cost, schedule, and performance										3																						1	0.03
Provide post delivery service, support, and sustainability										18																						1	0.03
Quick response																9																1	0.03
Resource and empower program development efforts										4																						1	0.03
Sales , Production and Inventory						3																										1	0.03
Self-inspection																															11	1	0.03
Structured team problem solving																								8								1	0.03
Supermarket																									25							1	0.03

Framework → / Elements ↓	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	Total	Percentage
The end to end process											5																					1	0.03
Time based competition																									1							1	0.03
Time economy									3																							1	0.03
Total Organisation buy in						4																										1	0.03
Utilize data from the extended enterprise to optimize future requirement definitions										6																						1	0.03
Utilize production knowledge and capabilities competitive advantage										13																						1	0.03
Value chain synchronization			3																													1	0.03
Visual predictable quality																8																1	0.03
Visual stream mapping													3																			1	0.03
Volume levers																											11					1	0.03
Zero defects																						6										1	0.03

Legend: F1- Cook and Graser; F2- CTRM Aero Composites; F 3- Lean Breakthru Consulting Group; F4- J.E. Boyer Company, Inc; F5--Beason; F6- Conner; F7- Karlsson and Åhlström; F8- Unlimited Possibilities Consulting LLC; F9-Fraunhofer IPA Slovakia; F10-The MIT Lean Aerospace Initiative; F11- Crawford; F12--Sayer and Williams; F13- Czarnecki and Loyd; F14- Scrimshire; F15- Columbus; F16- Unisa Strategic Partnerships; F17- Industrial Solutions, Inc; F18- Lucansky et al; F19- Wyrick Enterprises; F20- Karen Martin & Associates ; F21- Zayko; F22- Archfield Consulting Group; F23- Productivity Inc; F24- Bohan and Accorti; F25- Moffitt Associates Consultants; F26- Czabke ; F27- Lean Enterprise LLC; F28- Broadsight Analysis Lean Enterprise ; F29- Canford Consultants; F30- Just- in-Time Enterprise Institute; F31- Howardell

Appendix - G: Survey questionnaire

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Survey Questionnaire-III
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PART A: Company Particulars

Name of the Company	
Address	
Number of employees	a) 100 or less b) 101 -500 c) 501-1000 d) 1000 – 3000 e) 3001-5000 f) more than 5000
Name of the respondent	
Designation	
Email Id	
Experience in years	

1. Does your organization have a vision in lean enterprise?

2. Please write the vision and mission statements of your organization.

3. Please indicate the growth of your organization in the last 5 years:
a) Increase more than 30% b) Increase between 10 – 20% c) Increase between 0 - 10%
d) Decrease between 0 - 10% e) Decrease between 10 - 20% f) Decrease between 20 -30%

4. What is the average time taken for developing a new product in your organization?
a) 0 to 1.5 years b) 1.5 to 3 years c) 3 to 4.5 years
d) 4.5 to 6 years e) 6 to 7.5 years f) more than 7.5 years

5. Increase in the number of customers in the last 5 years: (in percentage)

6. No. of training programmes conducted in the last 5 years:
a) 25 or less b) 25-50 c) 50-100 d) 100 – 200 e) 200-300 f) more than 300

7. Number of new products launched in the last 5 years:

8. List of certifications your organization have (e.g. ISO 9000, QS9000, ISO 14000 etc):

9. Name the various awards the organization have won since last 5 years (Deming prize, TPM Prize, Rajiv Gandhi National Quality Award etc.):

10. Are you conducting supplier training programs? **YES/ NO**

11. Do you conduct supplier evaluation and rating programs? **YES/ NO**

12. Does your organization have technical/ marketing/ any other collaboration with other company: **YES/ NO**
if yes (name of the company and type of collaboration):

13. Please indicate using a tick (√), your company's annual sales:
a) 0.25 – 1.25 million US$ b) 1.25 – 2.5 million US$ c) 2.5 – 12.5 million US$
d) 12.5 – 25 million US$ e) greater than 25 million US$

14. Please indicate using a tick (√), your company's annual sales turnover during the last 5 years:
a) decreased more than 10% b) decreased up to 10% c) no change
d) increased up to 10% e) increased more than 10%

15. Please indicate using a tick (√), your company's market share during last 5 years:
a) decreased more than 10% b) decreased up to 10% c) no change
d) increased up to 10% e) increased more than 10%

16. Please indicate using a tick (√), your company's profits during the last 5 years:
a) decreased more than 10% b) decreased up to 10% c) no change
d) increased up to 10% e) increased more than 10%

17. How do you rate the degree of importance of the following competitive priorities (CP) for your organization?
1: Not important……………………5: Important

CP 1	Quality	1	2	3	4	5
CP 2	Cost	1	2	3	4	5
CP 3	Flexibility	1	2	3	4	5
CP 4	Delivery / Availability	1	2	3	4	5
CP 5	Customer relations	1	2	3	4	5
CP 6	Innovation	1	2	3	4	5
CP 7	Global focus	1	2	3	4	5
CP 8	Environment	1	2	3	4	5
CP 9	Reliability	1	2	3	4	5

PART B: Lean Enterprise Pillars and Elements

Instruction: You are requested to rate the degree or extent of practice of each item with reference to the respective factors in 1 to 5 scale

An Example:

ST 4	5S	1	2	3	4	**5**

Continuous Improvements						
1: Low------to------5: High						
CI 1	Cross functional teams	1	2	3	4	5
CI 2	Value stream mapping	1	2	3	4	5
CI 3	PDSA cycle (Plan- Do - Study- Act cycle)	1	2	3	4	5
CI 4	Mixed model assembly or process flexibility	1	2	3	4	5
CI 5	Bottleneck analysis	1	2	3	4	5
CI 6	Product and process simplification	1	2	3	4	5
CI 7	Use of flat hierarchy	1	2	3	4	5
CI 8	New process and equipment	1	2	3	4	5
CI 9	Integrate product and process development	1	2	3	4	5

Standardization						
1: Low------to------5: High						
ST 1	Standardize materials for specific products families	1	2	3	4	5
ST 2	Standardized products	1	2	3	4	5
ST 3	Standardized tools and equipment	1	2	3	4	5
ST 4	5S	1	2	3	4	5
ST 5	Andon	1	2	3	4	5
ST 6	Standardized work procedures	1	2	3	4	5
ST 7	Autonomation	1	2	3	4	5
ST 8	Group Technology	1	2	3	4	5
ST 9	Visual control boards	1	2	3	4	5

Information Technology System						
1: Low------to------5: High						
IT 1	Use of EDI to communicate between suppliers and customers	1	2	3	4	5
IT 2	Enterprise resource planning system	1	2	3	4	5
IT 3	Information technology employed at customer base	1	2	3	4	5
IT 4	Effective information flow throughout supply chain	1	2	3	4	5
IT 5	Use of Bar coding and scanner in logistics systems	1	2	3	4	5
IT 6	Modeling analysis and simulation tools or Computer-aided system like CAD/CAE	1	2	3	4	5
IT 7	Rapid Prototyping	1	2	3	4	5

Total Productive Maintenance						
1: Low------to------5: High						
TPM 1	Maintenance of equipment and tools	1	2	3	4	5
TPM 2	Safety improvement and Ergonomics programmes	1	2	3	4	5
TPM 3	Computer integrated maintenance system	1	2	3	4	5
TPM 4	Overall equipment effectiveness	1	2	3	4	5
TPM 5	Life cycle analysis	1	2	3	4	5
TPM 6	Maintenance practices/ procedures/ tools	1	2	3	4	5
TPM 7	Failure evaluation/debugging/fault finding	1	2	3	4	5
TPM 8	Point of use tool storage	1	2	3	4	5

