SOME ISSUES IN SUSTAINABLE MANUFACTURING: A SELECT STUDY OF INDIAN MANUFACTURING COMPANIES

by

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Submitted in fulfillment of the requirements of the degree of

Doctor of Philosophy

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

October 2016

A Doctoral Thesis on

Some Issues in Sustainable Manufacturing: A Select Study of Indian Manufacturing Companies

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Doctor of Philosophy

to the

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

October 2016

DEPARTMENT OF MECHANICAL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

JAIPUR (RAJASTHAN)-302017

CANDIDATE'S DECLARATION

I hereby certify that the Thesis **"Some Issues in Sustainable Manufacturing: A Select study of Indian Manufacturing Companies"** being submitted by me towards the partial fulfilment of the requirement towards the degree of **Doctor of Philosophy** is a bona-fide work carried out by me at the Department of Mechanical Engineering during the period of January 2013 to October 2016 under the supervision of Prof. Govind Sharan Dangayach, Dr. Amit Kumar Singh and Prof P. N. Rao. The results contained in this thesis have not been submitted in part or full to any other University or Institute for the award of degree or diploma.

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CERTIFICATE

This is certify that the thesis entitled **"Some Issues in Sustainable Manufacturing: A Select study of Indian Manufacturing Companies"** being submitted by **Sumit Gupta (2012RME9550)** to the Malaviya National Institute of Technology Jaipur for the award of the degree of **Doctor of Philosophy** in Department of Mechanical Engineering is a bona-fide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirement for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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DEDICATED

To the memory of my Loving sister Mrs. Sakshi Gupta (sonal)

and

To my parents

Mr. Rajendra kumar gupta & Mrs. Munni Gupta

and

To my loving and supportive wife Kavita

The love, encouragement and support of my parents and wife have been exemplary.

"The greatest of these is love"

ACKNOWLEDGEMENTS

I am immensely grateful to my supervisors Prof. Govind Sharan Dangayach, Dr. Amit Kumar Singh and Prof. P. N. Rao for their stimulated guidance and unwavering support. This thesis could not have attained its present form, both in content and presentation without their active interest, direction and help. Their unmatched excellence in the subject, bountiful energy, and personal care has been the source of great inspiration. I express my heartfelt thanks to Prof. Govind Sharan Dangayach, who constantly encouraged me and generously devoted an extensive amount of time and natured me to the level of a professional researcher. His pertinent suggestions and constructive criticism, not only strengthened my skills, but also helped to develop a positive inclination towards research.

I profusely thanks to Prof. S. L. Soni, Convener, DPGC and my research committee members Dr. M. L. Meena, Dr. Amar Patnaik and Dr. Har Lal Singh Mali for providing insight guidance in improving my research work.

I would like to thanks Prof. Govind Sharan Dangayach, Head, Mechanical Engineering Department. He provided me all the possible support during my research work.

I sincerely thank Mr. Anuj Kumar, Mr. Surender Mohan Saini, Mr. Sameer Kumar, Mr. S.K. Sharma, Mr. Deepak Gupta, Mr. Mohit kumar Gupta, Dr. Nidhi, Mr. Yogit and Mr. Anupam for their cooperation and help.

I would like to mention precious contribution of my wife Mrs. Kavita Gupta and my son Mohil S. Gupta, whose sacrifice, support and motivation helped me to chase the dream of Ph.D, which would not have been possible otherwise.

I specially thank to my father Shri Rajendra Kumar Gupta, my mother Smt. Munni Gupta, my elder Sister Mrs. Rekha Gupta, Brother in law Satish Gupta and my younger sister Mrs. Kavita Gupta, Brother in law Vikas, their support, sacrifice, and help in completing my research work.

I would like to thank to my Parent-in laws, Dr. Dwijendra Gupta & Mrs. Maya, Mr. Brijesh Gupta & Mrs. Mamta and Capt. Kamesh Gupta & Mrs. Lalita Gupta for their Love and moral supports.

I highly appreciate the constant encouragement, support and valuable guidance of Seniors Dr. Alok Mathur, Dr. Jinesh Kumar Jain and Dr. Anupam Krishna Their inspirations, support and cooperation are beyond the scope of my acknowledgement, yet I would like to express my gratitude to them.

I wish to extend a word of acknowledgement to my fellow scholars Mr. Deepak Kumar, Mrs. Bhavana Mathur, Mr. Vimal Pathak, Mr. Gaurav and Mr. Jitendra and my juniors for giving me great amount of moral and academic support.

My heartfelt thanks to everyone who have helped me for successful realization of this thesis. Finally, I would also like to thanks all the prospective readers of this work, since any piece of academia is useful if it is read and understood by others so that it can become a bridge for further research.

Finally, I express my heartiest devotion to the 'Almighty God' for his graceful blessing at every step without which nothing could have been accomplished.

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ABSTRACT

Sustainable manufacturing (SM) has attracted serious research attention in the recent past. Though, numerous articles dealing with the theory and practice of sustainable manufacturing have been published, the topic is still under considerable development and debate. Sustainable manufacturing represents a coordinated approach, which strives to achieve consistency between environmental sustainability, economical sustainability and social sustainability and policies and the agreed current and future manufacturing competitiveness necessary for success in the marketplace.

The research is aimed at examining the sustainable manufacturing practices in Indian manufacturing companies, through a questionnaire survey. The main objective of this research was to gain insights of sustainable manufacturing issues in automobile, electrical & electronics, machinery, and process sector companies.

This thesis has attempted to fill some of the gaps in the contemporary research in sustainable manufacturing. The research was conducted in four broad steps. Firstly a comprehensive bibliography on sustainable manufacturing issues is prepared and literature is classified to identify the research gaps. On the basis of identified gaps, a theoretical framework was conceptualized and its basis tested for feasibility using the survey opinion.

Secondly, an extensive multi-sector survey of Indian manufacturing companies is conducted to investigate various issues in sustainable manufacturing. The companies belonging to automobile, electrical & electronics, machinery, and process sectors have participated in the study. 1425 companies were selected and mailed the questionnaire. This yielded 345 usable responses. The survey was analyzed using the statistical tools available in the IBM SPSS 22.0 and IBM SPSS AMOS 22.0 Statistical Analysis Software, and the insights obtained from this analysis were used to shape the proposed framework.

The first order confirmatory factor analysis (CFA) was performed of the sustainable manufacturing practices (measurement model), the result showed that the model was fit with the reliability and validity. In addition, the second order factor analysis was performed to constitute the sustainable manufacturing as the second order latent construct. The result suggested that sustainable product and process design, lean practices, agile practices and customization, sustainable supply operations and distribution and product recovery and return

practice constitute the sustainable manufacturing. Finally the structural equation modeling (SEM) was performed with the research constructs of stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness. The statistical analysis suggested that the model was fit with the required validity.

The performance indices were calculated by regression equation coming from SEM analysis. The result reveals that Indian manufacturing companies are aware of sustainable manufacturing requirements. The sector wise comparative analysis was also performed for the detailed analysis of sustainable manufacturing practices and factors associated with it with respect to the various sectors. The study found significant SM practices, performance measures and manufacturing competitiveness in Indian manufacturing companies.

The result suggested that sustainable manufacturing significantly impacted the sustainable performance measure and sustainable manufacturing competitiveness. Sustainable performance significantly impacted on sustainable manufacturing competitiveness. Stakeholder's commitment also significantly impacted the sustainable manufacturing. However, stakeholder's commitment did not show any significant relationship with the sustainable performance measure and sustainable manufacturing competitiveness.

The third contribution to knowledge is made through development of four cases to obtain further insight on sectoral sustainable manufacturing issues. The result shows that the machinery company is highly focused on sustainable manufacturing practices and achieving higher level of sustainable manufacturing competitiveness in the market.

Fourth contribution to knowledge is based on the survey and case studies learning, a framework for implementation and assessment of sustainable manufacturing is proposed to achieve the manufacturing competitiveness.

The present research focuses on various issues of sustainable manufacturing. By building on the work of previous studies conducted in the industrialized countries, this study helps to provide a better understanding of sustainable manufacturing competence in a dynamic and changing business environment, and points out what sustainable manufacturing means for Indian manufacturers.

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LIST OF ABBREVIATIONS

AGFI……………………………. Adjusted Goodness of Fit
AMOS…………………………... Analysis of Moment Structure
ANOVA………………………… Analysis of Variance
APC……………………………... Agile Practices and Customization
AVE……………………………... Average variance Extracted
CFA……………………………… Confirmatory Factor Analysis
CFI……………………………….. Comparative Fit Index
CR………………………………… Composite Reliability
Df………………………………… Degree of Freedom
GFI…………………………....... Goodness of Fit Index
ISO……………………………….. International Organization of Standards
LP……………………………......Lean Practices
MLE……………………………...Maximum Likelihood Estimator
NFI………………………………..Normed Fit Index
PRRP……………………………...Product Recovery and Returns Practices
RMR………………………………Root Mean Square Residual
RMSEA…………………………...Root Mean Square of Error Approximation
SM……………………………......Sustainable Manufacturing
SMI……………………………......Sustainable Manufacturing Index
SMPD……………………………...Sustainable Manufacturing Process Design
SMC…………………………….....Sustainable Manufacturing Competitiveness
SMCI……………………………....Sustainable Manufacturing Competitiveness Index
SPD………………………………...Sustainable Product Design
SPPD………………………………Sustainable Product and Process Design
SPM…………………………….....Sustainable Performance Measures
SPI……………………………........Sustainable Performance
SPSS…………………………….....Statistical Package for Social Science
SSOD………………………………Sustainable Supply Operations and Distribution
SHC………………………………..Stakeholder's Commitment
TBL……………………………......Triple bottom line
(χ^2) (CMIN), df, p……………….………Chi square probability with degree of freedom

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The concept of sustainability emerged in the 1970s and 1980s, and was largely motivated by environmental incidents and disasters as well as fears about chemical contamination and resource depletion. Brundtland (1987) defines sustainability as ‘‘meeting the needs of the present generation without compromising the ability of future generations to meet their own needs’’. Boer (1996) providing insight to the sustainable production and the model has been adopted by an industrial group to develop its next generation of manufacturing systems. Young et. al. (1997) investigate that sustainable development in the manufacturing is very essential for the elimination of unwanted by-product through the use of dry cutting. Sarkis (1998) suggested that for Sustainable development in industries ISO 14000 standards practices being used by the stakeholders. Bras & McIntosh (1999) observed that sustainability increases by improving the product and process design for remanufacture. Veleva & Ellenbecker (2001) developed a framework to identify core sustainability indicators and awareness and measuring their progress toward sustainable production systems. Veleva et al. (2001) developed a framework to inform measure progress toward more sustainable systems of production. The framework focuses on environmental, health and safety aspects of manufacturing process. Maxwell & Van der Vorst (2003) proposed a framework to identify, assess and implement the options for optimum sustainability in the design and manufacturing. Abdul et al. (2008) suggested four sustainable manufacturing strategies like waste minimisation, material efficiency, eco-efficiency and resource efficiency. Material efficiency services in the market require more customer attention. Manufacturing industries become more sustainable by using these strategies. Sustainability in manufacturing also achieved by the improvement in green technologies and eco-innovations (Bartlett & Trifilova, 2010). Sustainability contents at the product, process and system levels for enabling sustainable manufacturing (Jayal et al., 2010). Yuan et al. (2012) focused on three dimensional system approaches for sustainable manufacturing from environmental perspective.

This addresses the sustainability issues of manufacturing from a pollution prevention standpoint, considering the three key components of manufacturing: technology, material and energy. Anttonen et al. (2013) suggested that sustainable innovation services are the basis of business efficiency. Garbie (2014) suggested three pillars of sustainability i.e. economic, social and environmental are modelled, estimated and incorporated into a concept for sustainable development in manufacturing. Gupta et al. (2015a) observed the practices of sustainable manufacturing, i.e. sustainable product and process design, green supply chain and lean practices, and product recovery. These practices play an important role in manufacturing industries for achievement of sustainability.

1.2 TRIPLE BOTTOM LINE (TBL)

The concept of Triple bottom line (TBL) was given by Elkington, 1994. The concept of TBL includes stakeholder's commitment to the main goal of business to achieve sustainability in terms of environmental, economic and social sustainability (Davies, 2012). Each TBL aspect is measured with respect to its impact on business profit, people and planet. In practical terms, triple bottom line (TBL) accounting of sustainability means expanding traditional economic reporting framework to take into account ecological and social performance in addition to the economic performance.

Sustainability has become an important issue for manufacturing industries in all over the world. Although the concept of sustainability has been widely accepted as a common practice, it is a complex problem with many issues that can be considered as essential components of sustainability.

In View of globalization and make in India initiative, Sustainability in manufacturing play an important role in term of TBL aspects viz. environmental, economical and social aspects. Sustainability in manufacturing is key of make in India initiative to promote minimizing or eliminating production and processing wastes through eco-efficient practices, and encourages adopting new environmental technologies. Increasing environmental consciousness in between stakeholders can be thought of as a reflection of many opportunities to improve the sustainable performance.

To some degree, these opportunities exist because their benefits may not be captured as profit within the current scenario. Environmentally focused manufacturing practices can bring along with them improved process efficiency, higher product quality and economic viability. TBL combines three dimensions of sustainability, i.e. environmental, economic and social within the manufacturing industries (Wang et al., 2015).

1.2.1 Environmental Sustainability

Environmental sustainability refers to the environmental management system in the manufacturing organisation. Environmental sustainability mainly concerns with the efficient use of energy resources, reducing greenhouse gas emissions, and minimizing the ecological footprint. According to Townsend (2008), environmental sustainability includes quantity of natural resources, the environment, global warming, and waste management, reductions in energy and alternative energy production, and improved pollution and emissions management.

1.2.2 Economical Sustainability

Economical sustainability is concerned with economic growth of an organisation while protecting the environment and the individuals that live in the environment (Yusuf et al. 2013). It pertains to the capability of the economy as one of the subsystems of sustainability to survive and evolve into the future in order to support future generations (Presley et al., 2007). To attain the economic sustainability, all organizations looking forward to such an objective, need to properly plan for their economic future by adopting certain measures (Jayakrishna et al., 2015).

1.2.3 Social Sustainability

Social sustainability refers to the beneficial and fair business practices to the labour employees, local community, and to the region in which the business exits (Elkington, 1994; Hall, 2011). The impact of the stakeholders needs to be highlighted, while making decisions regarding manufacturing of product for making score high on sustainability front. It involves contributing to the human needs, apart from meeting the other targets. Corporate social responsibility (CSR) adds much to the societal sustainability objective (Jayakrishna et al., 2015; Yusuf et al., 2013).

1.3 MANUFACTURING AND SUSTAINABILITY

Worldwide competition in today's global economies has brought significance challenges to many companies that want to meet continuously changing specific requirements of present and potential customers. Some of the critical issues that manufacturing companies should consider to remain competitive in the market are maintaining high quality products, lowering cost and prices, decreasing product cycle time and protecting environment (Gupta et al., 2015b).

Manufacturing has high influence on global development and growth, a trend that is likely to continue due to increased demand for consumer goods from a growing world population with improving quality of life (Haapala et al., 2013). Manufacturing plays an indispensable role within the global economy. Not only does manufacturing provide the goods needed by consumers and industries worldwide, it also accounts for a significant portion of the employment, community presence, and economic strength (Duflou et al., 2012).

Manufacturing has a major contribution to make towards a more sustainable society. The motivations for manufacturers' to become more proactive in improving their environmental performance are increasingly linked to cost reduction material and energy inputs as well as waste disposal costs have dramatically increased over the past decade as finite resources diminish (Despeisse et al., 2010). While economic viability is necessary for a manufacturing organization to survive, it is not sufficient to sustain the organization in the long run if it causes irreversible damage to the ecosystem by emitting greenhouse gases (GHG) and toxic wastes and depleting non-renewable resources or it fails to ensure safety, security, dignity, healthcare, minimum wage, indiscrimination and better working conditions for its employees, the community and the society in general. Therefore, it has become imperative for any organization to behave in a socially and environmentally responsible manner while trying to achieve its economic goals.

1.4 SUSTAINABLE MANUFACTURING

Sustainable manufacturing promotes minimizing or eliminating production and processing wastes through eco-efficient practices, and encourages adopting new environmental technologies. Increasing environmental consciousness between stakeholders can be thought of as a reflection of many opportunities to improve the sustainable performance (De Ron, 1998). The main purpose of sustainable manufacturing can be defined as a method for manufacturing that minimizes waste and reduces the environmental impact. These goals are to be obtained mainly by adopting practices that will influence the product design, process design and operational principles.

Table 1.1: Concept (definition) of Sustainable manufacturing reported in literature

Author	Concept (definition)
Melnyk and Smith (1996)	Sustainable manufacturing refers to minimizing environmental impact and trying to maximize resource efficiency.
De Ron (1998)	Sustainable manufacturing is concerned with the eliminating production and processing wastes through environmental technologies.
Fleischmann et al. (2000)	Sustainable manufacturing is defined as the creation of manufactured products that use processes that are non-polluting, conserve energy, and natural resources, as well as economically sound and safe for employees, communities, and consumers.
Maxwell & Van der Vorst (2003)	Sustainable manufacturing is emphasis on to design industrial systems by the use of natural resources.
Zangeneh et al. (2009)	Sustainable manufacturing refers to minimizing the environmental impact and reduce waste.
Jayal et al. (2010)	Sustainable manufacturing practices commonly used fall into the pollution prevention
Bai et al. (2012)	Sustainable manufacturing refers to the creation of manufactured products that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound.
Hallstedt et al. (2013)	Sustainable manufacturing requires simultaneous consideration of economic, environmental, and social implications associated with the production and delivery of goods.
Gunasekaran & Irani (2014)	Sustainable business development in manufacturing and services is highly recommended by the stake holders for achieving sustainable business environment.
Dubey et al. (2015)	World class sustainable manufacturing is helpful to achieving manufacturing excellence.