Elimination of Waste						
1: Low------to------5: High						
EW 1	7 wastes	1	2	3	4	5
EW 2	Reduction of WIP inventory	1	2	3	4	5
EW 3	Cellular layout	1	2	3	4	5
EW 4	Focused factory production	1	2	3	4	5
EW 5	Storage space reduction	1	2	3	4	5
EW 6	Synchronized of material flows and processes for simultaneous execution	1	2	3	4	5
EW 7	Single minute exchange of die	1	2	3	4	5
EW 8	Milk run	1	2	3	4	5
EW 9	Production smoothing	1	2	3	4	5

Just-in-time Production						
1: Low------to------5: High						
JIT 1	Single piece flow	1	2	3	4	5
JIT 2	Small lot size production	1	2	3	4	5
JIT 3	Pull production	1	2	3	4	5
JIT 4	Kanban	1	2	3	4	5
JIT 5	JIT deliveries throughout supply chain	1	2	3	4	5
JIT 6	Plant layout	1	2	3	4	5
JIT 7	Point of usage storage	1	2	3	4	5
JIT 8	Super Market	1	2	3	4	5

Human Resource Management						
1: Low------to------5: High						
HRM 1	Multi skilled employees	1	2	3	4	5
HRM 2	Employee involvement in every stage of organization	1	2	3	4	5
HRM 3	Suggestion scheme	1	2	3	4	5
HRM 4	Employee Training and education.	1	2	3	4	5

Human Resource Management						
1: Low------to------5: High						
HRM 5	Stable or long term employment	1	2	3	4	5
HRM 6	Job rotation	1	2	3	4	5
HRM 7	Job enrichment	1	2	3	4	5
HRM 8	Human Resource Management	1	2	3	4	5

Supply Chain Management						
1: Low------to------5: High						
SCM 1	Supplier training and development activity	1	2	3	4	5
SCM 2	Supplier evaluation and certification	1	2	3	4	5
SCM 3	Supplier feedback	1	2	3	4	5
SCM 4	Supplier proximity	1	2	3	4	5
SCM 5	Single source and reliable suppliers	1	2	3	4	5
SCM 6	Long term partnership with suppliers	1	2	3	4	5
SCM 7	Encouraging first tier suppliers with profit sharing	1	2	3	4	5

Management Commitment and Leadership						
1: Low------to------5: High						
ML 1	Lean Vision and mission	1	2	3	4	5
ML 2	Long-term business thinking	1	2	3	4	5
ML 3	Horizontal and Vertical information system	1	2	3	4	5
ML 4	Appropriate resource allocations	1	2	3	4	5
ML 5	Create a learning culture organization	1	2	3	4	5
ML 6	Holistic strategy for integrating system or organizational policy deployment	1	2	3	4	5
ML 7	Effective leadership development	1	2	3	4	5
ML 8	Research and Development (R&D) activities for product development.	1	2	3	4	5

Total Quality Management						
1: Low------to------5: High						
TQM 1	Quality improvement circle and teams	1	2	3	4	5
TQM 2	Operator responsibility for quality	1	2	3	4	5
TQM 3	Statistical process control	1	2	3	4	5
TQM 4	Error Proofing or poka yoke	1	2	3	4	5
TQM 5	5 whys or root cause analysis	1	2	3	4	5
TQM 6	Quality at the source	1	2	3	4	5
TQM 7	Supplier and customer involvement in quality development programmes	1	2	3	4	5
TQM 8	Process capability analysis	1	2	3	4	5

Customer Relationship Management						
1: Low------to------5: High						
CRM 1	Delivery performance improvement	1	2	3	4	5
CRM 2	Continuous evaluation of customer feedback	1	2	3	4	5
CRM 3	Maintain spare capacity	1	2	3	4	5
CRM 4	Specification of value in terms customer point view	1	2	3	4	5
CRM 5	Post sales service to customer	1	2	3	4	5
CRM 6	Takt time	1	2	3	4	5
CRM 7	Customer enrichment	1	2	3	4	5
CRM 8	Quality function deployment	1	2	3	4	5

Knowledge Management						
1: Low------to------5: High						
KM 1	Developing knowledge teams	1	2	3	4	5
KM 2	Knowledge capture and reuse	1	2	3	4	5
KM 3	Centralized and documented engineering knowledge	1	2	3	4	5
KM 4	Maintaining tools and techniques for knowledge storage, acquisition and decision support	1	2	3	4	5
KM 5	Specialist Career Path to knowledge managers	1	2	3	4	5
KM 6	Knowledge discovery and detection	1	2	3	4	5
KM 7	Innovation brain Storming	1	2	3	4	5
KM 8	Knowledge sharing within and across organizations	1	2	3	4	5

Concurrent Engineering						
1: Low------to------5: High						
CE 1	Supplier and customer involvement in design	1	2	3	4	5
CE 2	Design of experiments	1	2	3	4	5
CE 3	VA/VE(Value analysis/ Value engineering)	1	2	3	4	5
CE 4	Role of chief engineer	1	2	3	4	5
CE 5	Design for manufacturing and assembly	1	2	3	4	5
CE 6	Modern Stage gate model	1	2	3	4	5
CE 7	Design Structure Matrix	1	2	3	4	5
CE 8	Failure mode and effective analysis	1	2	3	4	5

Appendix – H: List of respondents company

List of companies for the automobile sector

S.No.	Company	Product	Address
1	Asahi India Glass Ltd.	Automotive Safety Glass	Global Business Park, Tower - B, 5th floor, Mehrauli - Gurgaon Road, Gurgaon, Haryana
2	Ashok Leyland Ltd.	Commercial Vehicles Medium & Heavy; Marine diesel engines; Industrial genset	Tej Building, 8 - B, Bahadur Shah Zafar Marg, New Delhi
3	Automotive Axles Ltd.	Rear Drive axles for heavy & light commercial vehicles, drakes, gear, sets & components thereof; Rear Drive Axles, Axle Housing, Gear Sets	Hootagalli Industrial Area, Off Hunsur Road, Mysore, Karnataka
4	Axles India Ltd.	Axle housings	Singaperumal Koil Road, Kancheepuram, Sriperumbadur, Tamil Nadu
5	Bajaj Auto Ltd.	Scooters, scooterettes, motorcycles, 3 wheeler passenger taxi vehicles & 3 wheeler goods carriers of pay load upto 775 kgs	Bombay Pune Raod, Akurdi, Pune, Maharashtra
6	Bajaj Motors Ltd.	Auto Components	39 - 40, KM Stone, Delhi - Jaipur Highway, Village Narsinghpur, Gurgaon, Haryana
7	Best & Crompton Engineering Ltd.	Centrifugal pumps, valves; Electrical contracting (transmission and distribution of power); Consultancy services; Automotive components; Mini - hydro turbines; Busducts, industrial plugs & sockets, control panels.	39, Industrial Estate (North), Ambattur, Chennai, Tamil Nadu
8	Bharat Earth Movers Ltd.	Bull Dozers, Dump Trucks, Excavator; Mining Shovel, Walking Dragline; Defence eqpt/aggregates; Rail Coaches.	No. 23/1, 4th Main, Sampangirama Nagar, Bangalore, Karnataka
9	Brakes India Ltd.	Complete brake systems and parts thereof and brake fluid.	Padi, Chennai, Tamil Nadu
10	Automotive india	Internal combustion engines; Diesel Engines (20 HP to 2700 HP); Diesel Generating Sets; Gas Engines (50 HP to 800 HP)	Kothrud, Pune, Maharashtra
11	Bridge & Roof Co (India) Ltd.	Truck mounted container; All types of civil, mechanical, piping.	Kankaria Center, 5th Floor, 2/1, Russel Street, Kolkata, West Bengal
12.	Daimler Chrysler India Pvt.. Ltd.	Passenger cars, MB vans	Chikhali Village, Sector 15 - A, Pimpri, Pune, Maharashtra
13	Delphi Automotive Systems Ltd.	Automotive components, modules and systems	Plot No 240, Udyog Vihar Phase - I, Gurgaon, Haryana
14	DGP Hinoday Industries Ltd.	Ferrite core; Automotive castings	Bhosari Industrial Estate, Pune, Maharashtra
15	Eicher Ltd.	Tractors; Motorcycles; M Engineering; Engines; Gears; Commercial Vehicles	12 Eicher House, Commercial Complex, Greater Kailash - II, Masjid Moth, New Delhi
16	Eicher Motors Ltd.	10.50 (5 Ton Comm Veh), 10.70 (7 Ton Comm Veh), 10.90 (9 Ton Comm Veh), 11.10 (11 ton Comm Veh).	Plot 102, Industrial Area No 1, Pithampur, Dhar, Madhya Pradesh
17	Escorts Ltd.	Tractors; Shock Absorbers; Railway Parts	Corporate Centre, 15/5, Mathura Road, Faridabad, Haryana
18	Fiat India Pvt. Ltd.	Motor vehicles	L B Shastri Marg, Kurla (West), Mumbai, Maharashtra

S.No.	Company	Product	Address
19	Force Motors Ltd.	Light commercial vehicles; LCV & diesel engines; Tractors	(Formerly Bajaj Tempo Ltd.), Bombay - Pune Road, Akurdi, Pune, Maharashtra
20	Ford India Pvt. Ltd.	Automobile, Parts & Accessories; Ford Ikon, Ford Fusion, Ford Fiesta, Ford Endeavour; Cars (Passenger)	S P Koil Post, Chengalpattu, Tamil Nadu
21	Gabriel India Ltd.	Shock Absorbers, Struts, Bimetal Strips; Bimetal Bearing	S - 304, L B S Marg, Mulund, Mumbai, Maharashtra
22	Gajra Gears Pvt. Ltd.	Automotive gears for heavy & light vehicles	Station Road, Dewas, Madhya Pradesh
23	GKN Driveline (India) Ltd.	Drive axle assemblies with constant velocity joints	Plot No 270, Sector 24, Faridabad, Haryana
24	GKN Sinter Metals Ltd.	Parts & accessories for motor vehicles & their engines	146, Mumbai Pune Road, Pimpri, Pune.
25	GKW Ltd.	Rolled/heat treated black bars and bright bars of: Special carbon steels, through hardening low alloy steels, case hardening low alloy steels, spring steels.	97, Andul Road, Howrah 711 103, West Bengal
26	Goetze (India) Ltd.	Cylinder liners; Piston rings; Vegetable oil; Leather garments; Light Alloy Products	A 26/3, Mohan Co - Operative Indl Estate, Mathura Road, New Delhi
27	Hero Honda Motors Ltd.	Motorcycles/two wheelers	34, Community Centre, Basant Lok, Vasant Vihar, New Delhi
28	Hero Motors Ltd.	Two Wheelers and Automotive Segements	601 International Trade Tower, Nehru Place, New Delhi
29	Hindustan Motors Ltd.	Project management & consultancy services; Automobiles & transport equipments; Power shift transmissions	Birla Buildiing, 9/1, R N Mukherjee Road, Kolkata, West Bengal
30	Hindustan Power plus Ltd.	Heavy duty diesel engines; Generator Sets; Earth Moving equipments	Mathagondapalli, Hosur, Tamil Nadu
31	Honda Motorcycle & Scooter India Pvt. Ltd.	Motor Vehicles; Parts & Accessories for Motor Vehicles & Engines; After Sales Service for Scooters	Plot No 1, Sector 3, IMT Manesar, Gurgaon, Haryana
32	Honda Siel Cars India Ltd.	Passenger cars	Plot No A - 1, Sector 40/41, Surajpur - Kasna Road, Greater Noida Industrial Development Area, Gautam Budh Nagar, Uttar Pradesh
33	Hyundai Motor India Ltd.	Motor car and spare parts thereof	Plot No H - 1, SIPCOT Industrial Park, Irrungattukotai, Sriperumbadur Taluk, Kancheepuram, Tamil Nadu
34	India Pistons Ltd.	Piston, Piston Rings, Gudgeon Pins; Non - ferrous castings; Ferrous	24 College Road, Chennai, Tamil Nadu
35	Indian Seamless Metal Tubes Ltd. (The)	Products: Seamless tubes and pipes, pressure tubing for boilers and casings, line pipes for all oil sector.; Cold rolled rings	Lunkad Towers, 1st Floor, S No 199, Lohegaon, Plot No3, Viman Nagar, Pune, Maharashtra
36	Jay Bharat Maruti Ltd.	Sheet metal parts for motor vehicles, welded assemblies and exhaust system	Neel House, Lado Sarai, Opp. Qutab Minar, New Delhi
37	Kalyani Steels Ltd.	Seamless tubes & pipes, pressure tubing for boilers & casings, line pipes for oil sector services.	Mundhwa, Pune, Maharashtra
38	Kinetic Motor Company Ltd.	Motorised two wheelers - Scooters & spare parts	Neeta Towers, Dapodi, Pune, Maharashtra
39	KLT Automotive And Tubular Products Ltd.	Automobiles chassis and tubular products	B - 1/1, Mayur Ma - Krupa Society, Opp Gokhale School, Shimpoli Road, Borivali (W), Mumbai