A more inclusive definition according to Melnyk and Smith, 1996, *"it is a system that integrates product and process design issues with issues of manufacturing, planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency".* The goal of responsible manufacturers should be to design and deliver products to the consumers that have minimal effects on the environment through their manufacture, use and disposal. The Concept (definition) of sustainable manufacturing are given in the Table 1.1.

1.5 NEED FOR SUSTAINABLE MANUFACTURING IN INDIAN MANUFACTURING COMPANIES

According to Dangayach & Deshmukh (2003), "*economic reforms and global competition have given Indian manufacturing companies an opportunity to look at the strategic role of manufacturing*". This has motivated Indian companies to give high priority to quality and technology management. Walton et al., (1998) concluded that green process can improve the manufacturing competitiveness of the company. Rao (2002) and Hall (2003) suggested that cost reduction, improve productivity and profitability and reduction in environmental impact are promoting the sustainable strategy.

Chandra Shukla et al., (2009) implemented various practices of environmentally and socially conscious supply chain management in the context of the automobile industry in India. Environmentally and socially conscious supply chain directly impacts economic performance, which yields high competitive advantage.

Ganapathy et al., (2014) argued that Indian manufacturing companies are striving to improve their sustainable performance in order to satisfy multiple stakeholders. Eco-innovation is promising approaches that decrease environmental impact and helps companies to increase the business performance.

Thirupathi & Vinodh (2016) emphasised on sustainable manufacturing practices in Indian automobile manufacturing sector and found that sustainable manufacturing practices are essential for automotive manufacturing companies to ensure competitive advantage in terms of cost, quality, delivery, flexibility, research and development, social well-being and environmental well-being. Therefore, Indian manufacturing companies need a sustainable manufacturing strategy for survival in globally. These all results are motivated to perform this research in Indian manufacturing industries.

According to the World Bank, Indian Manufacturing Industries contributes 16% of India's gross domestic product (GDP). India is 4^{th} largest emerging economy in the world. According to Mckinsey and company India's manufacturing sector poised to touch US$ one trillion by 2025 and expected to create 90 million domestic jobs by 2025 (IBEF, 2012). India could become the worlds' seventh biggest nation, with a 150 % increase in total, from US$ 20 trillion in 2013 to US$ 50trillion in 2018. The foreign direct investment (FDI) to India doubled to US$ 4.48 billion in January 2015, the highest inflow from January 2014.

As per the International monetary fund report (IMF), India is expected to become the world's fastest growing economy by 2016. India stands to gain growth rate of 7.47 % in 2015 and 7.8 % in 2016 (IBEF, 2015). Indian manufacturing sector has a strong and potential role in the international market. Government of India is committed to increase the manufacturing competitiveness through various measures.

In the current global manufacturing scenario, all major players are now in a position to commit themselves to sustainability in all their operational initiatives and each of them follows their own methodology to attain their goal of sustainability. But a thrust for aligning these characteristics in Indian manufacturing sector is still scant.

On the other hand, the stakeholders need to know how to respond to challenges of integrating environmental conscious technologies, techniques, strategies and environmental impacts. Sustainability become a business imperative, not just a social and environmental imperative, and is essential manufacturing practice to improve manufacturing competitiveness.

There are few useful studies in the literature on sustainable manufacturing in Indian context, and even these predominantly address supply chain management and performance measures of the company (Mitra & Datta, 2014; Luthra et al., 2015; Dubey et al., 2015a; Gopal & Thakkar, 2016). These studies are only focusing on either upstream or downstream part of the supply chain. As such they do not address the various practices of sustainable manufacturing i.e., lean practice, agile practices and customization, sustainable product design and mainly product recovery practices and impact on sustainable manufacturing competitiveness. Although Dubey et al., (2015c) consider the lean and agile practices in their study but they did not consider the product returns and recovery practices. In addition, literature does not provide the evidence of case study based research. The research on sustainable manufacturing with various practices and impact on sustainable performance measures and on sustainable manufacturing competiveness in the four sectors, i.e., automobile, electrical & electronics, machinery and process of Indian manufacturing is scant. Though there are such studies in the global context (Nunes Bennett, 2010; Jayal et al., 2010; Ghazilla et al., 2015 and Wang et al., 2015) but these studies only sector specific mostly in the automobile sector. In addition to this, the sustainable manufacturing issues vary from country to country and sector to sector because of commitment of stakeholders and the social performance evolve in the context of particular society.

Sustainable manufacturing practices are also difficult to implement owing to their complex nature, the greater degree of coordination needed and resource requirement to achieve manufacturing competiveness. To fill the void, an attempt has been made to integrate the stakeholder's commitment to the various sustainable manufacturing practices and sustainable performance in a comprehensive manner to achieve sustainable manufacturing competiveness.

1.6 RESEARCH OBJECTIVES

Present research mainly focused on the identification of sustainable manufacturing practices, stakeholder's commitments for sustainable manufacturing especially in Indian context have been introduced; that could be helpful for policy making for sustainability problem in manufacturing, identification of sustainable performance measures and investigates the appropriate sustainable manufacturing practice for achieving sustainable manufacturing competitiveness.

The main objective of this research is to gain insights of sustainable manufacturing in automobile, electrical & electronics, machinery and process companies. The specific objective of this research is given below.

- Comprehensive literature survey to identify the need of sustainable manufacturing in Indian context
- Develop a theoretical framework for issues of sustainable manufacturing
- Examine the measurement model of sustainable manufacturing practices
- To explore the relationship between sustainable manufacturing and stakeholder's commitment.
- To explore the relationship between sustainable manufacturing and sustainable performance measures
- To explore the relationship between sustainable manufacturing and sustainable manufacturing competitiveness.
- To investigate the relationship between stakeholder's commitment and sustainable performance measures
- To investigate the relationship between stakeholder's commitment and sustainable manufacturing competitiveness.
- To investigate the relationship between sustainable performance measures and sustainable manufacturing competitiveness.
- To study the comparative analysis of sustainable manufacturing practices, stakeholder's commitment, sustainable performance measures and sustainable manufacturing competitiveness
- Develop the case studies in four sectors automobile, electrical & electronics, machinery and process companies to validate the results coming from survey.
- To develop a framework for implementation of Sustainable Manufacturing in manufacturing companies.

1.7 ORGANISATION OF THESIS

The thesis is organised into seven chapters. A brief outline of the chapter is given below.

Chapter 1 comprises with introduction of the thesis and spread light on aim and objectives of the research. It also discusses the steps followed in present research

Chapter 2 covers a review of literature in terms of different approaches, methodology used and content analysis. The chapter summarises the literature, identifies the gaps in the research. On the basis of gaps identified a theoretical framework developed and also hypothesised research model developed for the study. The research hypotheses are formulated in this chapter.

Chapter 3 is devoted to the research methodology adopted in this research. Broadly this deals with the development of questionnaire, pilot study of questionnaire Reliability and Validity, target population and sample, Method of Sample and data collection and Data Analysis Tools and Techniques.

Chapter 4 presents preliminary data analysis, Investigation of associational inference of awareness of sustainability and Identification of Research constructs by Factor analysis. This chapter also presents the stakeholder’s commitment, sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness validation model by structural equation modelling (SEM). The relationships between various research constructs are investigated using SEM which is also used to assess the hypothesised model.

Chapter 5 presents the sector wise i.e. automobile, electrical and electronics, machinery and process comparative analysis of various research constructs like stakeholder’s commitment, sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness followed by one sample t test, ANOVA and Post hoc analysis.

Chapter 6 describe the case studies developed for validation of results. Total four cases are developed in this research. These include one case each from the automobile, electrical & electronics, machinery and process sectors.

Chapter 7 provides a framework for implementation and assessment of sustainable manufacturing in manufacturing companies. This framework is helpful for industry professionals and managers.

Chapter 8 provides summary of the work done, contribution of the research, limitations of the study, scope for future work and the concluding remarks.

1.8 SUMMARY

This chapter presents the background of the sustainability and manufacturing followed by triple bottom line (TBL) and various sustainability elements, i.e., environmental sustainability, economical sustainability and social sustainability. This chapter provides definition of sustainable manufacturing, the need for Sustainable Manufacturing in Indian Manufacturing Companies and the objectives of the research. The detailed literature review and proposed research framework will be discussed in next chapter.

2.1 INTRODUCTION

The basic concept of literature review is to explore the concept of "sustainable manufacturing" in the manufacturing organisations. The review of the literature enlightens the current scenario, the progress made so far, what is resolved and what still needs to be worked upon. In this research, the aim of review of literature is to explore how an organisation became sustainable in manufacturing via sustainable performance and practices.

Sustainable Manufacturing is becoming one of the most emerging areas of research in recent time. Changing business environment, Pressure from regulating bodies to adopt to environmental management strategies, positive impact on sustainable performance and also impact on manufacturing competitiveness are making it popular among practitioners and researchers in the current times. The previous chapter describes the background of sustainability, Triple bottom line (TBL), sustainable manufacturing and the objective of the research. This chapter summarizes past work done in the field of sustainable manufacturing, sustainable performance and its impact on sustainable manufacturing competitiveness.

2.2 SUSTAINABLE MANUFACTURING INITIATIVE

In the current situation, the sustainable manufacturing (SM) initiatives have been adopted by the manufacturing industries in many parts of the world. The level and type of SM implementation varies significantly on various factors like company size, type of company and type of product as suggested by the various researchers (de Ron, 1998; Curkovic, 2003; Ilgin & Gupta 2010; Garbie, 2013; Blok et al., 2015). In India, the sustainable manufacturing initiatives are a relatively new concept as compared to other developed countries like USA, UK, Germany and other European Union countries. Sustainable manufacturing represents involvements of stakeholders into each activity right from product development to the end of life (EoL) of the product (Yu & Ramanathan, 2015).

SM also involve the environmental management and corporate social responsibility (CSR) in the organisation perspective. The lack of consensus on sustainable manufacturing initiatives is due to the fact that SM is emerging area of the research and development, and the theoretical aspects in this area is under developed as pointed by De Ron (1998). The detailed review of literature has been discussed about the sustainable manufacturing initiatives, practices and performance.

2.3 SCHEME OF LITERATURE REVIEW

According to the Fink (1998), literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents''. Literature review is considered as the primary method of collecting the previous information about the research area. In this study, the structured literature review of the sustainable manufacturing is presented to identify the research gaps. The literature review has been carried out through an extensive use of the electronic database. The collection of data for the literature has been reviewed from 1997 to June 2016. Though the concept of sustainability was first proposed in 1950s, sustainable manufacturing gained importance only after the Brundtland Commission (1987) report. For the extensive literature, the data from Scopus, science direct, EBSCO Business source premier, Emerald, ProQuest, Taylor and Francis, Springer, ASME and Inderscience were used to find the current and pertaining literature on Sustainable Manufacturing. The keywords such as sustainable manufacturing, green manufacturing, environmental conscious manufacturing, sustainable product design, sustainable process design, lean practices, agile practice, sustainable supply chain management, product recovery, sustainable performance measures and manufacturing competitiveness were used to collect the literature from the various online databases. Overall, the literature review search yielded 820 articles which were carefully screened for duplication. Finally, 204 articles were selected for the review after a thorough screening of their heading, abstract, methodology and conclusion. These articles were considered significant as they dealt directly with manufacturing sustainability.

The basic aim of literature review is to summarize the state of the art in the subject field, as a basis for identifying areas in which further research would be beneficial (Rowley and Slack, 2004).

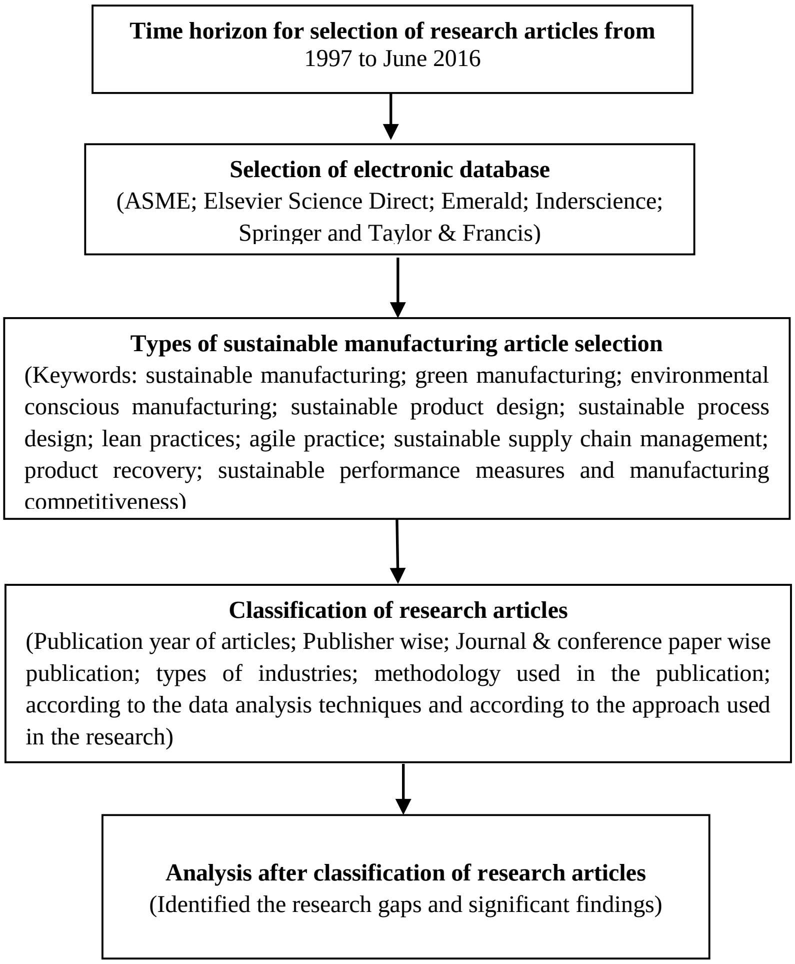


Figure 2.1: Methodology of Literature Review

For this purpose, all screened articles published in peer reviewed journals are reviewed. These articles are from the reputed journals and conferences. All the articles, which were screened, are divided into categories namely journal & conference paper wise publication, publication year of articles, Publisher wise, types of industries, methodology used in the publication, according to the data analysis techniques, according to the approach used in the research. The methodology used for the literature review has been illustrated in the Figure 2.1.

2.4 SUMMARY OF LITERATURE REVIEW AND DISCUSSION

A plethora of research papers are published with the theory and practice of sustainable manufacturing (SM) over the last few years, but the area of sustainable manufacturing is still under considerable development. In this regard, the literature published in referred journals and conferences was reviewed. Nearly 820 papers and other literature have been collected from the electronic database, after screening database comprising 204 references that were considered pertinent to the topic of the research.

2.5.1 Classification of research papers according to the year of publication

Table 2.1 shows that a year wise distribution of research papers regarding sustainable manufacturing practice.

Table 2.1: Year wise classification of papers

S. No.	Year	No. of Papers	%
1	1997	2	1.0
2	1998	3	1.5
3	1999	3	1.5
4	2000	3	1.5
5	2001	5	2.5
6	2002	3	1.5
7	2003	4	2.0
8	2004	2	1.0
9	2005	3	1.5
10	2006	1	0.5
11	2007	4	2.0
12	2008	7	3.4
13	2009	1	0.5
14	2010	9	4.4
15	2011	3	1.5
16	2012	22	10.8
17	2013	19	9.3
18	2014	26	12.7
19	2015	61	29.9
20	2016	23	11.3
Total		204	100.0

It is interesting to observe from Table-2.1 that during 1990-2000, a limited number of research papers appeared in the literature dealing with sustainable manufacturing practices. It is only in the last decade (2005-2015) that a significant amount (approximately 87%) of work has been carried out in this regard. This demonstrates the gradual increase in interest and enthusiasm of research and practitioners for implementation of sustainable manufacturing.

2.5.2 Classification of research papers according to Publisher

The literature review on sustainable manufacturing practices across 204 research papers has covered six publishers, namely Elsevier Science Direct, Taylor and Francis, Emerald, Springer, Inderscience and ASME. Table 2.2 shows that the Elsevier Science Direct published 121 (59.3%) followed by Taylor and Francis 42 (20.6%) articles. There were more publishers published article on sustainable manufacturing practices such as Emerald 28 (13.7%), Springer 10 (4.9%), Inderscience 2 (1.0%) and ASME 1 (0.5%). These are the renowned publishers which are actively participating to publish the research by the researcher and practitioners.

Table 2.2: Publisher wise classifications of papers

S. No.	Publisher	No. of Papers	%
1	Elsevier Science Direct	121	59.3
2	Taylor and Francis	42	20.6
3	Emerald	28	13.7
4	Springer	10	4.9
5	Inderscience	2	1.0
6	ASME	1	0.5
Total		204	100.0

2.5.3 Distribution of research papers according to the Journal and conferences

From the Table 2.3 it is clear that the total 204 references consist of 194 Journal articles and 100 Conference papers. A total of 204 research papers (from 47 refereed journals (194) and peer reviewed international conferences (19)) have been reviewed.

It is observed that 76.3% of the review papers of research topic have been published in eleven journals (Journal of Cleaner Production; International Journal of Production Economics; International Journal of Production Research; Production Planning & Control; International Journal of Operations & Production Management; Journal of Operations Management; Benchmarking: An International Journal; International Journal of Sustainable Engineering; Journal of Manufacturing Technology Management; Clean Technologies and Environmental Policy.