S.No.	Company	Product	Address
40	Krishna Maruti Ltd.	Seating system, moulded door trims, Moulded head liners, Moulded carpets & Injection moulded components	40 Km, Delhi Jaipur Highway, Village Narsingpur, Gurgaon, Haryana
41	LML Ltd.	Two wheelers (Scooters / Motorcycles)	C - 10, Panki Industrial Estate, Site II, Kanpur,
42	Lucas-TVS Ltd.	Lamps, wiping systems, generators, headlamps, distributors, flashers, screen wipers, sol switches, horns & fuel injection equipment; Starters, alternators, dynamos & regulators; Ignition systems	Aalim Centre, 82 Dr. Radhakrishnan Salai, Chennai.
43	Mahindra & Mahindra Ltd.	Implements; Multi - utility vehicles, light commercial vehicles; Agricultural tractors.	Gateway Building, Apollo Bunder, Mumbai, Maharashtra
44	Mark Auto Industries Ltd.	Fuel Tanks, Housings, Mufflers; Axle Housings, Exhaust Mufflers, Mount Ings, Suspension Parts	Plot No 2, MUL Joint Venture Complex, Gurgaon, Haryana
45	Maruti Udyog Ltd.	Passenger Cars	11th Floor, Jeevan Prakash Building, 25, Kasturba Gandhi Road, New Delhi
46	Minda Huf Ltd.	Mechanical & electrical Automotive locking system	D - 6 - 11, Sector 59, Noida, Uttar Pradesh
47	Minda Industries Ltd.	Locksets, door handles, ignition switches; Locks, lockswitches	Village Nawada Fatehpur, PO Sikanderpur Badda, Manesar, Gurgaon, Haryana
48	Motor Industries Co Ltd.	Shock absorbers and front forks for two wheelers and window balancers and struts for four wheelers	SP - 663, Sitapura Industrial Area, Sanganer, Jaipur, Rajasthan
49	Motorola India Pvt. Ltd.	Telecommunications; Domestic Appliances; Radio,	415/2, Mehrauli Gurgaon Road, Sector 14, Gurgaon, Haryana
50	Munjal Showa Ltd.		9 - 11, Maruti Industrial Area, Gurgaon, Haryana
51	Napino Auto Electronics Ltd.	Switch assembly winker, resistor assembly, capacitor discharge ignitor, regulator/rectifier, cap assy noise suppressor; Wiring harness	Plot No 753 - 754, Phase V, Udyog Vihar, Gurgaon, Haryana
52	Omax Autos Ltd.	Sheet metal Tubular, machined, welded & fabricated components	5/13, Sohna Road, Village Tikri, Gurgaon, Haryana
53	Piaggio Vehicles Pvt. Ltd.	Three wheeled passenger & cargo vehicles; Bodies for Motor Vehicles; Trailers and semi trailors	"Trade World", "B" Wing, 4th Floor, Unit No. 5, Kamala Mills Compound, Senapati Bapat Marg, Lower Parel, Mumbai, Maharashtra
54	Premier Instruments & Controls Ltd.	Dashboard Instruments, Flexible Cables, Switches, Guages, Sensors, Cigarette Lighters, Heater Ventilation.	P B No 6331, No 1087 - A, Avanashi Road, Coimbatore, Tamil Nadu
55	Purolator India Ltd.	Automotive filters & elements	Khandsa Plant, 38th Milestone, NH - 8, Village Khandsa, Gurgaon, Haryana
56	Rane (Madras) Ltd.	Manual steering & suspension systems, RCB steering gears, manual rack and pinion	Ganapathil Buildings, P B No 2628, 61 Velacherry Road, Chennai, Tamil Nadu
57	Rane Brake Linings Ltd.	Railway brake blocks; Brake linings, clutch facings, disc pads	“Maithri” 132, Cathedral Road, Chennai, Tamil Nadu
58	Royal Enfield	Two - wheeler Motorcycles (Bullets)	A Unit of Eicher Motors Ltd., Thiruvottiyur High Road, Thiruvottiyur, Chennai, Tamil Nadu
59	Sansera Engineering Pvt. Ltd.	High precision automotive components rocker arms for internal combustion engines, gear shifter forks, Crank shafts and connecting rods; Forging & Machining	261/C, Bommasandra Industrial Area, Bommasandra Post, Bangalore, Karnataka

S.No.	Company	Product	Address
60	Scooters India Ltd.	Manufacturer of three wheelers	Post Box No. 23, Sarozini Nagar, Lucknow, Uttar Pradesh
61	Skoda Auto India Pvt. Ltd.	Cars	Plot No A - 1/1, Five Star Industrial Area, MIDC Shendra, Aurangabad, Maharashtra
62	Subros Ltd.	Parts and accessories for Automotive Air - conditioning Systems and ventilators & Heaters	Lower Ground Floor, World Trade Centre, Barakhamba Lane, New Delhi
63	Sunbeam Auto Ltd.	Aluminium die - casted components; Automobile pistons	38/6 K M Stone, Delhi - Jaipur Highway, Narsingpur, Gurgaon, Haryana
64	Sundaram Brake Linings Ltd.	Friction material for automotive and non - automotive application in Asbestos & Asbestos - free grades	Padi, Chennai, Tamil Nadu
65	Sundaram-Clayton Ltd.	Air & air assisted braking system for medium / heavy commercial vehicles, vacuum product for light commercial vehicle and aluminium pressure and gravity die castings	Jayalakshmi Estates", 8, Haddows Road, Chennai 600 006, Tamil Nadu
66	Sundram Fasteners Ltd.	Precision formed gears; Radiator caps & metal form components; High tensile fasteners.	98 A, 7th Floor Dr. Radhakrishnan Salai, Mylapore, Chennai, Tamil Nadu
67	Tata Auto Plastic Systems Ltd.	Plastic Interiors and Exteriors of Automobiles	Survey No 235/245, Village Hinjewadi, Taluka - Mulshi, Pune, Maharashtra
68	Tata Cummins Ltd.	B series diesel engines & their parts for automotive industrial & genset application	TELCO Township, Jamshedpur, Jharkhand
69	Tata Johnson Controls Automotive Ltd.	Automotive System Design	Tata Johnson Automotive Ltd., 301/ 309, Sohrab Hall, 21, Sasoon Road, Behind Pune Railway Station, Pune, Maharashtra
70	Tata Motors Ltd.	Medium & heavy commercial vehicles, light	Bombay House, 24, Homi Modi Street, Hutatma Chowk, Mumbai, Maharashtra
71	Toyota Kirloskar Motor Pvt. Ltd.	Motor Vehicles	C/o Kirloskar Systems Ltd., Embassy Star, 8, Palace Road, Vasanthnagar, Bangalore, Karnataka
72	TVS Motor Company Ltd.	Mopeds, motorcycles, scooters	P B No 4, Harita, Hosur, Tamil Nadu
73	Uc74al Fuel Systems Ltd.	Carburetors for 2 & 4 wheelers, oil pumps	A - 98, 100, 107, PIPDIC Industrial Estate, Mettupalayalam, Pondicherry
74	UCAL Machine Tools Ltd.	Dies, depression chamber assemblies; Castings.	Raheja Towers, 7th Floor, Sigma Wing, 177 Anna Salai, Chennai, Tamil Nadu.
75	Unitech Machines Ltd.	Automobile lighting components	344/3, Oshu House, Lado Sarai, New Delhi
76	Wheels India Ltd.	Wheels for commercial vehicles, passenger cars, jeeps, tractors.	Padi, Chennai, Tamil Nadu

List of companies for the machinery and equipment sector

S.No.	Company	Product	Address
1	ABB Ltd.	Electrical engineering equipment for power generation, transmission & distribution, industrial & building systems and environmental applications;	Khanija Bhavan, 2nd Fl, East Wing, 49, Race Course Road, Bangalore
2	Ace Designers Ltd.	CNC lathes; Auto lathes	Plot No 533, 10th Main Road, 4th Phase, Peenya Industrial Area, Bangalore.
3	Ador Welding Ltd.	Manufacturing of welding consumable & equipment	Ador House, 4th Floor, 6 K Dubash Marg, Fort, Mumbai, Maharashtra