Table 2.3: Distribution of research papers according to the journals and conferences

S. No.	(A) Journal	No. of Papers	Percent of total Articles
1	Journal of Cleaner Production	53	27.3
2	International Journal of Production Economics	20	10.3
3	International Journal of Production Research	19	9.8
4	Production Planning & Control	12	6.2
5	International Journal of Operations & Production Management	9	4.6
6	Journal of Operations Management	9	4.6
7	Benchmarking: An International Journal	7	3.6
8	International Journal of Sustainable Engineering	6	3.1
9	Journal of Manufacturing Technology Management	5	2.6
10	Clean Technologies and Environmental Policy	4	2.1
11	The International Journal of Advanced Manufacturing Technology	4	2.1
12	CIRP Annals - Manufacturing Technology	3	1.5
13	Journal of Industrial and Production Engineering	3	1.5
14	Resources, Conservation and Recycling	3	1.5
15	European Journal of Operational Research	2	1.0
16	Journal of Environmental Management	2	1.0
17	Journal of Manufacturing Systems	2	1.0
18	Sustainable Production and Consumption	2	1.0
19	Journal of Manufacturing Systems	1	0.5
20	Applied Ergonomics	1	0.5
21	CIRP Journal of Manufacturing Science and Technology	1	0.5
22	Computers & Industrial Engineering	1	0.5
23	Ecological Economics	1	0.5

24	Ecological Indicators	1	0.5
25	Expert Systems with Applications	1	0.5
26	International Journal Manufacturing Technology and Management	1	0.5
27	International Journal of Computer Integrated Manufacturing	1	0.5
28	International Journal of Logistics: Research and Applications	1	0.5
29	International Journal of Physical Distribution & Logistics Management	1	0.5
30	International Journal of Quality & Reliability Management	1	0.5
31	International Journal of Systems Science: Operations & Logistics	1	0.5
32	International Journal Sustainable Manufacturing	1	0.5
33	Journal of Business Ethics	1	0.5
34	Journal of Business Research	1	0.5
35	Journal of Engineering, Design and Technology	1	0.5
36	Journal of Environmental Planning and Management	1	0.5
37	Journal of Manufacturing Science and Engineering	1	0.5
38	Journal of Materials Processing Technology	1	0.5
39	Journal of Purchasing & Supply Management	1	0.5
40	Management Decision	1	0.5
41	Management of Environmental Quality: An International Journal	1	0.5
42	Measuring Business Excellence	1	0.5
43	Omega	1	0.5
44	Renewable and Sustainable Energy Reviews	1	0.5
45	Resources Policy	1	0.5
46	Review of Managerial Science	1	0.5
47	Robotics and Computer Integrated Manufacturing	1	0.5
	Total	194	100.0
	(B) International Conferences	10	
	Grand Total	204	

The International Journal of Advanced Manufacturing Technology). The distribution of research articles in various journals is given in the Table 2.3. Detailed author wise distribution of the articles is given in the Table 2.4.

Table 2.4: Author wise distribution of the articles

Name of journal	No. of papers	Author (year)
Journal of Cleaner Production	53	Visvanathan & Kumar (1999), Severo et al. (2015), Musaazi et al. (2015), Jorge et al. (2015), Tan et al. (2015), Abdulrahman el al. (2015), Nieuwenhuis & Katsifou (2015), Nawrocka et al. (2009), Veleva & Ellenbecker (2001), Veleva et al. (2001), Maxwell & Van der Vorst (2003), Marksberry (2007), Glavič & Lukman (2007), Ellram et al. (2008), Qi et al. (2010), Zeng et al. (2010), Niinimäki & Hassi (2011), Deif (2011), Short et al. (2012), Dües et al. (2013), Egilmez et al. (2013), Rashid et al. (2013), Tseng et al. (2013), Muduli et al. (2013), Hahn & Kühnen (2013), Jabbour et al. (2013), Despeisse et al. (2013), Anttonen et al. (2013), De Medeiros et al. (2014), Li (2014), Khalili et al. (2014), Lee & Lee (2014), Lee et al. (2014b), Govindan et al. (2015a), Faulkner & Badurdeen (2014), Maletič et al. (2014), Govindan et al. (2014), Poulikidou et al. (2014), Gabaldón-Estevan et al. (2014), Hartmann & Germain (2015), Jabbour et. al. (2015), Alkaya & Demirer (2015), Yusof et al. (2016), Blok et al. (2015), Ribeiro et al. (2016), Gupta et al. (2016), Sen et al. (2015), Zailani et al. (2015a), Galeazzo & Klassen (2015), Ruparathna & Hewage (2015), Kushwaha & Sharma (2015), Luthra et al. (2016), Thurner et al. (2016)
International Journal of Production Economics	20	Yang et al. (2010), Gimenez et al. (2012), Gunasekaran & Spalanzani (2012), Wong et al. (2012), Law & Gunasekaran (2012), Smith & Ball (2012), Gavronski et al. (2012), Gaussin et al. (2013), Ngai et al. (2013). Yusuf et al. (2013), Chen et al. (2014), Golini et al. (2014), Dubey et al. (2015a), Giannakis & Papadopoulos (2016), Wang et al. (2015). Kristianto et al. (2015), Akhtar et al. (2016), Wang et al. (2016), Ji et al. (2015)
International Journal of Production Research	19	O'Brien (2002), Zhu & Sarkis (2007), Jayaraman et al. (2012), Yakovleva et al. (2012), Garbie (2013), Medini et al. (2014), Mitra & Datta (2014), Mittal & Sangwan (2014), Mani et al. (2014), Garbie (2014), Yu & Ramanathan (2015), Govindan et al. (2015b), Harik et al. (2015), Dubey et al. (2015c), Thirupathi & Vinodh (2016), Mothilal (2012), Hollos et al. (2012), Govindan et al. (2015c), Medini et al. (2015)
Production Planning & Control	12	Dangayach & Deshmukh (2001), Despeisse et al. (2010), Garetti & Taisch (2012), Cagno et al. (2012), Chuang (2014), de Oliveira Neto et al. (2015), Gopal & Thakkar (2016), Jaegler & Burlat (2012), Ferguson & Browne (2001),

		Majstorovic (2015), Essex el al. (2016), Lage Junior & Godinho Filho (2015)
International Journal of Operations & Production Management	9	Azzone & Noci (1998), Rao (2004), Zhu et al. (2005), Piercy & Rich (2015), Lewis (2000), Blome et al. (2014), Walker et al. (2014), Rao & Holt (2005), Hsu et al. (2016)
Journal of Operations Management	9	Handfield et al. (1997), Narasimhan & Kim (2002), Sarkis et al. (2010), Hofer et al. (2012), Narasimhan & Das (2001), Li et al. (2005), Linton et al. (2007), Duray et al. (2000), Huang et al. (2008)
Benchmarking: An International Journal	7	Nunes Bennett (2010), Brockhaus et al. (2016), Ibrahim et al. (2015), Dev & Shankar (2016), Jasti et al. (2015), Ravi & Shankar (2015), Malviya & Kant (2015)
International Journal of Sustainable Engineering	6	Flores et al. (2008), Abdul et al. (2008), Davies (2012), Vinodh et al. (2013), Jayakrishna et al. (2015), Sasikumar & Kannan (2008)
Procedia CIRP	6	Sari et al. (2015), Hankammer & Steiner (2015), Gupta et al. (2015b), Hami et al. (2015), Ghazilla et al. (2015), Bhanot et al. (2015b)
Journal of Manufacturing Technology Management	5	Bartlett & Trifilova (2010), Thomas et al. (2012), Mittal & Sangwan (2014), Kara et al. (2014), Siong et al. (2011), Yang & Li, (2002)
Clean Technologies and Environmental Policy	4	Vinodh & Joy (2012), Singh et al. (2014), Bhanot et al. (2016), Vinodh et al. (2016)
The International Journal of Advanced Manufacturing Technology	4	Bourhis et al. (2013), Kim et al. (2015), Dubey et al. (2015d), Singh et al. (2015)
CIRP Annals - Manufacturing Technology	3	Jovane et al. (2008), Yuan et al. (2012), Duflou et al. (2012)
Journal of Industrial and Production Engineering	3	Koho et al. (2015), MacCarthy et al. (2003), Fogliatto et al. (2012)
Procedia - Social and Behavioral Sciences	3	Gupta et al. (2015a), Bhanot et al. (2015a), Mani et al. (2015)
Resources, Conservation and Recycling	3	Govindan et al. (2016), Dubey et al. (2016), Mani et al. (2016)
European Journal of Operational Research	2	Sarkis (1998), Curkovic, (2003)
Journal of Manufacturing Systems	2	Zhang et al. (2015), Trentesaux & Prabhu (2015)
Sustainable Production and Consumption	2	Dubey et al. (2015b), Kumar et al. (2016)
Journal of Environmental Management	2	Ilgin & Gupta (2010), Gotschol et al. (2014)
Applied Ergonomics	1	Siemieniuch & Sinclair (2015)
CIRP Journal of Manufacturing Science and Technology	1	Jayal et al. (2010)
Computers & Industrial Engineering	1	Gungor & Gupta (1999)
Ecological Economics	1	Zhu et al. (2016)
Ecological Indicators	1	Joung et al. (2012)

Expert Systems with Applications	1	Lee et al. (2014a)
International Journal of Production Ecomomics	1	de Ron, (1998)
International Journal Manufacturing Technology and Management	1	Dangayach & Deshmukh (2004)
International Journal of Computer Integrated Manufacturing	1	Gunasekaran et al. (2015)
International Journal of Logistics: Research and Applications	1	Choi et al. (2016)
International Journal of Physical Distribution & Logistics Management	1	Meixell & Luoma (2015)
International Journal of Quality & Reliability Management	1	Fai Pun (2006)
International Journal of Systems Science: Operations & Logistics	1	Dubey et al. (2015e)
International Journal Sustainable Manufacturing	1	Seliger et al. (2008)
Journal of Business Ethics	1	Chen & Chang (2013)
Journal of Business Research	1	Pujari et al. (2003)
Journal of Engineering, Design and Technology	1	Fore & Mbohwa (2015)
Journal of Environmental Planning and Management	1	Despotovic et al. (2015)
Journal of Manufacturing Systems	1	Zhang et al. (1997)
Journal of Manufacturing Science and Engineering	1	Haapala et al. (2013)
Journal of Purchasing & Supply Management	1	Gualandris & Kalchschmidt (2014)
Management Decision	1	Chang et al. (2013)
Management of Environmental Quality: An International Journal	1	Svensson & Wagner (2015)
Measuring Business Excellence	1	Digalwar et al. (2013)
Omega	1	Fleischmann et al. (2000)
Procedia Manufacturing	1	Hartini & Ciptomulyono (2015)
Renewable and Sustainable Energy Reviews	1	Hussain et al. (2016)
Resources Policy	1	Luthra et al. (2015)
Review of Managerial Science	1	Zailani et al. (2015b)
Robotics and Computer Integrated Manufacturing	1	Bras & McIntosh (1999)

2.5.4 Classification of research papers according research methodology

The journal articles have been classified according research methodology used by the researchers. For this classification, we have used the classification scheme viz. Conceptual, Descriptive, Empirical, Exploratory-Cross Sectional, Exploratory-Longitudinal and Literature review as suggested by Dangayach & Deshmukh (2001) is given in the Table 2.5.

Table 2.5: Scheme for classification of Research Papers according to research methodology

Sl. No.	Research Methodology	Explanation
1.	Conceptual	A paper using a normative approach and presenting a new concept or idea in the field, with or without proof.
2.	Descriptive	A paper which describes earlier research, attempting to clarify or summarise it, without any new contribution.
3.	Empirical	A paper synthesizing earlier research by way of literature review, proposing new dimensions, methods, frameworks or design supported by none or only one case study.
4.	Exploratory-Cross Sectional	A paper synthesizing earlier research by way of literature review and surveys an appropriate cross-section of population at one point of time to derive/support new proposals/ideas/ frameworks etc.
5.	Exploratory-Longitudinal	A paper synthesizing earlier research by way of literature reviews and uses an appropriate survey for registering observations over a period time.
6.	Literature Review	A paper which provides an overview of the general issue or a literature review with wide ranging issues and implications, but does not qualify for being conceptual.

Table 2.6 shows a classification of research papers according to the research methodology used by the various researchers. It seems that exploratory longitudinal studies 10 (4.9%) are less reported as compared to the other methodologies as Descriptive 10 (6.9%), Exploratory-Cross Sectional 25 (12.3%), Conceptual 39 (19.1%), Literature Review 47 (23.0) and Empirical 69 (33.8%).

Table 2.6: Classifications of research papers according to the research methodology

S. No.	Research Methodology	No. of Papers	%
1	Empirical	69	33.8
2	Literature Review	47	23.0
3	Conceptual	39	19.1
4	Exploratory-Cross Sectional	25	12.3
5	Descriptive	14	6.9
6	Exploratory-Longitudinal	10	4.9
Total		204	100.0

2.5.5 Classification of research papers according data analysis techniques

The information about the data analysis techniques used by the researchers for data analysis has been given in the Table 2.7. For the data analysis, statistical techniques 144 (70.6%) used by the researcher as compared to the multi criteria decision making (MCDM) methods (29.4%).

Table 2.7 Classifications of research papers according to the data analysis techniques

S. No.	Data analysis techniques	No. of Papers	%
1	Statistical techniques	144	70.6
2	MCDM Methods	60	29.4
Total		204	100.0

2.5.5.1 Classification according to the Statistical techniques

Statistical techniques used by the researchers for data analysis is shown in Figure 2.2. It is clear from the literature review of research papers that Mean/standard deviation 39 (27.1%), structural equation modelling (SEM) 37 (25.7%), and regression analysis 23 (16.0%) was used by the researchers as compared to other techniques such as correlation 6 (4.2%) and ANOVA 9 (6.3%).

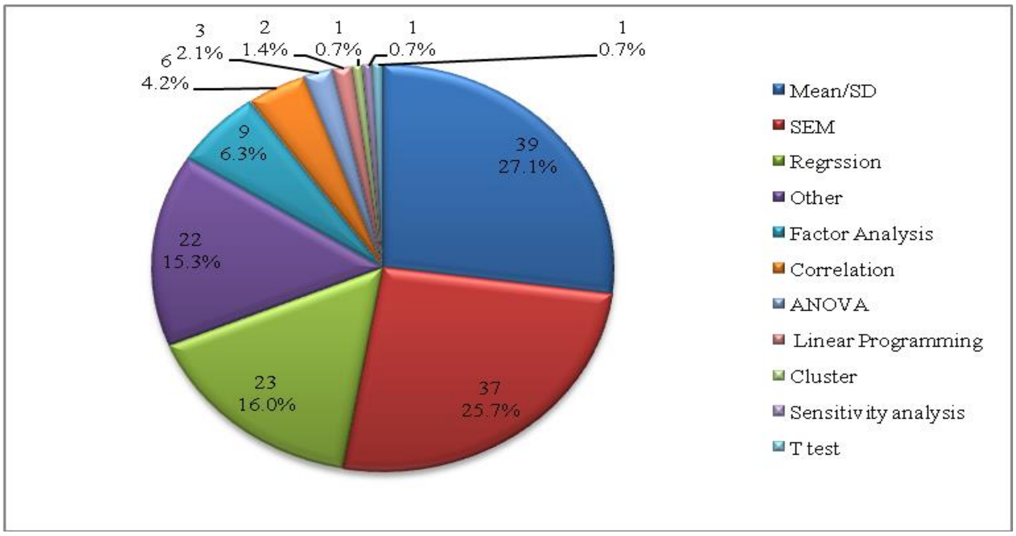


Figure 2.2: Classification of research papers according to Statistical techniques

2.5.5.2 Classification according to the MCDM Methods

MCDM methods are used by the many researchers. Figure 2.3 shows various MCDM methods used across 204 research papers. A total of 60 research papers out of 204 papers used MCDM methods. In this regards weighted sum method 22 (36.7%), AHP 9 (15.0%) and ISM 6 (10.0%) ANP 4 (6.7%) and fuzzy 4 (6.7%) are mostly used by the researchers. Other techniques like graph theory, DEMATEL, TOPSIS and Integer programming are less used by the researcher. All these methods help organisations to adopt sustainable manufacturing practices or undertake remedial improvements.

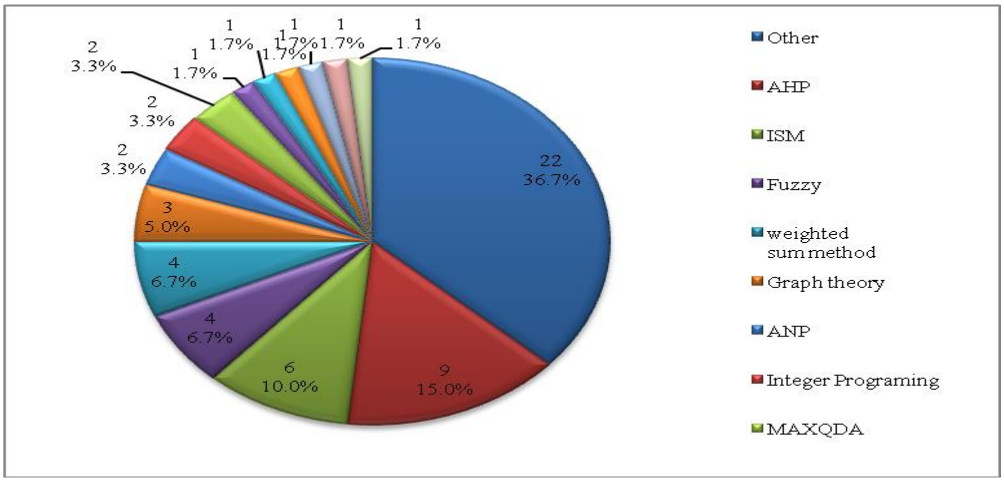


Figure 2.3: Classification of research papers according to MCDM Methods

2.5.6 Classification of research papers according to the type of Industry

The industry wise classification of research papers as exhibited in Figure 2.4 is helpful as it shows which type of industries favour sustainable manufacturing implementation research, and which is less amenable to sustainability. From the Figure 2.4, it is clear that manufacturing companies focused in large number 115 (56.4%) followed by automobile industries 30 (14.7%), Electrical and electronics 8 (3.9%) and Process Industry 8 (3.9%). Almost all types of industries such as cement, ceramic, gear manufacturing, mining, textile and clothing, SMEs and other industries are considered by various researchers and practitioners.

It is observed that most of the researchers conduct their research in manufacturing sector and automotive sectors. There is a gap for the research in multi sector study for sustainable manufacturing. The multi sector study would reveal that the comparative evaluation of sustainable manufacturing implementation across various sectors.

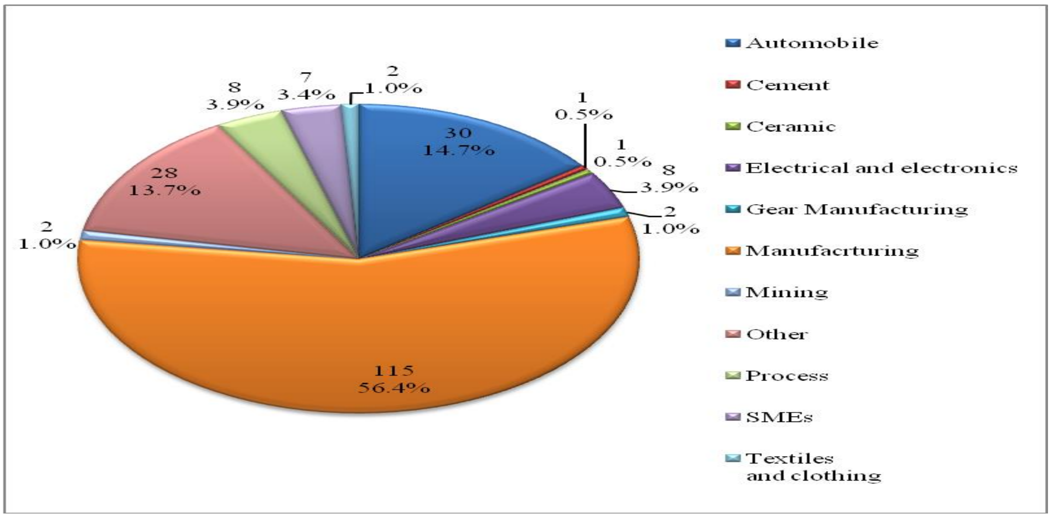


Figure 2.4: Classification of research papers according to Industry focus

2.5.7 Content Analysis

The literature has been analysed for its content. Content Analysis reveals areas in which adequate research is lacking and further research is needed. In this research literature has been classified into mainly four classes viz. Sustainable Manufacturing Practices (Lee & Lee, 2014;

Govindan et al., 2015a; Dubey et al., 2016 and Gupta et al., 2016), Sustainable Performance Measures (Habidin et al. 2013; Comoglio & Botta 2012 and Yusof et al. 2016), Sustainable Manufacturing Competitiveness (Tan et al. 2011; Joshi et al., 2013 and Gallardo-Vázquez et al. 2014) and Stakeholder's Commitment for Sustainable Manufacturing (Matos & Silvestre, 2013; Zuraidah Raja Mohd Rasi et al., 2014; Yu & Ramanathan, 2014 and Betts et al., 2015). These classes have been created keeping in view of the research presented in this literature, as also with a view to provide direction to present research. The result of Content classification is tabulated in Table 2.8.

Table 2.8: Content wise Classification

S. No.	Content	Description
1	**Sustainable Manufacturing Practices (SMPs)**	Sustainable manufacturing practices are the set of dimensions which integrate sustainable performance to achieve manufacturing competitiveness with the help of stakeholders.
1.1	Sustainable Product Design	Sustainable product design involves the integration of economical, environmental and social perspective to design the product and also involve Design for environment.
1.2	Sustainable Manufacturing Process Design	Sustainable manufacturing process design involves resource utilization and raw materials extraction in the manufacturing stage.
1.3	Lean Practices	Lean practices are reducing or eliminating non-value-added activities throughout a product's entire value stream, within an organization.
1.4	Agile Practices and Customization	Agility practices and customization involve the internal capabilities of organisation to meet dynamic needs of the market place.
1.5	Sustainable Supply Operation and Distribution	Sustainable supply operation and distribution involve supplier selection, procurement, third party logistics and transportation that aim to minimize environmental impact of the product.
1.6	Product Recovery and Return Practices	Product returns and recovery practices deals with the reuse, recycle and remanufacturing and ultimate to the End of Life (EoL) disposal of the product.
2	**Stakeholders Commitment for sustainable Manufacturing (SHC)**	Stakeholder's commitment involves the legitimate interest to perform the organization's activities.
3	**Sustainable Performance Measures (SPM)**	Sustainable performance measures include environmental sustainability, economic sustainability and social sustainability issues.
4	**Sustainable Manufacturing Competitiveness (SMC)**	Sustainable manufacturing competitiveness includes the Innovation, technology, cost, quality flexibility etc.

A study of Table 2.9 reveals some interesting aspects. In spite of an initial screening to retain only relevant articles, 19.1% of the articles do not directly deal with sustainable manufacturing. However, nearly, 8 (3.9%) of the total articles pertain to stakeholders commitment, 23 (11.3%) of the total articles pertain sustainable performance measures and the remaining 8 (3.9%) deal with the sustainable manufacturing competitiveness. From the Table 2.9, it is observed that 165 (80.9%) articles are related to sustainable manufacturing practices.

Table 2.9: Content wise classification of research papers

S. No.	Content of Paper	No. of Papers	%
1	**Sustainable Manufacturing Practices (SMPs)**		
1.1	Sustainable Product Design (SPD)	21	10.3
1.2	Sustainable Manufacturing Process Design (SMPD)	52	25.5
1.3	Lean Practices (LP)	9	4.4
1.4	Agile Practices and Customization (APC)	12	5.9
1.5	Sustainable Supply Operation and Distribution (SSOD)	55	27.0
1.6	Product Recovery and Return Practices (PRRP)	16	7.8
2	**Stakeholders Commitment for sustainable Manufacturing (SHC)**	**8**	**3.9**
3	**Sustainable Performance Measures (SPM)**	**23**	**11.3**
4	**Sustainable Manufacturing Competitiveness (SMC)**	**8**	**3.9**
Total		**204**	**100.0**

2.5.7.1 Sustainable Manufacturing Practices

Many researchers (Visvanathan & Kumar, 1999; Veleva et al., 2001; Curkovic, 2003; Marksberry, 2007; Abdul et al., 2008; Law & Gunasekaran, 2012; Yuan et al., 2012; Vinodh et al., 2013; Lee & Lee, 2014; Govindan et al., 2015a; Dubey et al., 2016 and Gupta et al., 2016) described the sustainable manufacturing practices (SMPs) i.e. *sustainable product design (SPD), Sustainable Manufacturing Process Design (SMPD), Lean Practices (LP), Agile Practices and Customization (APC), Sustainable Supply Operation and Distribution (SSOD) and Product Recovery and Return Practices (PRRP)* in the different sectors. Gunasekaran & Spalanzani (2012) have greatly contribute to the sustainable business development (SBD) in manufacturing and services (M&S) by proposing different research direction viz. sustainable product and process development, sustainable supply chain and product recovery operation etc.

that play an important role achieving sustainability. Jabbour et al. (2015) proposed a framework to obtain the relationship of human/organizational aspects to green product development. Gupta et al. (2015b) identified that the Product life cycle, 6R (reuse, recover, recycle, redesign, reduce and remanufacture) and service infrastructure are the important tools for sustainable product development. Thomas et al. (2012) identified traditional business improvement strategies, such as Lean and Agility in an attempt to become more robust and economically stable.

Similarly, Gupta et al. (2015a) evaluate Eco-design, process design; green supply chain, lean practices, product recovery and cleaner production are the key practices of sustainable manufacturing.

Thus, although there are many studies on SMPs as mentioned above, these have been carried out in the different countries such as USA, UK, Australia and other European countries with different context. As we know, sustainable manufacturing practices vary from country to country and are highly contextual in nature. In addition, most of the SMPs studies have been supply chain oriented rather than other practices. A similar study by Ribeiro et al. (2016) has also described the sustainable manufacturing practices but these practices focuses on only on the product development and supply chain management for achieving sustainability. As this discussion reveals, there have been numerous studies on sustainable manufacturing conducted in the various countries and various practices have been identified specific to the location of the studies. In Indian context, no study has been found to describe the various sustainable manufacturing practices suitable for Indian manufacturing industries. Based on this research gap, the first research question is as follows:

RQ-1 What are the sustainable manufacturing practices specific to the Indian Manufacturing Industries and can these practices constitute sustainable manufacturing?

The next section discusses the review of literature related to the various sustainable manufacturing practices.

2.5.7.1.1 Sustainable Product Design (SPD)

Several researchers (Pujari et al, 2003; Fuller et al., 2004; Choi et al., 2008; Garbie, 2013; Kam-Sing Wong, 2012; Mayyas et al., 2012; Khor & Udin, 2013; Yan & Feng, 2013; Gmelin & Seuring, 2014 and Jabbour et al., 2015) described about the sustainable product design (SPD). Zhang et al. (1997) aim to collect the information about Environmentally Conscious Design and provide some general information and guidelines for implementation. Sarkis (1998) evaluated the design for the environment, total quality environmental management, life cycle analysis, green supply chain management, and design for Packaging and ISO 14000 standards practices used by the managers. De Medeiros et al. (2014) and Poulikidou et al. (2014) draw the Success factors for environmentally sustainable product innovation and the concept of Design for Environment (DfE). Design for environment is an approach to reduce the environmental impact of product across its life cycle. Life cycle assessment (LCA) is the methodology for evaluating the environmental impact of product and materials for design for environment. LCA has emerged as the most objective tool available for evaluating the environmental impact of a product (Ramani et al., 2010).

According to Fuller et al. (2004), Sustainable product design represents a practical and logical way to reverse ecosystems degradation while providing benefits to customers and financial incentives to firms. Choi et al. (2008) developed a framework for the integration of environmental and business aspects toward sustainable product development, that Integrate environmental and business aspects of a product system to become more profitable. Kara et al. (2014) suggested the design tools such as LCA, DFE and ECQFD methods are utilised in the medium-and high-complexity product development by OEM manufacturers.

2.5.7.1.2 Sustainable Manufacturing Process Design (SMPD)

Many authors (Nowosielski et al., 2007; Kopac, 2009; Pusavec et al., 2010; Boubekri et al., 2010; Duflou et al., 2012; Ngai et al., 2013; Despeisse et al., 2013; Agan et al., 2013; Severo et al. 2015; Chuang & Yang 2014) find the sustainable manufacturing process design to be very effective and important practice for sustainable manufacturing. According to Kopac (2009), sustainable machining alternatives offer economic, environmental and social performance improvement in comparison to conventional machining. Pusavec et al. (2010) suggested that sustainable production is going to entail the use of alternative manufacturing technologies to reduce consumption rates, environmental burdens, and health risks simultaneously, while increasing performances and profitability.

Nowosielski et al. (2007) described that minimization of waste and reductions in material and energy inputs are the most important environmental aims and technological innovation is an important factor and seems to play a central role in the long-term initiation of cleaner production. Boubekri et al. (2010) suggested that use of efficient and clean technology to reduce carbon dioxide foot print and improving the utilisation of vegetable oil based metalworking fluids. Clean and Sustainable approach is necessary to increased energy efficiency in manufacturing industries based on systematic environmental performance (Alkaya & Demirer, 2015). SMPD practices provide an important foundation for the researchers and managers.

2.5.7.1.3 Lean Practices (LP)

Lean practices lead to Green practices and green practices are in alignment with the path to sustainability (Lee et al., 2012; Hajmohammad, et al., 2013; Martínez-Jurado & Moyano-Fuentes, 2014; Duarte & Cruz-Machado, 2013; Habidin et al., 2013; Kurdve et al., 2014; Dhingra et al., 2014; Glover et al., 2015; Alves et al., 2015; Longoni et al., 2015). Lewis (2000) also suggested that Lean practice implementation can be achieve long-term sustainability. Dhingra et al. (2014) also examined Lean practices that lead to Green practices and green practices are in alignment with the path to sustainability.

Faulkner & Badurdeen (2014) developed a comprehensive methodology for Sustainable Value Stream Mapping and suggested lean practices provided a foundation for sustainability improvement. Several lean practices can be identified from the literature such as Continuous improvement/Kaizen/Pokayoke/Mistake proofing; 5S; Total productive maintenance; and Just-in-Time (Habidin et al., 2013).

Alves et al. (2015) found that incorporating environmental considerations into manufacturing provides the company with favourable conditions for maintaining the continuous improvement of its processes. Glover et al. (2015) investigated the relationship between continuous improvement and rapid improvement sustainability and suggest the rapid improvement efforts, e.g., Kaizen events, and continuous improvement efforts, i.e., kaizen both leads to the sustainability. Longoni et al. (2015) suggested that the cross-functional executive involvement and worker involvement positively affect the strategic alignment of the lean manufacturing statement and bundles (just-in-time, total quality management, total preventive maintenance, and human resources management) with environmental and social goals and practices.

2.5.7.1.4 Agile Practices and Customization (APC)

Gunasekaran & Yusuf (2002) investigated agile practice requires enriching of the customer; cooperating with competitors; organizing to manage change, uncertainty and complexity; and leveraging people and information. Many researchers (Yusuf et al., 1999; Gunasekaran, 1999; Sharifi & Zhang 2001; Narasimhan et al., 2006; Calvo et al., 2008; Hallgren & Olhager, 2009; Vinodh, 2010; Vinodh et al., 2012; Dubey et al., 2015) work on agile practices. Vinodh et al. (2010) found significant improvement of agility and sustainability in the design and development of knob of rotary switch.

Dangayach & Deshmukh (2004) assessed advanced manufacturing technologies relevant to Indian manufacturing companies. Duray et al. (2000) investigated production cycle and modularity used in the product is the two key variables of agile practices and customization.

Yang & Li (2002) found that mass customization of product agility manufacturing is formed by three aspects, enterprise organization management, products design and processing and manufacturing.

MacCarthy et al., (2003); Majstorovic (2015) and Hankammer & Steiner (2015) suggested that mass customization has six fundamental strategies viz. Order taking and co-ordination, Product development and design, Product validation and manufacturing engineering, Order fulfilment management, Order fulfilment realization and post order process and found that the combination of mass customization patterns and product service system patterns carries a significant potential to foster the environmental sustainability.

2.5.7.1.5 Sustainable Supply Operation and Distribution (SSOD)

Many authors (Zhu & Sarkis, 2004; Li et al., 2006; Vachon & Klassen, 2008; Zhu et al., 2008; Eltayeb et al., 2011; Lai & Wong, 2012; Zailani et al., 2012; Govindan et al., 2014; Soda et al., 2015; Govindan et al., 2016) worked upon sustainable supply chain in different countries and in different context. Zhu & Sarkis (2007) found that increasing environmental pressure to implement green supply chain practices viz. green purchasing and investment recovery for environmental consciousness. Gimenez et al. (2012) analysed the impact of sustainable operations on triple bottom line (environmental, social and economic performance) and found that collaborative practices with supply chain partners are not affected the triple bottom line. Gotschol et al. (2014) investigated Green supply chain initiatives are more effective and economically more sustainable than internal actions.

Dubey et al. (2015b) suggested green supply chain management enablers include top management commitment, institutional pressures, supplier and customer relationship management. Zhu et al. (2016) argued that adoption of environmental management (EM) practices has evolved to be more proactive and external as the focus has shifted to supply chains. Zailani et al. (2012) found that environmental purchasing has a positive effect on three categories of outcomes (economic, social and operational) and sustainable packaging has a positive effect on environmental, economic and social outcomes. Hollos et al. (2012) found sustainable supplier co-operation effects on organization performance across social, green and economic dimensions and Key success factor of skilled logistics professionals improved the operational measure of customer satisfaction and the financial measure of profit growth.

2.5.7.1.6 Product Recovery and Return Practices (PRRP)

Gungor & Gupta (1999) identified environmentally conscious manufacturing and product recovery (ECMPRO) practices. ECMPRO related issues viz. life cycle of products, disassembly, material recovery, and remanufacturing and pollution prevention are key enablers for achieving green manufacturing. After that many researchers (White et al., 2003; Sundin &

Bras, 2005; Ijomah et al., 2007; Sasikumar & Kannan, 2009; Hatcher et al., 2011; Mangla et al., 2013; Abdulrahman et al., 2013; Subramanian et al., 2014; Ilgin et al., 2015; Shaharudin et al., 2015) investigated Product Recovery operations practices. Seliger et al. (2008) suggested Recycling, Remanufacturing and Reuse are the bases of sustainable manufacturing.

Ijomah et al. (2007) described that remanufacturing is a process of bringing used products to a like-new functional state with warranty to match. Its significance is that it can be both profitable and less harmful to the environment in comparison to conventional manufacturing. Ilgin & Gupta (2010) investigate four major categories of product recovery viz., environmentally conscious product design, reverse and closed-loop supply chains, remanufacturing, and disassembly.

Subramanian et al. (2014) investigated the factors for implementing end-of-life product reverse logistics. Legislation, Customer demand, Incentive, Strategic cost/benefits, Environmental concern, Resource, Integration and coordination, and Volume and quality are the key factors of end-of-life product reverse logistics. As suggested by the literature on sustainable manufacturing practices (SPD, SMPD, LP, APC, SSOD and PRRP) has been scant and focused on the single practice only. The scarcity of literature on sustainable manufacturing covering all six practices has prompted to formulate the research question.