S.No.	Company	Product	Address
4	Atlas Copco (India) Ltd.	Rock drilling equipment & tools, mining equipment, construction tools, air & gas compressors	Mahatma Gandhi Memorial Buildiing, Netaji Subhas Road, Mumbai, Maharashtra
5	Audco India Ltd.	Industrial valves; Actuator & Accessories; Safety Systems and equipments	Mount Poonamallee Road, Manapakkam, Chennai, Kancheepuram, Tamil Nadu
6	Best & Crompton Engineering Ltd.	Centrifugal pumps, valves; Electrical contracting (transmission and distribution of power)	39, Industrial Estate (North), Ambattur, Chennai, Tamil Nadu
7	Bharat Earth Movers Ltd.	Bull Dozers, Dump Trucks, Excavator; Mining Shovel, Walking Dragline.	No. 23/1, 4th Main, Sampangirama Nagar, Bangalore, Karnataka
8	Blue Star Ltd.	Screw Chillers, Centrifugal Chillers, Air Handling unit.	Kasturi Building, Mohan T Advani Chowk, Jamshedji Tata Road, Mumbai, Maharashtra
9	BOC India Ltd.	Medical Appliances such as Oxygen Concentrators, Nebulizers; Air separation unit plants; Industrial Medical & Special Gases; Cryogenic Plants and Vessels	Oxygen House, P - 43, Taratala Road, Kolkata, West Bengal
10	Bosch Rexroth (India) Ltd.	Hydraulic components, cylinders, power packs, manifold blocks and controls. Pneumatic products.	Opp. Vatva Railway Station, Vatva, Taluka Dascroi, Ahmedabad, Gujarat
11	Brakes India Ltd.	Complete brake systems and parts thereof and brake fluid	Padi, Chennai, Tamil Nadu
12	Caterpillar India Pvt. Ltd.	Mining & Construction Equipment	PO Melnallathur, Thiruvallur
13	Eicher Ltd.	Tractors; Motorcycles; M Engineering; Engines; Gears; Commercial Vehicles	12 Eicher House, Commercial Complex, Greater Kailash - II, Masjid Moth, Delhi
14	Electrolux Kelvinator Ltd.	Household Appliances; Refrigerators; Microwave Owens, Cooking Range, Dish Washer; Air - Conditioner, Chest Freezers; Washing Machine	1410A, Beverley Park II, DLF City, Phase II, Mehrauli - Gurgaon Road, Gurgaon, Haryana
15	FL Smidth Ltd.	Machinery & Equipments - Cement; Basic Iron & Steel, C. Machinery Parts; Casting of Metal; Engineering; Technical Activities	180, Kodambakkam High Road, Chennai, Tamil Nadu
16	Force Motors Ltd.	Light commercial vehicles; LCV & diesel engines; Tractors	(Formerly Bajaj Tempo Ltd.), Bombay - Pune Road, Akurdi, Pune
17	Gabriel India Ltd.	Shock Absorbers, Struts, Bimetal Strips; Bimetal	S - 304, L B S Marg, Mulund, Mumbai
18	Gannon Dunkerley & Co Ltd.	Electronic instrument, electronic goods; Building construction industry.	Chartered Bank Building, M G Road, Fort, PB No. 1547, Mumbai
19	Grasim Industries Ltd.	Basic chemicals; Manmade fiber; Rubber products; Plastic products; Fabricated metal products.	Birlagram, Nagda, Ujjain, Madhya Pradesh

S.No.	Company	Product	Address
20	Greaves Cotton Ltd.	Diesel engines, Generating Sets, Petrol Engines, Industrial Gear Boxes, Fluid Couplings, Vibratory Compactors, Tandem Rollers, Concrete Pumps .	Industry Manor, Appasaheb Marathe Marg, Mumbai, Maharashtra
21	Hindustan Powerplus Ltd.	Heavy duty diesel engines; Generator Sets; Earth Moving equipments	Mathagondapalli, Hosur, Tamil Nadu
22	Honda Siel Power Products Ltd.	Gensets; Engines; Water Pump	Plot No 5, Sector 41 (Kasna), Greater Noida Industrial Development Area, GN, UP
23	Hyderabad Industries Ltd.	Technical & management services; Engineering products; Earth moving equipment; Fibre cement products.	Sanathnagar, Hyderabad, Andhra Pradesh
24	Ingersoll Rand (India) Ltd.	Air & gas compressors & pumps; Construction and mining equipment, road machinery equipment	Phase 1, Peenya Industrial Estate, Peenya, Bangalore, Karnataka
25	International Tractors Ltd.	Tractors	Village Chuck Gujran, P.O. Pipanwala, Jallandhar Road, Hoshiarpur, Punjab
26	Kirloskar Oil Engines Ltd.	Diesel engines 5 - 20 HP engines, pump sets spares.	13, Laxmanrao Kirloskar Road, Khadki, Pune, Maharashtra
27	Kirloskar Pneumatic Co Ltd.	Pneumatic systems viz. Compressed air, air conditioning, power transmission equipment.	Hadapsar Industrial Estate, Pune, Maharashtra
28	Ordnance Factory	Guns & shells for defence forces	Cossipore, Kolkata, West Bengal
29	Sandvik Asia Ltd.	Metal cutting & forming tools; Rock excavation tools; Rock excavation equipments; Bulk material handling equipments; Stainless steels & special alloys; Cobalt powder & salts; Process systems	Mumbai - Pune Road, Pune, Maharashtra
30	SKF Bearings India Ltd.	Textile machinery components; Selection of bearings for various applications training on mounting, dismounting.	Mahatma Gandhi Memorial Building, Netaji Subhash Road, Mumbai, Maharashtra
31	Suzlon Energy Ltd.	Wind turbine generators - “wind mills”	Godrej Millennium, 5th Floor, 9, Koregaon Park Road, Pune, Maharashtra
32	Tata Steel Ltd.	Ferro alloys, bars, rods, strips; Bearings; Tubes; Steel; Engineering products; Minerals; Structurals	General Office Building, 1st floor, Jamshedpur, Jharkhand
33	Tetra Pak India Pvt. Ltd.	Aseptic packaging material; Machinery for processing fruit juice/dairy products	Mayfair Towers, Ground Floor, Wakdewadi, Shivajinagar, Pune.
34	Zenith Ltd.	Basic Iron & Steel (Galvanised & Black Steel Pipes); Cutting tools; Dye intermediates; Industrial knives & tools; Man - made fibre yarn	1st Floor, Dalamal House, Nariman Point, Mumbai, Maharashtra

List of companies for the electronics and components sector

S.No.	Company	Product	Address
1	Bharat Electronics Ltd.	Television & Commn equipments; Electronic Components; Medical appliances and instruments; Software	Nagavara, Outer Ring Road, Bangalore, Karnataka
2	Continental Device India Ltd.	Discrete semiconductor devices, chips, dice; Wound components; Contract manufacturing of electronic PCB Assembly; Electronic contract manufacturing	C – 120, Naraina Industrial Area, New Delhi
3	Crompton Greaves Ltd.	Electrical products; Motors; Electronic products; applications; Software solutions.	CG House, 6th floor, Dr Annie Besant Road, Prabhadevi, Mumbai,
4	Gannon Dunkerley & Co Ltd.	Electronic instrument, electronic goods; Building construction industry	Chartered Bank Building, M G Road, Fort, PB No. 1547, Mumbai
5	Godrej & Boyce Mfg Co Ltd.	Office & home furniture, Office equipment; Dot matrix printers; Machine tools; Locks, latches & door accessories.	Pirojshanagar, Vikhroli (West), Mumbai, Maharashtra
6	HBL Nife Power Systems Ltd.	Specialised Batteries; Power Electronic products, Railway electronics products	8 – 2 – 601, Road No 10, Banjara Hills, Hyderabad, Andhra Pradesh
7	Kirloskar Electric Co Ltd.	Alternators, controls for alternators / generators; Switchgear; Motors; Transformers.	P B No 5555, Malleswaram (W), Bangalore, Karnataka
8	JCT Electronics Ltd.	Colour picture tubes	“Thapar House”, 124, Janpath, New Delhi
9	LG Electronics India Pvt. Ltd.	Washing Machines; Video Equipments; Colour televisions; Window & split air – conditioners; Refrigerators.	Plot No 51, Udyog Vihar, Surajpur, Kasna Road, Greater Noida, Gautam Budh Nagar, UP
10	Motorola India Pvt. Ltd.	Telecommunications; Domestic Appliances; Radio, Television & Communication Equipment & apparatus; Transport Equipment.	415/2, Mehrauli Gurgaon Road, Sector 14, Gurgaon, Haryana
11	Comptech Electronics Pvt Ltd.	Computer monitors; Motherboards; Add on cards; CD ROM drives; Hard disc; CPUs	T - 1 (A), Chona Centre',3rd Floor, 45 College Road’,Chennai',600 006',Tamil Nadu',India
12	Samcor Glass Ltd.	Glass for Color Funnels	7KM stone, Kota – Baran Road, Kota, Rajasthan
13	Samtel Color Ltd.	Color picture tubes (14”, 20”, 21” FST & 21” F & FST); 29” True Flat, 29” True flat	52, Community Centre, New Friends Colony, New Delhi
14	Siemens Ltd.	Installation and other services; EPABX/EPAX/Intercom and key telephone systems; Switchgear items.	130, Padurang Budhkar Marg, Worli, Mumbai, Maharashtra
15	Sony India Pvt. Ltd.	Electronic Products	A – 31, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi

S.No.	Company	Product	Address
16	Tyco Electronics Corporation India Ltd.	Wire harness, fibre optic, RF and wireless interconnection systems, application.	No 4, Maruthi Industrial Estate, Hoody Rajapalya, Whitefield Main Road, Mahadevapura Post, Bangalore.
17	Vishay Components India Pvt. Ltd.	Film capacitors, electrolytic capacitors, variable capacitors; Potentiometers; Resistors	Loni – Kalbhor, (Central Railway), Pune, Maharashtra
18	General Industrial Controls Pvt. Ltd.	Time delay relays/ timers – electromechanical (synchronous) and time switches	T – 107, MIDC, Bhosari, Pune, Maharashtra
19	Gujarat Poly-Avx Electronics Ltd.	Single Layer Ceramic capacitors; Multiple Layer Ceramic Capacitor; Metal Oxide Varistor.	7, J Tata Road, Churchgate Reclamation, Mumbai, Maharashtra
20	Honeywell International (India) Pvt. Ltd.	Amorphous Metals – Electronic Cores and Other Products; Basic chemicals, Other chemical products; Man – made fibers.	4th floor, Nirlac House, B – 25, Qutab Institutional Area, New Delhi
21	Incap Ltd.	Aluminium Electrolytic Capacitors	1 – 58, Nidamanur, Vijayawada, Andhra Pradesh
22	ISK Raemeco Seahorse Ltd.	Energy meters; Defence electronic systems	96, Meter Factory Road, Trichy, Tamil Nadu
23	Peerless Fabrikkerne (India) Ltd.	Loudspeakers & IT Components; Hi – Fi Loudspeakers.	18 – 19, SDF1, SEEPZ, Andheri (E), Mumbai
24	Precision Electronics Ltd.	Digital Microwave Radios, Multiplexers, DVDR`s & communication system for armed forces.	D – 10, Sector – 3, Noida, Uttar Pradesh
25	Prem Conductors Pvt. Ltd.	AAA and ACSR Conductors	G/11, 12 Swapna Complex, Nr A K Patel Hous, Mithakhali Six Road, Ahmedabad
26	Solectron Centum Electronics Ltd.	Electronic components	44, KHB Industrial Area, Yelahanka New Township, Bangalore, Karnataka
27	Speck Systems Ltd.	Manufacture of Digital film, Recorders for Strategic applications,	B – 49, Electronics Complex, Kushaiguda, Hyderabad, Andhra Pradesh
28	Texas Instruments (India) Pvt. Ltd.	Semiconductor Design & Software	Golf View Homes, Wind Tunnel Road, Murgeshpalya, Bangalore
29	TVS Cherry Pvt. Ltd.	Electromechnical precision switches; Hall effect sensors (magnetic).	Madurai Melur Road, Vellaripatti, Madurai, Tamil Nadu
30	Udhaya Energy Photo Voltaics Pvt. Ltd.	Solar Modules & Solar Cells	1/279/Z, Mudalipalayam, Arasur Post, Coimbatore, Tamil Nadu
31	Vetal Textiles & Electronics Pvt. Ltd.	Textiles; Agro Products; Electronic products	Plot No 1, Industrial Estate, Civil Aero PO, Coimbatore, Tamil Nadu
32	Webel Power Electronics Ltd.	Power Electronic Items; Supervisory Control & Data Acquisition System	p - 1, Taratolla Road, Kolkata, West Bengal
33	West Bengal Electronics Indl Development Corpn	Components, equipment, system in electronics & telecom; Development of electronics industry in West Bengal	Webel Bhawan, Block EP & GP, Sector V, Salt Lake, Kolkata, West Bengal

List of companies for the process sector

S.No.	Company	Product	Address
1	ACE Refractories Ltd.	Refractories; Castable, Plastic, Gunning Material, High Alumina cement, Catalyst Bed Support, Basic Bricks; High Alumina Bricks	Pushpkunj, 4th Floor, 26 Central Bazaar Road, Ramdaspeth, Nagpur, Maharashtra
2	Agro Industrial Packaging India Ltd.	Corrugated fibre board cartons, Non metal waste & scrap	Nigam Vihar, Shimla, Himachal Pradesh
3	Amrutanjan Ltd.	Pain Balm and allied products	42 - 45, Luz Church Road, Mylapore, Chennai, Tamil Nadu
4	Andhra Pradesh Paper Mills Ltd.	Paper & paperboards, newsprint	501 - 509, Swapnalok Complex, 92/93, Sarojini Devi Road, Secunderabad
5	Asian Paints (India) Ltd.	Paints & enamels; Penta erythritol; Phthalic anhydride	6A, Shantinagar, Vakola, Santacruz (East), Mumbai, Maharashtra
6	Associated Cement Companies Ltd.	Cement; Engineering & consultancy, Project Exports; Refractories.	Cement House, 121, Maharshi Karve Road, Mumbai, Maharashtra
7	Aurobindo Pharma Ltd.	Bulk Drugs, Sterile Bulk Drugs, Drug Intermediates, Formulations, Sterile Formulations; Bulk Drugs & Formulations	Plot No 2, Maitri Vihar, Ameerpet, Hyderabad, Andhra Pradesh
8	Aventis Pharma Ltd.	Pharmaceuticals; Drugs & Pharmaceuticals	Aventis House, 54/A, Sir Mathuradas Vasanji Road, Andheri (East), Mumbai, Maharashtra
9	Ballarpur Industries Ltd.	Paper; Chemicals; Agri products; Writing & Printing paper and Coated Wood - Free Paper.	First India Place, Tower C, Block A, Sushant Lok - I, Mehrauli - Gurgaon Road, Gurgaon.
10	Biostadt India Ltd.	Agro chemical, pharmaceuticals, aqua products, hybrid seeds	Poonam Chambers, A Wing, 6th Floor, Dr Annie Besant Road, Worli, Mumbai.
11	Chambal Fertilisers And Chemicals Ltd.	Urea Fertilisers	International Trade Tower, F - Block, 3rd Floor, Nehru Place, New Delhi
12	Claris Lifesciences Ltd.	Blood Products, Nutritional Products, Renal Care Products, Anesthetics, Antibiotics, Common I.V. Solutions	Corporate Towers, Near Parimal Railway Crossing, Ellisbridge, Ahmedabad, Gujarat
13	Coromandel Fertilisers Ltd.	N P fertilizer - grade 28:28:0; N P K fertilizer - grade 14:35:14; N P fertilizer - grade 20:20:0; Phosphotic Fertilizers	Coromandel House, 1 - 2 - 10, Sardar Patel
14	Dabur India Ltd.	Ayurvedic medicines; Pharmaceuticals; Herbal healthcare & personal care, cosmetics; Foods	3, Factory Road, Near Safdarjang Hospital, Ring Road, New Delhi
15	Dalmia Cement (Bharat) Ltd.	Cement; Deadburnt Magnesite; Sugar; Electronic Goods	Dalmiapuram, Trichy, Tamil Nadu
16	DCM Shriram Consolidated Ltd.	Textile spinning; Urea; Caustic soda, Chlorine; Stable Bleaching Powder.	5th Floor, Kanchenjunga Building, 18, Barakhamba Road, New Delhi