2.5.7.2 Stakeholders Commitment for sustainable Manufacturing (SHC)

The involvement of the stakeholders in the decision making about the sustainability Initiatives in the organisation is a vital issue. Sarkis et al. (2010) assessed the stakeholder pressure to adoption of environmental practices and found that Stakeholder pressure positively related to the environmental initiatives for achieving sustainability. Qi et al. (2010) investigated the relationship between Environmental regulations, Managerial concerns, and stakeholder pressure with green Innovation.

Many researchers (Moneva et al., 2007; Sarkis et al., 2010; Lam et al., 2010; Theyel & Hofmann, 2012; Matos & Silvestre, 2013; Blome et al., 2014; Nejati et al., 2014; Zuraidah Raja Mohd Rasi et al., 2014; Yu & Ramanathan, 2014; Betts et al., 2015) focused on the stakeholders' involvement in sustainability. Hahn & Kühnen (2013) identified the determinants of sustainability and Stakeholder pressure and legitimacy aspects as the important determinants of sustainability.

Blome et al. (2014) identified the effect of green procurement and green supplier development on supplier performance by increasing the stakeholder's involvement. Meixell & Luoma (2015) investigate the stakeholder pressure in sustainable supply chain management and found that stakeholder perspective helps to understand sustainability in the supply chain management. Yu & Ramanathan (2014) investigated stakeholder pressures, green operation practices and environmental performance in UK. Theyel & Hofmann (2012) investigated the Stakeholder relations and sustainability practices. Stakeholders such as community advocacy groups, employees, suppliers, and customers are influenced by the adoption of sustainability practices, and firms with high adoption rates of environmental practices are more successful in product and process innovation.

Matos & Silvestre (2013) investigate the stakeholder relations in development of sustainable business and found that stakeholders, encouraging both learning and capability building in the organisation. Nejati et al. (2014) examined stakeholders' influence on environmental responsibility. Stakeholders significantly influenced environmental responsibility practices. Environmental responsibility results in financial improvements and better relations with employees and customers. Zuraidah Raja Mohd Rasi et al. (2014) found that environmental practices are influenced significantly by interactions between stakeholders while customers and employee's involvements are targeted at process based changes, while senior managers are interested in internal management improvements.

Kumar et al. (2016) investigated the Cross sector comparison of sustainability in stakeholder's perspective and found that Stakeholders are directly affecting the economic dimension of sustainability. Thus the literature affirms that stakeholder's commitment for achieving sustainability only for the supply chain practices and operations. In addition, literature gives the information about environmental performance and less information about the manufacturing competitiveness. To fulfil these research gaps, the following are the research questions.

RQ-2 Can stakeholder's commitment leads to the sustainable manufacturing in Indian context?

RQ-3 Is there a relationship between stakeholder's commitment and Sustainable performance measures?

RQ-4 Is there a relationship between stakeholder's commitment and sustainable manufacturing competitiveness?

2.5.7.3 Sustainable Performance Measures (SPM)

According to Habidin et al. (2013), sustainable performance measures are used to improve organisational overall performance. Environmental initiatives considered include ISO 14000 certification, pollution prevention and waste reduction. Melnyk et al. (2003) assessed the impact of environmental management systems on corporate and environmental performance and found that Firms in possession of a formal EMS, perceive impacts well beyond pollution abatement and measure a positive impact on many dimensions of operations performance.

In Labuschagne et al. (2005) suggested that Business sustainability incorporates the social equity, economic efficiency and environmental performance. Environmental Management Systems (EMS) under the ISO 14001 system of standards, leads significantly to sound environmental performance (Rao et al., 2006). Vachon et al. (2008) investigated environmental collaboration with primary suppliers is predominantly linked to superior delivery and flexibility performance. Joung et al. (2012) categorised sustainability indicators, based on mutual similarity, in five dimensions of sustainability: environmental stewardship, economic growth, social well-being, technological advancement, and performance management.

Yang et al. (2013) assessed the influence of Supplier Management and Continuous Improvement on cost and delivery performance is reduced with the presence of Environmental Management programs. Comoglio & Botta (2012) investigated and found that there is significant environmental impact on performance of ISO 14001 companies. Egilmez et al. (2013) assessed the sustainability in US manufacturing sector. They have quantified Greenhouse gas emissions, energy use, water withdrawals, hazardous waste generation, and toxic releases of each manufacturing sector using the Economic Input-Output life cycle assessment. Yusof et al. (2016) suggested that Environmental practices help to improve the environmental behaviour of the organization.

Zairi & Peters (2002) investigated the impact of social responsibility on business performance and conclude that Social sustainability consciousness pays off in the long run and it also improves the business performance. Lehmann et al. (2013) found that Social life cycle assessment (SLCA) understood social issues related directly to the technology.

Economic performance plays an important role in sustainability. Sen et al. (2015) found that there is a Positive correlation of environmental proactively with financial performance, manufacturing based operational performance and non-manufacturing based operational performance. Svensson & Wagner (2015) suggested an economic constituent is the basis of business sustainability. The literature suggested a set of sustainable performance measures for successful implementation of sustainability. Available literature investigates the possible performance measures and according to Habidin et al. (2013) that sustainable performance includes environmental performance, economic performance, and social performance issues as an integrated strategy for sustainability in manufacturing industries.

Thus literature suggests that economical, environmental and social performance represent the sustainable performance measures. There is abundant literature available on environmental performance and economic performance but very little literature in social performance measures. There is plethora of literature available on environmental performance and supply chain practices and other related practices but scant of literature available on sustainable performance and sustainable manufacturing practices. To fill this gap, the next research question is as follows:

RQ-5 Can adoption of sustainable manufacturing leads to a better sustainable performance measures?

2.5.7.4 Sustainable Manufacturing Competitiveness (SMC)

Noble (1977) investigated that cost, quality, delivery, flexibility, productivity, innovation, adaptability are the manufacturing competitive priorities. Avella et al. (2001) found that manufacturing strategy is important to competitive success. Markley et al. (2007) investigated that the potential competitive advantage of firms can create through sustainable supply chain. Competitive sustainable manufacturing (CSM) has been widely considered as main enabler for the growth of an organisation by Jovane et al. (2008).

Management strategies to improve the competitiveness drivers and their effects on overall supply chain competitiveness of the firm (Joshi et al., 2013). Jin et al. (2013) assessed proprietary technologies directly impact competitive advantage. Vanpoucke et al. (2014) argued that supplier integration capabilities for sustainable competitive advantage are positively related in term of cost quality, flexibility and innovation.

Gallardo-Vázquez et al. (2014) found that positive effect of social responsibility orientation of firms to competitive success. Tan et al. (2011) observed that sustainable practices can contribute to the improvement of sustainable performance and also contribute to business competitiveness. From the literature, it is observed that till now no attempt has been made to investigate the improvement in sustainable manufacturing competitiveness after adoption of sustainable manufacturing in the Indian context. There is limited literature available to analyse the relationship between sustainable manufacturing competitiveness and sustainable performance measures. To fill these gaps, the following are the research questions framed:

RQ-6 Can adoption of sustainable manufacturing leads to sustainable manufacturing competitiveness?

RQ-7 Is there a relationship between sustainable performance measures and sustainable manufacturing competitiveness?

2.5.8 Frameworks Developed for sustainable Manufacturing

Sarkis (1998) developed a framework for environmentally conscious business practices by incorporating the design for environment (DFE), total quality environmental management, life cycle analysis, green supply chain management and ISO 14000 standard practices are the key factors used by managers. The strategic element issues need to be integrated to determine the full impact of different constructs. Veleva et al. (2001) developed a framework for sustainable production to inform decision-making and measure progress towards more sustainable systems of production. The framework focuses on environmental, health and safety aspects of production. The major shortcoming of the model is to clarify and simplify the numerous indicator systems with industry professionals.

Maxwell & Van der Vorst (2003) developed a framework for implementing Sustainable Product and Service Developments (SPSD) which is used to implement sustainability in the design and development of a product and/or service.

Nunes Bennett (2010) developed a framework for Green operation practices like green buildings, eco-design, green supply chains, green manufacturing, reverse logistics and innovation as the best practices for green manufacturing in automobile industry. The major limitation of this model is selection of company. This model only developed for major three companies in automobile sector.

Jayal et al. (2010) explored sustainability in different direction, viz. sustainable product development and sustainable process. The shortcoming of this model is to develop improved sustainability scoring methods for products and processes, and predictive models and optimization techniques for sustainable manufacturing processes, they focused only on dry, near-dry and cryogenic machining.

Wong et al. (2012) investigated that Process stewardship has a positive influence on performance outcomes and environmental management capabilities of suppliers moderates the relationship between process stewardship and financial performance. This study is conducted in the context of electronics manufacturing which is the major limitation of this study.

Anttonen et al. (2013) focused on sustainable innovation. Services business efficiency is improved by sustainable innovation. Material efficiency services in the market require more customer attention. In this study survey response rate was adequate, but not high. It was only 17.2 % which was less than 20%.

Lee & Lee (2014) proposed a framework for a research inventory that focuses on sustainability assessment in manufacturing. Lee et al. (2014a) developed a framework and identified the relationship between green supply chain management (GSCM) practices and technological innovation (TI) in manufacturing firms. Green purchasing and cooperation with customers do not have a significant positive correlation with technology innovation.

The limitation of this study was that it would be beneficial to advance the statistical techniques by using Structural Equation Modeling-Artificial to further improve the validity and reliability of the results, at the same time producing a more accurate prediction.

Dubey et al. (2015c) developed a framework for world-class sustainable manufacturing and found that the respondents have regarded that leadership, regulatory pressure, Supplier relationship management, employee involvement, lean production and agile manufacturing are all equally important for achieving superior economic performance, environmental performance and social performance. This study focused only on manufacturing firms that are large scale enterprises. This framework needs to further explore with product complexity and Effects of Information and Communications Technologies on WCSM framework.

Thirupathi & Vinodh (2016) developed ISM and SEM model for sustainable manufacturing factors. The data collected from 50 automotive components manufacturing organisations located in Southern India. Data could be collected from more number of industries in the sector across the region or country. Some of the cause and effect relationship could not be explained like product recovery and return practices and sustainable manufacturing competiveness.

Table 2.10: Frameworks developed for sustainable manufacturing

S. No.	Author	Framework developed
1	Sarkis (1998)	Developed a framework for Environmentally conscious business practices by incorporating the design for environment (DFE), total quality environmental management, life cycle analysis, green supply chain management and ISO 14000 standard practices.
2	Veleva et al. (2001)	Developed a framework for sustainable production to inform decision-making and measure progress towards more sustainable systems of production. The framework focuses on environmental, health and safety aspects of production.
3	Maxwell & Van der Vorst (2003)	Developed a framework for implementing Sustainable Product and Service Developments (SPSD).
4	Nunes Bennett (2010)	Developed a framework for Green operation practices like green buildings, eco-design, green supply chains, green manufacturing, reverse logistics and innovation as the best practices for green manufacturing in automobile industry.
5	Jayal et al. (2010)	Explored sustainability in different direction, viz. sustainable product development and sustainable process.
6	Wong et al. (2012)	Investigated a framework for Process stewardship. Process stewardship has a positive influence on performance outcomes and environmental management capabilities of suppliers moderates the relationship between process stewardship and financial performance.
7	Anttonen et al. (2013)	Developed a framework on sustainable innovation. Services business efficiency is improved by sustainable innovation.
8	Lee & Lee (2014)	Proposed a framework for a research inventory that focuses on sustainability assessment in manufacturing.
9	Lee et al. (2014a)	Developed a framework and identified the relationship between green supply chain management (GSCM) practices and technological innovation (TI) in manufacturing firms.
10	Dubey et al. (2015c)	Developed a framework for world-class sustainable manufacturing and found the readership between regulatory pressure, Supplier relationship management, employee involvement, lean production and agile manufacturing and sustainable performance measurement.
11	Thirupathi & Vinodh (2016)	Developed a framework for sustainable manufacturing factors and found the relationship between product recovery and return practices and sustainable manufacturing competiveness.

Some of the limitations of the above discussed frameworks are: Nunes Bennett (2010); Wong et al. (2012); Dubey et al. (2015c) and Thirupathi & Vinodh (2016) have developed frameworks that are industry oriented; while Anttonen et al. (2013) focused on sustainable innovation but with less response rate 17.2%.

All these frameworks do not consider the stakeholder's commitment for sustainable manufacturing and also do not focus on sustainable manufacturing practices like manufacturing process design and product returns and recovery.

Though Dubey et al. (2015c) tried to develop a framework with lean and agile practices but still it is not comprehensive. In order to have an advanced study in sustainable manufacturing, it is necessary to have a suitable measurement model in Indian context. Though Thirupathi & Vinodh (2016) developed a measurement model, it has many deficiencies such as lack of consistency in scores due to group understanding in latent variables that might have resulted in biased component estimation, loading and path co-efficient.

Therefore, a framework that is suitable for a wide range of sustainable manufacturing practices is required for successful implementation of sustainability in the four sectors, i.e., automobile, electrical and electronics, machinery and process in Indian manufacturing industries. In Table 2.10 shows differenct frameworks developed for sustainable manufacturing.

The framework should not only discuss the sustainable manufacturing practices but also discuss about the impact on sustainable performance and sustainable manufacturing competitiveness and the stakeholder's commitment for sustainable manufacturing.

2.5 RESEARCH GAPS IDENTIFIED

Although literature review indicates that the sustainable manufacturing has become an important concept for manufacturing industries to deal with the environmental, economic and social sustainability, there are many issues that still exist which needs further investigation as describe below.

- Many researchers adopted manufacturing and automotive sectors for their study. There is not a single multisector study in Indian context. The multisector study would reveal a comparative evaluation of sustainable manufacturing implementation across various sectors.

- Since many researchers adopted different practices according to the specific requirement, there is need to identify comprehensive sustainable manufacturing practices related to Indian context.
- There is a need to develop a framework that comprises comprehensive sustainable manufacturing practices and stakeholder's commitment for sustainability in Indian scenario.
- To advance study, there is a need to develop a measurement model that includes stakeholder's commitment, sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness.
- Stakeholders are the backbone of industry so that there is a need to explore the relationship of stakeholder's commitment with sustainable manufacturing practices and the impact on sustainable performance measures and sustainable manufacturing competitiveness in Indian context.
- There is a need to explore the relationship of sustainable manufacturing practices with sustainable performance measures and sustainable manufacturing competitiveness.
- From the literature, it is found that most of the developed frameworks are not validated in industries therefore it is needed to validate the framework through case studies.

2.6 DEVELOPMENT OF RESEARCH FRAMEWORK

Based on the identified gaps in the literature, this research combining sustainable manufacturing practices (SPMs), sustainable performance measures (SPM) and sustainable manufacturing competitiveness (SMC) with stakeholder's commitment towards sustainable manufacturing in the Indian context. *Stakeholder's commitment* is pivotal to the success of sustainable manufacturing in the organisation. The organisation has to form a bond with its top management, employee, suppliers and its customers to motivate them for a common goal of sustainability.

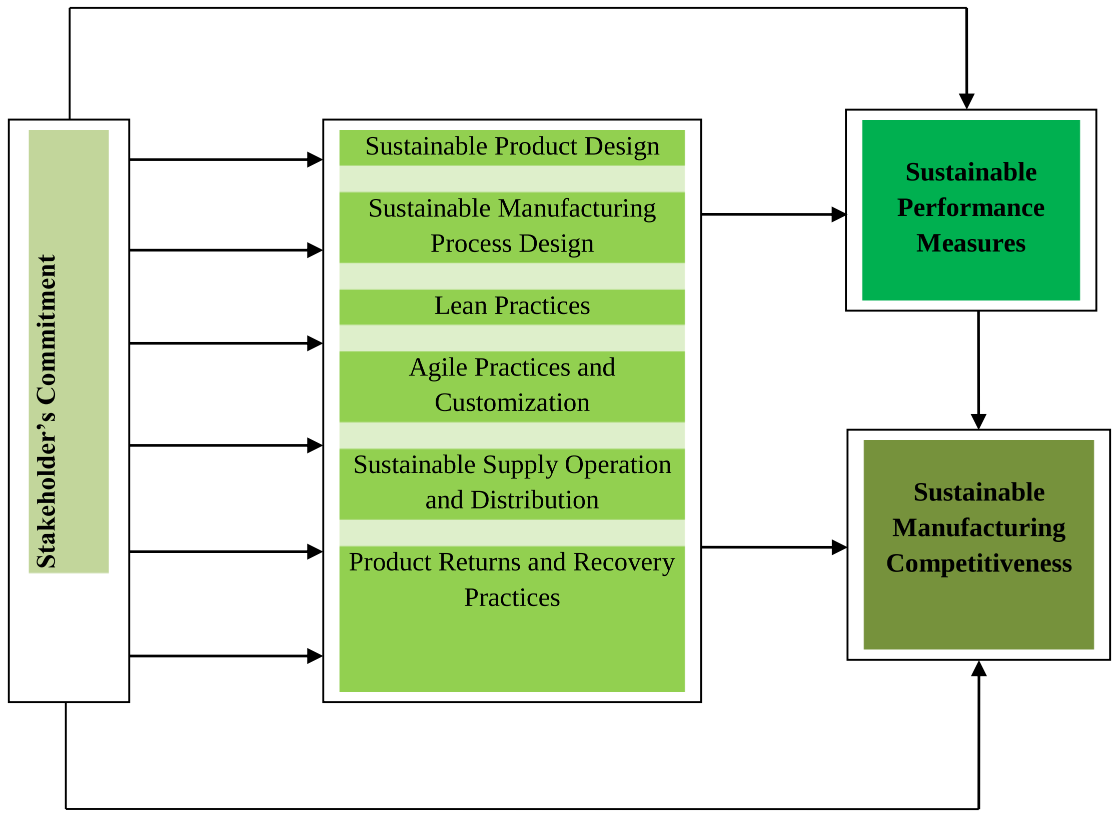


Figure 2.5: Proposed Theoretical Framework

The stakeholder plays an important role for successful adoption of sustainable manufacturing. Sustainable manufacturing practices, i.e., *sustainable product design, Sustainable manufacturing process design, Lean Practices, Agile practices and customization, Sustainable supply operation and distribution, Product returns and recovery* practices leads to the sustainable manufacturing (Habidin et al., 2013; Dubey et al. 2015c) and improve *sustainable performance*. Sustainable manufacturing also helps to achieve *sustainable manufacturing competiveness*. The proposed research framework is shown in Figure 2.5 to link the stakeholder's commitment, major practices of sustainable manufacturing and their effect on sustainable performance measures and sustainable manufacturing competiveness.

2.7 DEVELOPMENT OF HYPOTHESES

Based on the literature and available evidences the research hypotheses are framed to fill the identified gaps and to answer the framed research questions as discussed. The discussion provided above reveals that the stakeholder's commitment is associated with better implementation of sustainable manufacturing practices for achieving better sustainable performance and sustainable manufacturing competitiveness in Indian scenario. The hypotheses involving all the relationships developed for this research are given below.

2.8.1 Sustainable Manufacturing practices (SMPs)

As discussed in the various frameworks, there are many practices for sustainable manufacturing in the manufacturing industries. Various researchers have identified specific sustainable manufacturing practices that can be used in the manufacturing industries. Despeisse et al. (2013) identified sustainable manufacturing improvement opportunities through combined analysis of manufacturing operations, supporting facility systems and production buildings, and integration of best practices available from manufacturers. Agan et al. (2013) investigate the different practices like disposal, reduction, recycling, design, and environmental management systems and their impact on company performance. Gupta et al. (2015a) evaluated sustainable manufacturing practices, i.e., Eco-design, process design, green supply chain, lean practices, product recovery and cleaner production and found that these practices are the key practices of sustainable manufacturing. Based on the literature review and to achieve the RQ-1, the hypotheses are formulated for sustainable manufacturing.

RQ-1 What are the sustainable manufacturing practices specific to the Indian Manufacturing Industries and can these practices constitute sustainable manufacturing?

H1: Issues related to sustainable product design (SPD) constitute sustainable manufacturing.

H2: Issues related to sustainable manufacturing process design (SMPD) constitute sustainable manufacturing.

H3: Issues related to Lean Practices (LP) constitute sustainable manufacturing.

H4: Issues related to Agile practices and customization (APC) constitute sustainable manufacturing.

H5: Issues related to Sustainable Supply Operation and Distribution (SSOD) constitutes sustainable manufacturing.

H6: Issues related to Product recovery and return practices (PRRP) constitute sustainable manufacturing.

Based on the hypotheses H1 to H6, a conceptual model is developed as shown in Figure 2.6.

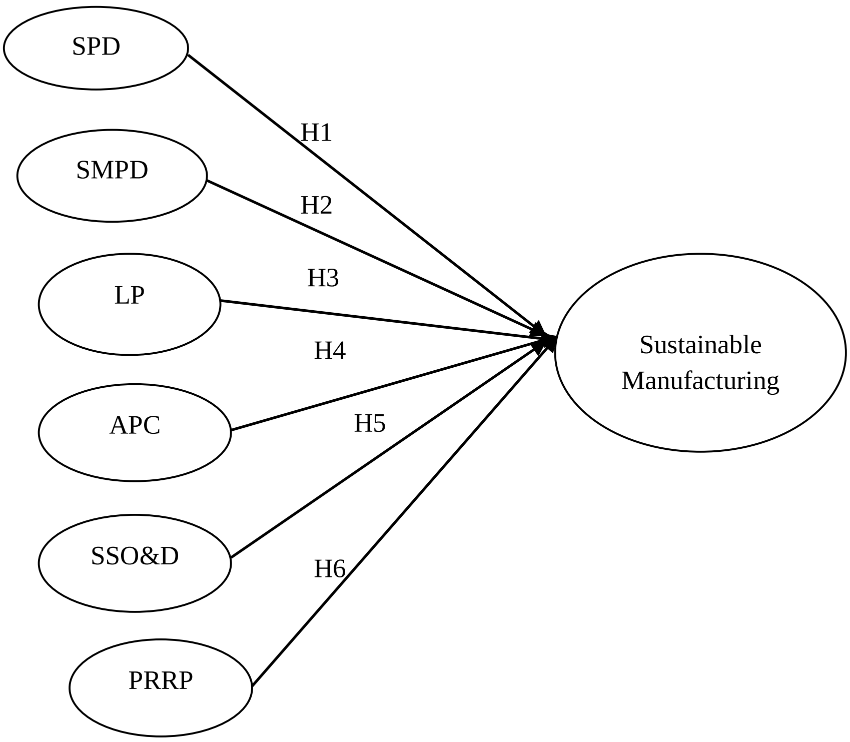


Figure 2.6: A conceptual model for sustainable manufacturing

2.8.2 Stakeholder's Commitment

Blome et al. (2014) observed that adoption of green manufacturing by the stakeholder's commitment and pressure. Yu & Ramanathan (2014) investigated that stakeholder pressures have a significant positive effect on internal green management, and that internal green management significantly affects green product/process design. Lam et al. (2010) identified the factors affecting the implementation of green technology and observed that leadership, responsibility and stakeholder involvement are the fundamental factors of green specification. Sarkis et al. (2010) investigated the relationship between Stakeholder pressure and the adoption of environmental practices and found relationship between stakeholder pressure and the dimensions of dynamic capabilities are positively related in resource based theory. System model for proactive action is proposed implement Competitive sustainable manufacturing at national and global levels (Jovane et al., 2008). Zuraidah Raja Mohd Rasi et al. (2014) observed that environmental practices are influenced significantly by interactions between stakeholders while customers and employee's involvements are targeted at process based changes, and senior managers are interested in internal management improvements. Based on the literature review and to achieve the RQ-2, RQ-3 and RQ-4, the hypotheses are formulated for the relationship of stakeholder's commitment to Sustainable performance measures and sustainable manufacturing competitiveness.

RQ-2 Can stakeholder's commitment leads to the sustainable manufacturing in Indian context?

RQ-3 Is there a relationship between stakeholder's commitment and Sustainable performance measures?

RQ-4 Is there a relationship between stakeholder's commitment and sustainable manufacturing competitiveness?

H7: There is a positive relationship between stakeholder's Commitment and sustainable manufacturing in Indian context

H8: There is a positive relationship between stakeholder's commitment and Sustainable performance measures

H9: There is a positive relationship between stakeholder's commitment and sustainable manufacturing competitiveness.

2.8.3 Sustainable Manufacturing and sustainable performance measures

Pusavec et al. (2010) argued that the use of sustainable production, i.e., alternative manufacturing machining technologies to reduce consumption rates, environmental burdens, and health risks is increasing performances and profitability. Duflou et al. (2012) explored that redesign of machine tools and selective control can significantly increase the energy efficiency for better environmental performance. Mani et al. (2014) Identified manufacturing process classifications scheme for sustainable manufacturing and evaluate sustainability performance for manufacturing with a focus on the environmental impact.

Alkaya & Demirer (2015) observed that clean and sustainable approach is necessary to increased water and energy efficiency in manufacturing industries based on systematic environmental performance. Based on the literature review and to achieve the RQ-5 the hypothesis is formulated for the relationship of sustainable manufacturing leads to a better sustainable performance measures.

RQ-5 Can adoption of sustainable manufacturing leads to a better sustainable performance measures?

H10: There is appositive relationship between sustainable manufacturing and sustainable performance measures?

2.8.4 Sustainable Manufacturing and sustainable manufacturing competitiveness

Pujari et al. (2003) argued that Green and competitiveness are positively related to environmental new product development performance. Kristianto et al. (2015) found that responsiveness, robustness and resilience (the “Triple R”) have become key objectives in global manufacturing, as a way of gaining competitive advantage in the global marketplace. Mitra & Datta (2014) investigated supplier collaboration for environmental sustainability and found positive impact on environmentally sustainable product design and logistics, which in turn was positively related to competitiveness and economic performance of the firm. Rao & Holt (2005) investigated that sustainable supply chain leads to an integrated green supply chain, which ultimately leads to competitiveness and economic performance. De Ron (1998) argues that companies using sustainable production techniques are more competitive over their competitors because of reduced costs, improved quality and better organisation. Based on the literature review and to achieve the RQ-6 the hypothesis is formulated for the relationship of sustainable manufacturing leads to a better sustainable manufacturing competitiveness.

RQ-6 Can adoption of sustainable manufacturing leads to sustainable manufacturing competitiveness?

H11: There is appositive relationship between sustainable manufacturing and sustainable manufacturing competitiveness

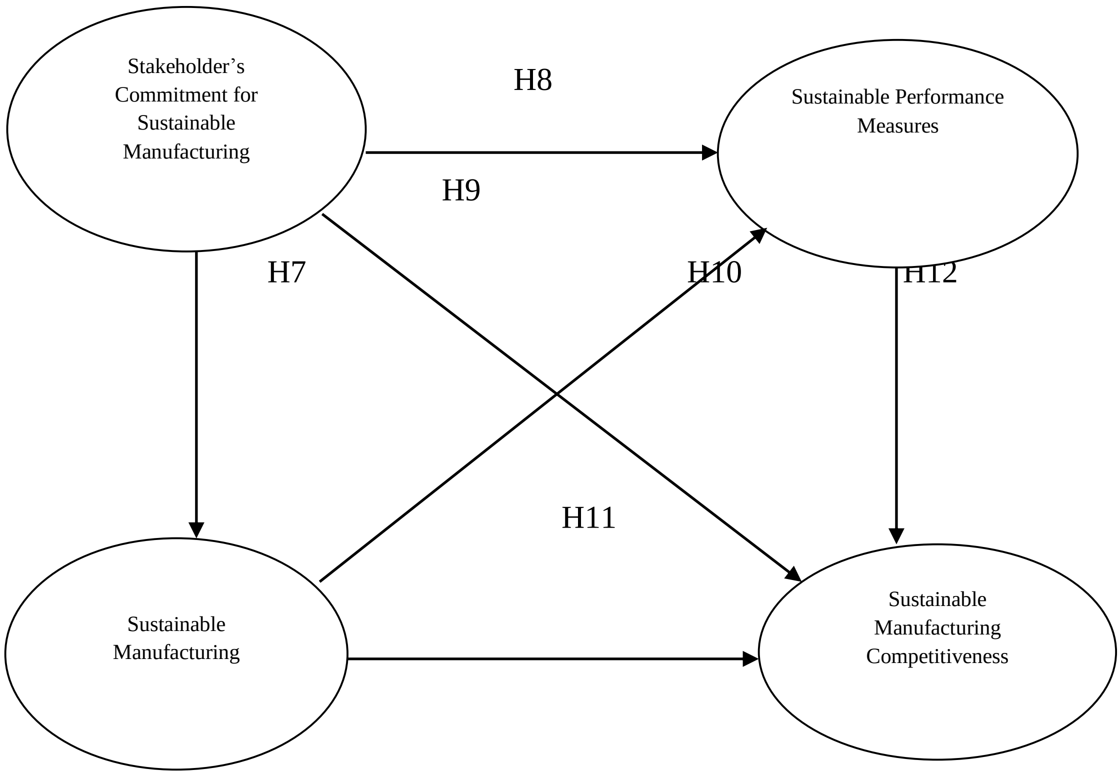


Figure 2.7: A conceptual model for relationship of SPMs, SCH, SPM and SCM

2.8.5 Sustainable performance measures and sustainable manufacturing competitiveness

Despotovic et al. (2015) investigated the economic, social and environmental dimension of sustainable competitiveness and he argued desirable change in economic and social dimensions affect the promotion of competitiveness. Tan et al. (2015) identified that sustainability is becoming a source of competitive advantage and have a Positive relation between sustainability performance and business competitiveness. Jorge et al. (2015) assessed that the environmental performance has a positive, direct and significant influence on competitiveness. Based on the literature review and to achieve the RQ-7 the hypothesis is formulated for the relationship of sustainable performance measures and sustainable manufacturing competitiveness.

RQ-7 Is there a relationship between sustainable performance measures and sustainable manufacturing competitiveness?

H12: There is a positive relationship between Sustainable performance measures and sustainable manufacturing competitiveness

Based on the hypotheses H7 to H12, a conceptual model for the relationship of SPMs, SCH, SPM and SCM is developed as shown in Figure 2.7.

Literature review provides the deeper insight on stakeholder's commitment for sustainable manufacturing and the impact on sustainable performance measures and manufacturing competitiveness. Similarly literature also provides the insight to the impact of sustainable manufacturing on sustainable performance measures and manufacturing competitiveness. Based on the literature and research questions framed, a proposed framework is developed which includes four major constructs, i.e., stakeholder's commitment, sustainable manufacturing practices, sustainable performance measure and sustainable manufacturing competitiveness.

2.8 SUMMARY

The chapter presents a review of literature on various issues of sustainable manufacturing practices. The chapter not only discusses the fundamentals sustainable manufacturing but also the sustainable manufacturing practices to improve the performance and sustainable manufacturing competitiveness. The aim of the literature review was to identify research gaps and development of research framework to fill these gaps.

Sustainable manufacturing is an emerging area in the world. Stakeholders are highly focused to adopt sustainable manufacturing and the implementation of environmental practices and strategies (Betts et al., 2015). Literature is explored to get deeper insight into the concept of sustainable manufacturing highlighting the sustainable manufacturing practices. The literature review has been done in four phases to describe the present study framework. First, sustainable manufacturing initiatives in the different countries are discussed. Second phase, literature review scheme and methodology has been discussed in terms of year wise, research paper wise, publishers wise, on the basis of research methodology, and content analysis. In the third phase, issues related to sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness is discussed. In the fourth phase, the various models on green and sustainable manufacturing has been studied. In the fifth phase, a theoretical framework is proposed and hypotheses are formulated. The detail methodology adopted to fulfil the research objectives will be discussed in the next chapter.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

The previous chapter described the detailed review of literature on sustainable manufacturing practices, theoretical framework and hypotheses of the research. The research methodology and its justification will be described in chapter three. The research methodology is based on the survey of Indian manufacturing industries to assess the role of stakeholders in adoption of sustainable manufacturing practices and the impact on sustainable performance and manufacturing competitiveness. The research includes two phases, in the phase one (macro phase), a theoretical framework of sustainable manufacturing practices has been explored through literature, semi structured interviews and survey of Indian manufacturing organisations. In the second phase (micro phase), case studies have been performed to validate the survey results.

3.2 RESEARCH METHODOLOGY

The aim of the current research is to explore the sustainable manufacturing practices among Indian manufacturing industries through a survey. The research methodology is based on data collected through a survey questionnaire. Case studies are developed to validate the results observed in the survey. A database of manufacturing companies was extracted from industrial directory (2015) and structured questionnaire was developed.

The questionnaire was administered in 1425 companies from four major sectors, viz. Automobile, electrical & electronics, machinery and process. As depicted in Figure 3.1, the research process as conducted in two phases which are design to achieve the aim. Macro phase focuses on preliminary analysis of sustainable manufacturing practice adoption, semi structured interview, survey questionnaire and validation of sustainable manufacturing practices model. Micro Phase focuses on case studies to validate the results observed from the Macro phase.

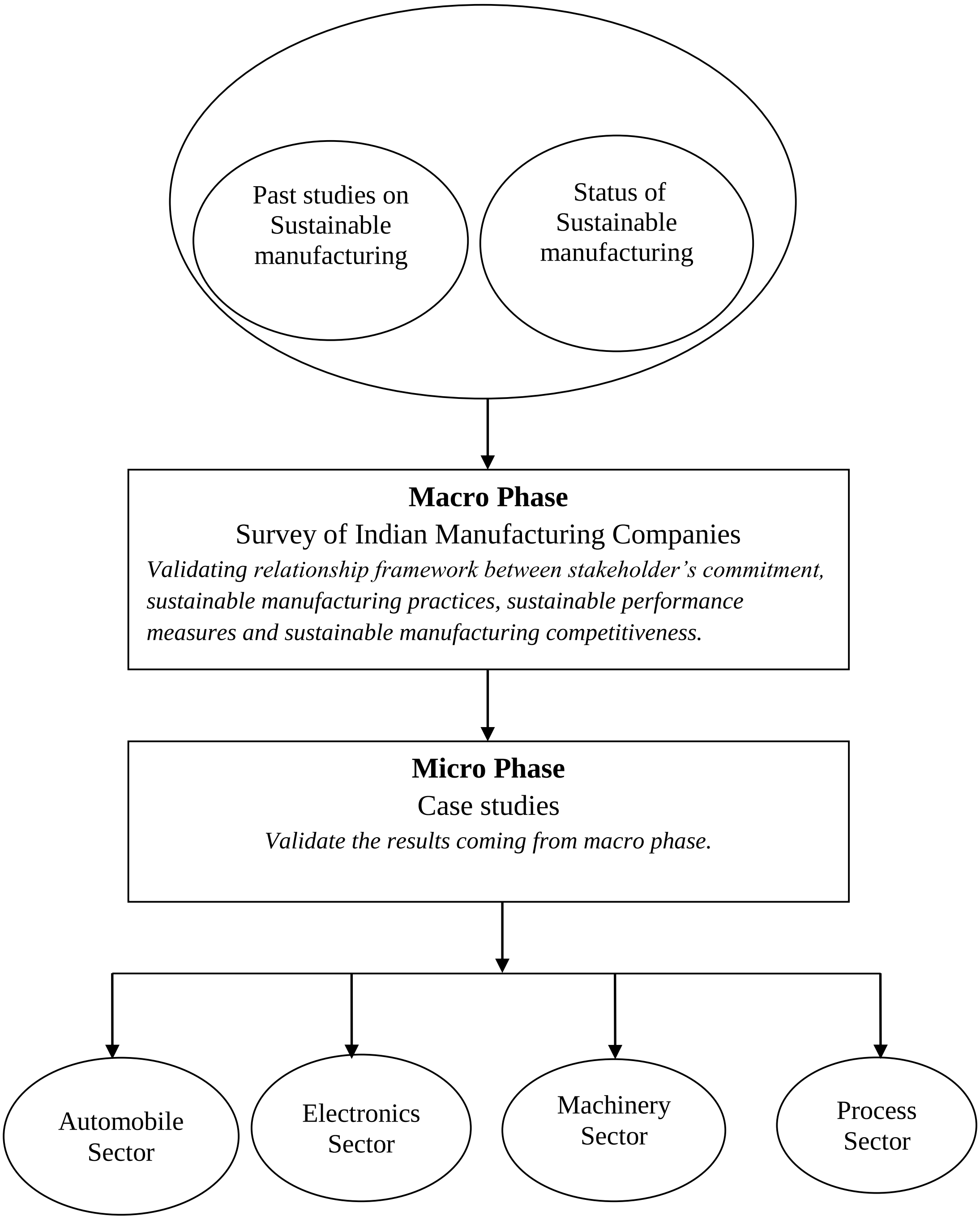


Figure 3.1: Research Methodology

3.3 JUSTIFICATION OF RESEARCH METHODOLOGY

In this study, empirical research is used to document the practices of sustainable manufacturing in Indian companies. The term empirical (which means knowledge based on real world observation) is used here to describe field based research, which uses data gathered from naturally occurring situations or experiments, rather than via laboratory or simulation studies. Where the researches have more control over the event being studied (Flynn et al., 1990). Empirical research provides a powerful tool for building and/or verifying the theory.