S.No.	Company	Product	Address
17	DCM Shriram Industries Ltd.	Sugar, sugar cubes / satchets; Yarn / fabric, processed yarn; Shipping containers.	Kanchenjunga Building, 18, Barakhamba Road, New Delhi
18	Deepak Fertilisers And Petrochemicals Corporation Ltd.	Fertilizers and petrochemicals; Liquified Carbon Dioxide; Methanol; Nitric Acid; Ammonium Nitrate.	Opp Golf Course, Shastri Nagar, Yerawada, Pune, Maharashtra
19	Elder Pharmaceuticals Ltd.	Pharmaceutical formulations, bulk drugs; OTC products	Elder House, C - 9, Dalia Industrial Estate, Off New Lind Road, Andheri (W), Mumbai.
20	Emcure Pharmaceuticals Ltd.	Pharmaceutical formulations	Emcure House, T - 184, MIDC, Bhosari, Pune, Maharashtra
21	Khanna Paper Mills Pvt. Ltd.	Paper & Paper Boards	Fatehpur Road, Amritsar, Punjab
22	Kirloskar Bros Ltd.	Power driven pumps; Industrail Valves; Commercial castings; Anti corrosion coating; Centrifugal pump; Hemetic Sealed Compressors	Udyog Bhavan, Tilak Road, Pune, Maharashtra
23	Lafarge India Pvt. Ltd.	Cement; Building Materials	101 B, Sunny Towers, 43, Ashutosh Choudhari Avenue, Kolkata, West Bengal
24	Lanco Industries Ltd.	Pig iron; Cement	Rachagunneri Village, Srikalahasthi Mandal, Chittoor, Andhra Pradesh
25	Larsen & Toubro Ltd.	Information technology and communications; Cement; Switchgear - standard and tailormade, metering & protection systems.	L & T House, Ballard Estate, Mumbai, Maharashtra
26	Lupin Ltd.	Bulk drugs and formulations. (ANTI TB & cephalosporins)	4th Floor, World Trade Towers, Barakhamba Avenue, Connaught Place, New Delhi
27	Madras Cements Ltd.	Cement; Ready Mix Concrete, Dry Mix	98 - A, Dr Radhakrishnan Salai, Mylapore, Chenna
28	Malayala Manorama Company Ltd.	Publications, Media, Newspaper & periodicals; News Print, Consumables; Capital Goods	Manorama Building, KK Road, PR No. 26, Kottayam, Kerala
29	Max India Ltd.	Drugs; Allopathic Pharmaceutical Drugs	Max House (3rd Floor), 1, Dr Jha Marg, Okhla - III, New Delhi
30	Orient Paper & Industries	Portland cement; Technical know - how to paper industry; Paper & paper board.	9/1, R N Mukherjee Road, Birla Building, Kolkata, West Bengal
31	Ranbaxy Laboratories Ltd.	API`s & dosage forms	Plot No. 90, Institutional Area, Sector 32, Gurgaon, Haryana
32	Raymond Ltd. - Cement Division	Aviation; Cement & Clinker	Mahindra Towers, B Wing, 3rd Floor, P B Marg, Worli, Mumbai
33	Reckitt Benckiser (India) Ltd.	Food products; Pharmaceuticals; Laundry products, household products, toiletries; Liquids, tablets.	Enkay Center, 2nd Floor, Vanijay Nikunj, Udyog Vihar, Phase - 5, Gurgaon, Haryana

List of companies for the textile sector

S.No.	Company	Product	Address
1	Abhishek Industries Ltd.	Cotton yarn, Acrylic yarn, Polyester yarn	Raikot Road, Barnala, Punjab
2	Alps Industries Ltd.	Venetian & vertical blinds; False ceilings; Cotton fabrics, cotton yarn; Made - ups; Natural dyes.	57/2, Site IV, Industrial Area, Ghaziabad, Sahibabad, Uttar Pradesh
3	Arvind Mills Ltd.	Denim Fabric; Shirting Fabric; Knits Fabric; Knits Garments; Shirts; Yarns	Naroda Road, Ahmedabad
4	Ashima Ltd.	100% Cotton Textiles / Yarn Dyed Fabrics, Denim, Grey Fabrics; Ready to Stitch Fabrics; Garments.	Texcellence Complex, Khokhra Mehmedabad, Ahmedabad
5	Bombay Dyeing & Mfg Co Ltd.	Yarn, textile fabrics, textile piece goods; Leasing; Textile made - ups; Di - methyl terephthalate	Neville House, J N Heredia Marg, Ballard Estate, Mumbai.
6	DCM Shriram Consolidated Ltd.	Textile spinning; Urea; Caustic soda, Chlorine.	5th Floor, Kanchenjunga Building, 18, Barakhamba Road, New Delhi
7	DCM Shriram Industries Ltd.	Sugar, sugar cubes / satchets; Yarn / fabric.	Kanchenjunga Building, 18, Barakhamba Road, New Delhi
8	Eurotex Industries And Exports Ltd.	Cotton yarn; Knitted fabric	Raheja Chambers, 12th Floor, 213, Nariman Point, Mumbai.
9	Fenner (India) Ltd.	Transmission Belts, Oil Seals; Conveyor belting (PVC); Other fabricated metal products.	Khivraj Complex - II, 5th Floor, 480, Anna Salai, Nandanam, Chennai
10	Indo Rama Synthetics (India) Ltd.	Man - made fibers Spinning, Weaving & Finishing of Textiles	Dr Gopal Das Bhawan, 28, Barakhamba Road, New Delhi
11	JCT Ltd.	Textile fabrics, nylon & fibre yarn	Thapar House, 124, Janpath, New Delhi
12	Kanoria Chemicals & Industries Ltd.	Heavy chemicals; Jute & jute goods; Textiles.	Park Plaza, 71, Park Street, Kolkata, West Bengal
13	Kurlon Ltd.	Rubberised coir mattresses & polyester fibre pillows.	Admn Office, N - 301, South Block, Manipal Centre, 47, Dickenson Road, Bangalore.
14	LG Balakrishnan & Bros Ltd.	Rollon automotive timing chains.	6/16/13, Krishnarayapuram Road, P.O Box No. 2003, Ganapathy Post, Coimbatore, Tamil Nadu
15	Loyal Textile Mills Ltd.	Cotton Yarn, Fabric, Garments	21/4, Mill Street, Kovilpatti, Kovilpatti, Tamil Nadu
16	Malwa Cotton Spinning Mills Ltd.	Hand knitting yarn and various worsted yarn (both grey and dyed)	D - 52, East of Kailash, New Delhi
17	Mahavir Spinning Mills Ltd.	Spinning, weaving & finishing of textiles; Other textiles; Yarn; Fabrics.	Vardhaman Group Corporate Office, Chandigarh Road, Ludhiana, Punjab
18	Patspin India Ltd.	Cotton Yarn	3rd Floor, Palal Towers, Ravipuram, M G Road, Kochi, Ernakulam, Kerala
19	Pioneer Embroideries Ltd.	Embroidered fabric; Laces and motifs	Hakoba Compound, Western Express Highway, Borivali (East), Mumbai, Maharashtra