Survey involved the collection of information from a large group of population. The survey research is prominent as a methodology that has been used to study unstructured organisational problems in the production and operation (POM) area. Survey methodology is often been used to compute data from business organisations (Malhotra & Grover, 1998). Flynn et al. (1990) indicate the survey designs with questionnaire are the most commonly used methodology in empirical POM research.

The survey was structured to elicit responses on general sustainable manufacturing practices while the case study methodology was used due to exploratory nature of this research. Case study provides an in-depth, relatively unstructured, approach to develop framework and theories. Yin (2003) suggested that case study can be employed to explain a hypothesis and the results of a study are often rich in its explanation of phenomenon. In the situation of paucity of theory and complexity of phenomenon with lack of well supported definition and metrics, case study approach offer /more promising results than other approaches.

3.4 RESEARCH DESIGN FOR FIRST PHASE (SURVEY BASED METHODOLOGY)

In the first phase, realistic views on sustainable manufacturing practices were obtained through structured design of research as shown in Figure 3.2. Research design starts to establish a conceptual background planning and implementation of sustainable manufacturing through literature review. The gaps were identified on the basis of literature review. The perceptions, practices and inclinations towards sustainable manufacturing are operationalised through an empirical study based on survey focusing on Indian industry.

The research hypothesis and critical interaction among sustainable manufacturing practices, sustainable performance measures and manufacturing competitiveness variables are examined in chapter 2. No existing questionnaire was found to directly applicable to the stakeholder's commitment to adopt sustainable manufacturing, perceptive sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness. In this regard, semi-structured interviews were conducted with the industry professional and academicians.

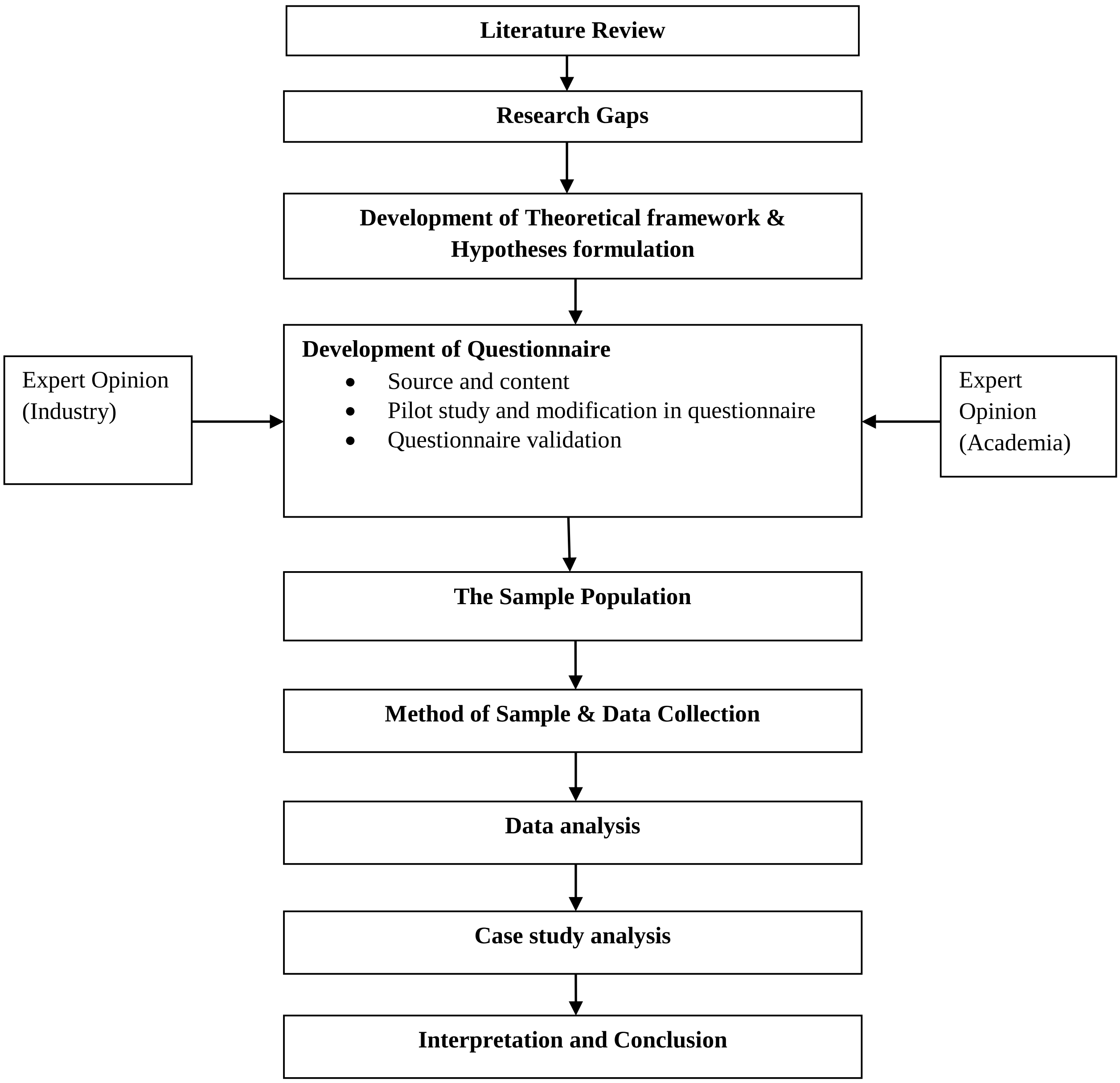


Figure 3.2: Research Design

The open ended questions were asked related to their perception on stakeholder's commitment to adopt *sustainable manufacturing, sustainable product design (SPD), sustainable manufacturing process design (SMPD), lean practices (LP), agile practice & customization (APC), sustainable supply operation and distribution (SSOD) and product recovery & return practices (PRRP)* relative importance of sustainable manufacturing practices, preferences of sustainable performance measures and sustainable manufacturing competitiveness. Based on the outcomes of literature review, a preliminary interview, the questionnaire was developed to investigate the research objectives.

3.5 DEVELOPMENT OF QUESTIONNAIRE

3.5.1 Source and Content

The objective of the broad scale survey was to collect data suitable for empirical assessment of theoretical framework presented in chapeter-2. Based on the literature (Dangayach & Deshmukh, 2001, Zhu et al., 2005, Zhu & Sarkis, 2007, Sarkis et al., 2010, Li, 2014, Dubey et al., 2015c, Luthra et al., 2016). In the literature it was found that the survey questionnaires have been commonly used in the recent studies to explore supply chain management, environmental management and green supply chain management practices. However, for the sustainable manufacturing practices, performances and competitiveness it is not widely utilized and in Indian scenario, the area is unexplored. This is the motivation to develop a new questionnaire in Indian context. Thus based on the discussion of industry and academia professionals and literature review, a survey questionnaire was designed. The questionnaire has been developed on a five point Likert scale (details of which are given in Appendix-I). Various issues of stakeholder's commitment, sustainable performance, sustainable manufacturing competiveness and the issues related to the sustainable manufacturing practices, viz. SPD, SMPD, LP, APC, SSOD and PRRP have been incorporated relevant to the Indian context.

Triple bottom line (TBL) has changed the way to manufacturing sustainability and the performance of projects or policies. TBL includes the all phases of manufacturing sustainability like pre manufacturing and post manufacturing. TBL allows organizations to apply the concept in a manner suitable to their specific needs. This research basically focuses on the all phases of manufacturing, which include the stakeholder's commitment, sustainable manufacturing practice, sustainable performance and sustainable manufacturing competiveness.

The questionnaire was split into two parts. Part A containing twenty four questions about general information of the company and respondents such as Company, Nature of Ownership, Type of Company, Number of Employees, Age, Gender, work experience, Position in the Company, Area of work, region of parent company, ISO 9000 certification, Sustainable/Green strategy, environmental initiatives, certification programs, annual sales turnover, growth of the organization, market share of the organization and twenty fifth question is about Stakeholder's Commitments for adoption of Sustainable Manufacturing.
Part B contains six questions related to the issues of sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competiveness which are directly related to the TBL.

Most of the variables in the study are measured using ordinal scale wherein, respondents assess the concept by rating on a five point Likert scale. Respondents were asked to rate the stakeholder's commitment on a five point Likert scale, ranging 1= very low, 2= low, 3=moderate, 4=high and 5=very high. View regarding the sustainable manufacturing practices, performance measures and manufacturing competitiveness were rated on a mixed five point Likert scale rating from 1= very low, 2= low, 3=moderate, 4=high and 5=very high and 1= totally disagree, 2= disagree, 3=moderate, 4=agree, 5= totally agree respectively.

Table 3.1 summarizes the issues of stakeholder's commitment, sustainable manufacturing practices, sustainable performance measures, and sustainable manufacturing competiveness along with the literature source.

Table 3.1: Issues Mentioned in the questionnaire

S. No.	Construct	No. of Items	Items	Literature Source
1	**Stakeholder's commitment**	6	1. Environmental compliances as per governmental policies are strictly adhered 2. Cross-functional cooperation for sustainable manufacturing 3. Motivation towards Sustainability 4. Emphasis on improving eco efficiency 5. Stakeholders Expertise 6. Total quality environmental management	Moneva et al. (2007), Sarkis et al. (2010), Lam et al. (2010), Theyel & Hofmann (2012), Matos & Silvestre (2013), Blome et al. (2014), Nejati et al. (2014), Zuraidah Raja Mohd Rasi et al. (2014), Yu & Ramanathan (2014), Betts et al. (2015).
2	**Sustainable product design**	5	1. Design of products for reduced consumption of material and energy. 2. Design of products to reduce the use of hazardous of products and manufacturing process 3. Design for Packaging 4. Design for environment (DFE) 5. Use of Life cycle assessment (LCA)	Pujari et al. (2003), Fuller et al. (2004), Choi et al (2008), Garbie (2013), Kam-Sing Wong (2012), Mayyas et al. (2012), Khor & Udin (2013), Yan & Feng (2013), Gmelin & Seuring (2014), Jabbour et al. (2015)
3	**Sustainable manufacturing process design**	6	1. Minimizing waste during machining process 2. Energy efficiency during production process 3. Improve resources utilization (materials, water, manpower) on shop floor 4.Use of efficient and clean technology to reduce carbon di oxide foot print 5.Improving the utilization of vegetable oil based metalworking fluids/cryogenic machining 6. Use of additive Manufacturing	Nowosielski et al. (2007), Kopac (2009), Pusavec et al. (2010), Boubekri et al. (2010), Duflou et al. (2012), Ngai et al. (2013), Despeisse et al. (2013), Agan et al. (2013), Severo et al. (2015), Chuang & Yang (2014)
4	**Lean practices**	6	1. Value Stream Mapping (VSM) 2. Continuous improvement /Kaizen/ Pokayoke/Mistake proofing	Lee et al. (2012), Hajmohammad, et al. (2013), Martínez-Jurado & Moyano-Fuentes (2014), Duarte &

			3. 5S (Sort, Shine, Set in order, Standardise, and Sustain) 4. Total productive maintenance (TPM) 5. Just-in-Time (JIT) 6. Kanban/Pull Production	Cruz-Machado (2013), Habidin et al. (2014), Dhingra et al. (2014), Glover et al. (2015), Alves et al. (2015), Longoni et al. (2015)
5	**Agile practices and customization**	6	1. Use of Flexible Manufacturing system (CAD/CAM/CAE, CAPP and CIM) 2. Use of Automation System (CNC, DNC & Robotics) 3. Use of Information Technology (ERP, MRP, SAP) 4. Quickly respond to customer 5. Flexibility to change volume as per customer demand 6. Product variety without increasing cost and sacrificing quality	Yusuf et al. (1999), Gunasekaran (1999), Sharifi & Zhang (2001), Gunasekaran & Yusuf (2002), Narasimhan et al. (2006), Calvo et al. (2008), Hallgren & Olhager (2009), Vinodh (2010), Vinodh et al. (2012), Dubey et al. (2015)
6	**Sustainable supply operation and distribution**	6	1. Cooperation with suppliers for environmental objectives 2. Second-tier supplier environmentally friendly practice evaluation 3. Cooperation with customers for green packaging 4. Supplier's advances in developing environmentally friendly packages 5. Investment recovery (sale) of excess inventories/ materials 6. Sale of scrap material, used materials and excess capital equipment	Zhu & Sarki (2004), Li et al. (2006), Vachon & Klassen (2008), Zhu et al. (2008), Eltayeb et al. (2011), Lai & Wong (2012), Zailani et al. (2012), Govindan et al. (2014), Soda et al. (2015), Govindan et al. (2016).
7	**Product recovery and recycling practices**	6	1. Reduce resource utilisation (Energy and water) 2. Recycle of returned product/material 3. Reusability of returned product/material 4. Recover of returned product/material for further processing	White et al. (2003), Sundin & Bras (2005), Ijomah et al. (2007), Sasikumar & Kannan (2009), Hatcher et al. (2011), Mangla et al. (2013), Abdulrahman et al. (2013), Subramanian et al (2014), Ilgin et al. (2015), Shaharudin et al. (2015).

			5. Re manufacturing of returned products as usable product (Recondition and Repair)	
			6. Redesign post-use processes and products	
8	**Sustainable manufacturing competiveness**	7	1. Reduced product manufacturing cost	Noble (1997), Avella et al. (2001), Markley et al. (2007), Jovane et al. (2008), Kristianto et al. (2010), Tan et al. (2011), Joshi et al. (2013), Jin et al. (2013), Vanpoucke et al (2014), Gallardo-Vázquez et al. (2014).
			2. Improvement in product and process quality	
			3. On time delivery of customer products	
			4. Innovation in product and process design	
			5. Adoption of advanced technology	
			6. Increase in profitability	
			7. Improve Corporate Social Responsibility and organizational growth	
9	**Sustainable performance measures**	10	1. Reduction of air emission, water waste and solid wastes	Zairi & Peters (2002), Melnyk et al. (2003), Labuschagne et al. (2005), Rao et al. (2006), Vachon et al. (2008), Yang et al. (2013),
			2. Decrease of consumption of hazardous/ harmful/ toxic materials	
			3. Decrease of frequency for environmental accidents	
			4. Decrease in cost of materials purchasing	
			5. Decrease in cost of waste treatment	
			6. Decrease in cost of energy consumption	Comoglio & Botta (2012), Egilmez et al. (2013), Lehmann et al. (2013), Li (2014)
			7. Provide good remunerations and wages to employee for stability	
			8. Provide quality health and safety management practices	
			9. Provide Employee training and career development program	
			10. Customer satisfaction	

3.5.2 Pilot Study

For this research, the pilot testing of the questionnaire was done in two phases:

In the first phase, the questionnaire was distributed to 20 students of mechanical engineering pursuing their final semester of post-graduation (M. Tech.) studies. They examined the questionnaire and also provided dummy responses to the questionnaire. This exercise revealed a few shortcomings of the questionnaire in proper communication of the intent of the question to the respondent, and the questions were suitably amended. In the second phase, the amended questionnaire was sent to thirty six experts, fifteen from academia and twenty one from industry, for favor of their scrutiny and suggestions for improvement of the questionnaire. Their suggestions were further incorporated in the questionnaire and confirmed face validity of items in the questionnaire. The questionnaire was now finalized and ready for administration. In conjunction with this qualitative assessment, quantitative assessment was also done for further purification of scale items. For this corrected item-to-total correlation was computed. The corrected item-to-total correlation equal to or greater than 0.6 is considered acceptable (Nunnally and Bernstein, 1994). The result found that the computed item-to-total correlation was greater than 0.6, therefore no item was deleted.