S.No.	Company	Product	Address
20	Precot Mills Ltd.	Cotton Yarn, Blended Yarn	Supreme, P B 7161, Green Fields, 737, Puliakulam Road, Coimbatore, Tamil Nadu
21	Premier Mills Pvt.. Ltd.	Yarn, Grey & Processed Fabrics	244 ATD Street, Race Course, Coimbatore, Tamil Nadu
22	Rajshree Sugars & Chemicals Ltd.	Sugar; Industrial Alcohol; Organic Manure; Electricity; Real Estate Activity; Yarn	338, Avanashi Road, Peelamedu, Coimbatore, Tamil Nadu
23	Shri Ramalinga Mills Ltd.	Cotton yarn	“Theerth”, 8 - 12, Nethaji Road, Pappanaickenpalayam, Coimbatore, Tamil Nadu
24	Siyaram Silk Mills Ltd.	Fabrics & Yarns	B - 5, Trade World, Kamala City, Senapati Bapat Marg, Lower Parel, Mumbai
25	SRF Ltd.	Nylon tyre yarn/nylon tyre cord fabric.	Block - C, Sector - 45, 9 - 10, Bahadur Shah Zafar Marg, Gurgaon, Haryana
26	Supreme Yarns Ltd.	Yarns	Village Kanganwal, P O Jugiana, Ludhiana, Punjab
27	Suryalata Spinning Mills Ltd.	Polyester / Viscose / PV Yarn	Surya Towers, 1st Floor, 105, SP Road, Secunderabad, AP
28	Thiagarajar Mills Ltd.	Cotton yarn & fabrics	Kappalur, Madurai, Tamil Nadu
29	Vardhman Acrylics Ltd.	Acrylic fibre & to	755, GIDC, Jhagadia Mega Estate, Jhagadia, Bharuch, Gujarat
30	Visaka Industries Ltd.	Spinning; Building materials: Asbestos cement sheet	Visaka Towers, 69/3, S P Road, Secunderabad, Hyderabad, Andhra Pradesh
31	Welspun India Ltd.	Home Textile Products	Trade World, B Wing, 8th Floor, Kamala Mills Compound, Lower Parel (W), Mumbai, Maharashtra
32	Winsome Yarns Lt	100% cotton raw white, melange yarns, cotton blended yarns, 100% acrylic, yarns	SCO 144 - 145, Sector 34 - A, Chandigarh

List of Publications

International journal articles (peer-reviewed) accepted

1. **Jasti, N.V.K and Kodali, R (2014),** "A literature review of empirical research methodology in lean manufacturing", International Journal of Operations and Production Management, Vol. 34 No.8, pp.****.
2. **Jasti, N.V.K and Kodali, R (2014),** "Lean production: literature review and trends", International Journal of Production Research, (Under Publication).
3. **Jasti, N.V.K and Kodali, R (2016),** "An empirical study for implementation of lean principles in Indian manufacturing industry", Benchmarking: An International Journal, Vol. 23 No. 2, pp.****.
4. **Jasti, N.V.K and Kodali, R (2014),** "Validity and reliability of lean manufacturing frameworks: An empirical study in Indian manufacturing industries ", International Journal of Lean Six Sigma, Vol. 5 No. 4, pp.****.
5. **Jasti, N.V.K and Kodali, R (2014), "**Validity and reliability of lean product development frameworks in Indian manufacturing industries ", Measuring Business Excellence, Vol.18 No.4, pp. ****.
6. **Jasti, N.V.K., Sharma, A and Kodali, R (2011),** "Lean to Green supply chain management: A case study", Journal of Environmental Research and Development, Vol. 6 No. 3A, pp.890-899.

International journal (peer-reviewed) articles under review

1. **Jasti, N.V.K and Kodali, R (2014),** "Validity and reliability of lean enterprise frameworks in Indian manufacturing industries ", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture,* Under Review.
2. **Jasti, N.V.K and Kodali, R (2014),** "Validity and reliability of lean supply chain management frameworks in Indian manufacturing industries", *Journal of Industrial and Production Engineering*, Under Review.

Under preparation

1. **Jasti, N.V.K and Kodali, R,** "A critical review of lean enterprise frameworks: Proposed framework".
2. **Jasti, N.V.K and Kodali, R,** "A critical review of lean supply chain management frameworks: Proposed framework".
3. **Jasti, N.V.K and Kodali, R,** "A critical review of lean manufacturing frameworks: Proposed framework".
4. **Jasti, N.V.K and Kodali, R,** "A critical review of lean enterprise frameworks: Proposed framework".
5. **Jasti, N.V.K and Kodali, R,** "Development of lean enterprise framework".
6. **Jasti, N.V.K and Kodali, R,** "Path analysis for LE excellence framework in Indian manufacturing industry".

Brief biography of the candidate

NAGA VAMSI KRISHNA JASTI did his B.Tech (Mechanical Engineering) from Jawaharlal Nehru Technological University, Hyderabad and M.E (Mechanical Engineering) from BITS Pilani, Rajasthan. He is presently a Lecturer with Department of Mechanical Engineering, BITS-Pilani, Pilani Campus, Pilani, India. He is also In-charge for Bharat Forge and SKF India Ltd., Pune collaboration programmes for the past eight years. He has over 8 years teaching experience at under graduate and graduate levels. His areas of research interest are Lean manufacturing and Green manufacturing.

Brief biography of the supervisor

RAMBABU KODALI is presently Director, National Institute of Technology, Jamshedpur, India. Prior to appointment, Professor Rambabu Kodali was a Professor in the Department of Mechanical Engineering of BITS-Pilani, Pilani Campus, India and also “Shri S.K Birla Chair Professor” from 2nd April 2012 to 2ndAugust 2012. He was Group Leader (HOD) of Mechanical Engineering Group and Engineering Technology Group from 1994 and 2004 respectively to 2010. He has 27 years of teaching/ research experience and 16 years of administrative experience as a Group Leader (HOD). He has published around 200 papers in various national and international journals. His research areas are: Toyota production system, lean manufacturing, manufacturing excellence, FMS, innovative product design and development, supply chain management, manufacturing management. He has supervised 9 PhDs and currently supervising 3 more. He has completed 11 research projects in FMS, Computer Integrated Manufacturing Systems, World-class manufacturing, and manufacturing excellence. He has developed 4 on-campus degree programmes and 14 off-campus degree programmes at BITS, Pilani. He has developed and established the state-of-the-art FMS laboratory apart from modernizing various Mechanical Engineering laboratories at BITS-Pilani, Pilani campus, Pilani, India.