3.5.3 Reliability and Validity

To ensure the precise and accurate study, it is necessary to have procedure for testing goodness of the data for measurement. There are two traditional criteria for testing the goodness of any measurement process: reliability and validity (Menrzer and Flint, 1997). The study employed structural modelling that take care of convergent and discriminate validity and reliability analysis was also performed.

Reliability

Reliability is the quality of a measure that is consistent; which means that it gives consistent result when used with repletion on the same subject and in similar circumstances. Reliability refers to the degree of inter- correlation between the items measuring a later variable (Menrzer and Flint, 1997). Cronbach’s alpha value more than 0.6 are also considered. (Nunnally and Bernstein, 1994).

Validity

Creswell and miller (2000) define that validity as the ability to measure adequately what it is supposed to measure. The validity measures two things. First, does the items / scale truly what it is supposed to measure? Second. Does it measure nothing? The validity represents the relationship between the construct and its indicators. There are many different types of validity like: content validity, constrict validity, convergent validity and discriminate validity.

Content validity is a judgment, by expert, of the extent to which a scale truly measures the concept that it is intended to measure. For the content validity, the few questionnaires were send to the leading practitioners and academicians for pilot study.

Construct validity tries to establish an agreement between the measuring instrument and theoretical concepts. To establish construct validity, one must first establish relationship and examine the empirical relationship. Empirical finding should then be interpreted in terms of how they clarify the construct validity.

Convergent validity measures the extent of correlation among items that, theoretically, are intended to capture the essence of a latent abstract variable or construct. In othrder words convergence validity is the extent to which items intended to measure a latent variable statistically converge together (Bagozzi and Phillips, 1982).

Discriminant validity measures the degree to which items intended to measure a certain latent variable are unique to that variable (Byrne, 2013).

3.6 THE TARGET POPULATION AND SAMPLE

Sample design and size are important to establish the representativeness of the sample for generalizability (Hair et al., 2006).

Table 3.2: List of Typical products manufactured by respondent companies

S. No.	Sector	Typical products
1	Automobile	• Four wheelers including cars, trucks, tractors, and buses • Three wheelers including tractors • Two wheelers includes scooter and motorbike • Automotive components include shock absorber, head lights, battery bearings, clutches, brakes, steering and suspension systems, speedometers, mileage meters, piston and piston rings, engine assembly etc.
2	Electrical & Electronics	• Electronic consumer items such as television, washing machines, AC, fan, mobile phones radio, telephones etc. • Computers, desktop, notebooks and its parts • Measuring instruments including optical pyrometer, electronic energy meters, stabilizers, • Industrial electronics including microcircuits, electronic panels, fuse, telephone exchange chambers, cables transformers etc.
3	Machinery	• Agriculture machinery and equipment, • Sewing machines, • Material handling equipment such as forklift trucks, cranes, etc. • Construction machinery, Grinding machines, Diesel engines, • Generators, inverters, rotors, stators, electric motors etc. Medical equipment, Fluid control
4	Process	• Tyres, Paint, cement, fertilizers, papers textiles, food products, chemicals and oil and gas.

(Source: Dangayach & Deshmukh, 2001)

The target population of this research is Indian manufacturing industries which are divided into four sectors, viz. automobile, electrical/electronic, machinery and process industry (Dangayach & Deshmukh, 2001). All these four sectors are included in this study. Table 3.2 shows list of products manufactured by respondent companies in different sectors.
The criteria for selection of automobile and electrical & electronics sector in our study is based on the fact that companies belonging to these two sectors are fairly developed one and highly involve in research and development.

The increased criticism of the automobile and electrical & electronics as the largest source of pollution has put tremendous pressure on companies to upgrade not only the technology to increase efficiency and use better devices to control CO_2 emissions but also to incorporate the sustainable measures in their manufacturing practices.

As the environmental awareness is growing across, Machinery sector is also facing heavy pressure to reduce the emissions throughout the supply chain. Process sector are traditional polluters and have experienced higher environmental regulatory pressure. Stakeholders are much interesting in the process industry to greening their operations. To identify the current status of industries, these four sectors have been taken in to account.

3.7 METHOD OF SAMPLE AND DATA COLLECTION

In this research, the Information of manufacturing companies is collected from Confederation of Indian Industry (CII) Membership Database (2015), and ACMA Automotive Component Manufacturers Association of India database (2015). This contains name of organisation, their location, main products and type of industry, turnover and their email address. A selection criterion was based on two parameters, i.e., number of employees (≥100) and the annual sales turnover (≥0.15 million US $).

As a result, a database of 1425 manufacturing companies that are evenly distributed among all the manufacturing sectors across India was created. The data was collected through mail and telephone through convenient sampling. The survey was converted to on-line survey format.

The survey was launched online using the Google survey form. A web link was created for the survey and emailed to all the email ids available from the survey sample. The questionnaire was emailed to 1425 addresses. It was found that in spite of taking this care of verifying the email addresses few emails were returned undelivered. It was possible to contact some of them on phone who provided new addresses for mailings or asked the survey to be sent to them in email.

An email reminder was sent to all the non-respondents after a month of initial posting. After another 7 days, an SMS reminder was sent to the non-respondents. Telephonic follow-up was also done. These efforts helped, and response rate increased. Finally, 345 usable responses from a survey sample of 1425 received. The size of Received responses was much better than the other studies (Mitra & Datta, 2014; Sen et al., 2015; Gopal & Thakkar, 2016).

3.8 ANALYSIS OF DATA

Data Analysis can be defined as ‘a systematic and orderly approach taken towards the collection of the data so that information can be obtained from the data’. It is difficult to draw conclusions from empirical data and to generalize them without the assistance of statistical evidence. The IBM Statistical Package for Social Sciences (SPSS) version 22.0 and IBM SPSS AMOS 22.0 software package was used to analyze the data.

3.9 DATA ANALYSIS TOOLS AND TECHNIQUES

The various statistical procedures were followed to get the proper inference of collected data and to test the research hypotheses. The following tests were briefed in this section.

3.9.1 Preliminary analysis

A preliminary examination of data was carried out. These were used to conduct a preliminary analysis and to ensure validity of responses. Cronbach’s alpha coefficient, composite reliability, Mean, Standard deviation, Skewness & Kurtosis and confirmatory factor analysis was performed as an appropriate statistical test for assessing the reliability and validity of instrument using SPSS 22.0 and AMOS 22.0 software package.

3.9.2 Descriptive Statistics

Descriptive statistics include mean, standard deviation, standard error, frequencies, cross tabulation etc. This is used for computing segment wise and overall statistics for various issues of sustainable manufacturing. It helps to generate the basic information regarding the industries on sector wise and practices on sustainable manufacturing.

3.9.3 Test of Independence

The Chi Square one-variable test was used to test the association between two variables. The test of independence hypothesizes that the two variables are unrelated--that is, that the column proportions are the same across columns and any observed discrepancies are due to chance variation.

A larger chi-square statistic indicates a greater discrepancy between the observed and expected cell counts; that the hypothesis of independence is incorrect, and, therefore, that the two variables are not independent.

3.9.4 Analysis of Variances (ANOVA)

Analysis of variance (ANOVA) is a procedure, which is used to make comparisons among three or more means. One-way ANOVA is used to calculate F-statistic for testing relationship between several variables in this research.

3.9.5 Factor Analysis

In this research factor analysis is used by using SPSS 22.0 to extract the factor structure for the research. Similarly, we have evaluated the reliability and validity of constructs.

3.9.6 Confirmatory factor analysis (CFA)

In order to test the psychometric properties of the scale items, a confirmatory factor analysis was performed by using SPSS Amos 22.0. In this various measures such as convergent validity and discriminate validity of the items were evaluated. In this study AMOS 22.0 was used to model the first order factors and how these factors measure the second order dimension (Sustainable manufacturing) was ascertained.

3.9.7 Structural equation modeling (SEM)

Structural equation modeling is increasingly gaining acceptance in many research disciplines. SEM is being employed as a powerful alternative to multiple regression, path analysis, factor analysis and analysis of variance (Hair et al., 2006). SEM model is used to test the theoretical model, and to help establish the association between constructs. It provides the powerful data analysis technique that allow the entire theory put forward in a research model and test it simultaneously by examining the structure of interrelationships expressed in a series of equations, similar to a multiple regression equation (Hair et al., 2006).

Structural model using Amos 22.0 has been created to test the proposed hypothesis. In order to evaluate the model fit; various model fit indices, such as chi- squire value, CFI, AGFI, NFI RMSEA, GFI were evaluated. The path loadings and their significance were evaluated to check; how well the measurement scale predicts the dependent variables.

3.10 RESEARCH DESIGN FOR MICRO PHASE

In macro phase, based on the micro study (survey) four case studies were performed in the four sectors viz. automobile, electrical & electronics, machinery and process industry. Case studies are longitudinal in nature and sustainable manufacturing practices were discussed with more than one manager for data collection, therefore non response bias is reduced to minimum. Various researchers used case study approach for their research (Dangayach and Deshmukh, 2001; Despeisse et al., 2010; Niinimäki & Hassi 2011). The primary objective of case study was to gain in-depth understanding of the SM practices.

3.11 SUMMARY

The systematic approach used in the current research has been discussed in some detail in this chapter. The research methodology followed in the research has been described in detail. This chapter includes development of survey questionnaire, pilot study of survey questionnaire, development of database for the survey and the sample selection. The chapter also discussed the Method of Sample and data collection, Data Analysis Tools and Techniques and research design for macro phase. The next chapter deals with the data analysis, result and discussion.

4.1 INTRODUCTION

In the previous chapter (chapter-3), the research methodology was discussed along with the research design for macro and micro study of concerned research. In this chapter, data analysis is taken as a prime concern. The analysis of data collected from the main test survey includes demographic analysis, descriptive analysis, reliability and validity, factor analysis, associational analysis, sector wise comparative analysis and regression analysis of the sustainable manufacturing among the Indian industry. The analysis will further continue in the next chapter employing structural equation modelling (SEM) to examine the research hypothesis.

4.2 PRELIMINARY OBSERVATIONS OF SURVEY

Out of 1425 sampled Indian manufacturing companies, 345 usable responses were received. Therefore, the response rate achieved was 24.21%. It is worth mentioning that response rate achieved in present study is similar to other such studies carried out in Indian context. Gotschol et al. (2014), Ruparathna & Hewage (2015) and Gopal & Thakkar (2016) could achieve the response rate of 17.12%, 10.80% and 16.2% respectively. Nonetheless, according to the Dangayach and Deshmukh (2004) this response rate is adequate in India for this type of surveys.

4.2.1 Data coding and screening

After receiving the responses, it is necessary to coding the data before computing any inferential statistics. The process of coding includes the numbering of variables, their levels and values (Coakes et al. 2007). The coding of measurement scales were performed mainly for items of stakeholder’s commitment and items of section B. The coding of each item was done before proceeding to the statistical analysis. A set of complete coded Items and constructs are given in the (Appendix-I).

After codification, screening of data was initiated considering the common assumptions that were usually implied in various statistical analyses. Leech et al. (2005) suggested the need of preliminary data analysis prior to any inferential study with the following sequence: first, to explore outliers, distribution in data pattern, and missing data and errors in inputting the data in database; second, to examine the extent to which the assumption of statistical methods are met; and third, demographic information of subject which improves the level of understanding regarding research problem.

4.2.2 Missing value Analysis

Missing value analysis procedure was used to identify missing values and patterns of missing values in the data. It helps in deciding how the missing values are to be treated. This analysis is used informally to examine the missing data and take a decision of not inputting means to missing values. In our data, we found no missing value.

4.2.3 Outliers

In this study Mahalanobis distance (D^2) which is the distance of a particular case from the centroid of remaining cases was used as a measure of outliers. The point created by the means of all variables is called centroid. Hair et al. (2006) suggested that critical level for the measure D^2/Df should be less than 3 or 4 in large samples (more than one hundred). In this study no evidence was found of outliers when tested with SPSS 22.0 software package.

4.2.4 Non Responses bias

The non-response bias test was carried out to assess whether there is any significant difference between the early and late respondents of the returned survey. In this context, the early and late respondents of the returned survey were compared using independent test for all variables of the study. The comparison was made based on the assumption that the late respondents were considered as non-respondents, as suggested by Armstrong and Overton (1977) and Lambert and Harrington (1990). In this study, a total of 345 survey respondents were divided into early (n = 155, 44.9 %) and late (n = 190, 55.1%) respondents.

By using independent t-test analysis, the comparison was made to identify any significant difference of the mean values of the nine constructs of the study. The results of the comparison between early and late respondents was insignificant for all variables at the 5 % significance level, thus suggesting that the non-response bias was not present and not a problem in this study.

4.2.5 Vital statistics of respondent companies

This section provides background information on the respondent companies of the questionnaire. After reminders, phone calls, emails and re-reminders, 345 filled responses have been received from Indian manufacturing companies (automobile, electrical & electronics, machinery and process industry), which give the 24.2% response rate. From Figure 4.1 graphically, It was seen that 13 (3.8%) respondents are from East region, 16 (4.6%) respondents are from south region, 46 (13.3%) are from west region in India respectively. The largest number of respondents are from north region 270 (78.3%). In this study, the majority of respondents are from north region.

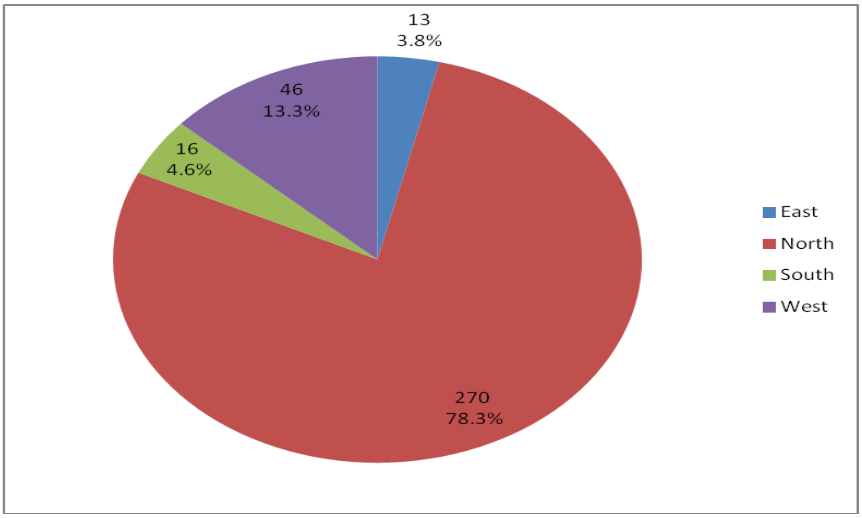


Figure 4.1: Region wise statistics of respondent companies

Table 4.2 gives the statistics of the respondent companies, i.e., nature of ownership, types of company (sector), no. of employees, annual sales turnover, company growth and market share.

Among 345 respondent companies from private limited, public limited and public sector, maximum 281 (81.4%) responses are from private limited companies.

Table 4.1: Statistics of respondent companies

Nature of Ownership	Respondent companies	Percentage
Private Limited	281	81.4
Public Limited	50	14.5
Public Sector	14	4.1
Type of Company (Sector)	Respondent companies	Percentage
Automobile	115	33.3
Electrical & Electronics	65	18.8
Machinery	75	21.7
Process	90	26.1
Number of Employees	Respondent companies	Percentage
100	58	16.8
101- 500	105	30.4
501 – 1000	42	12.2
1001 – 5000	72	20.9
5001 and above	68	19.7
Annual sales turnover	Respondent companies	Percentage
0.15 – 0.75 Million US$	15	4.3
0.75 – 1.5 Million US$	18	5.2
1.5 –7. 5 Million US$	51	14.8
7.5-15 Million US$	65	18.8
15-75 Million US$	76	22.0
Above 75 Million US$	120	34.8
Growth of the company during the last three years	Respondent companies	Percentage
Increase up to 10% per year	4	1.2
Increase more than 10% per year	28	8.1
Constant	105	30.4
Decrease up to 10% per year	208	60.3
Market share of the company during the last three years	Respondent companies	Percentage
Increase up to 10% per year	6	1.7
Increase more than 10% per year	69	20.0
Constant	122	35.4
Decrease up to 10% per year	148	42.9
Total no. of respondent companies = 345		

The distribution of respondent companies were 115 (33.3%) from automobile, 90 (26.1) from process sectors, 75 (21.8) from machinery and 65 (18.8%) from electrical and electronics sector. Maximum 105 (30.4%) of respondent companies have number of employees in the range of 101-500 peoples. In terms of company growth during last three years, 208 (60.5%) companies have decreased up to 10%. Similar in the case of market share during last three years, 148 (42.9%) companies have decreased up to 10%. Out of 345 companies, annual sales turnover of 120 (34.8%) is more than 75 million US$, while companies with annual sales turnover from 0.15-0.75 million US$ have contributed 15 (4.3%) responses.

4.2.6 Descriptive statistics

Descriptive analysis is useful to explore the data collected and it is particularly useful if one is focused to describe the general features of samples like demographic analysis, frequency distribution, percentage, mean, range, standard deviation, skewness and kurtosis (Leech et al., 2005). The descriptive analysis is performed to study the mean and standard deviation, which will further help to study the sustainable manufacturing practices and its impact on sustainable performance measures and manufacturing competitiveness. The descriptive analysis of the research constructs are shown in Table 4.1. In this table mean, standard deviation, skewness and kurtosis was calculated for further analysis.

Table 4.2: Descriptive statistics of Items of research constructs

Constructs	Code	Description of Items	Mean	Std. Deviation	Skewness	Kurtosis
SPD	SPD1	Design of products for reduced consumption of material and energy.	4.043	.8147	-.567	-.014
	SPD2	Design of products to reduce the use of hazardous of products and manufacturing process	3.974	.8435	-.564	-.059
	SPD3	Design for Packaging	3.957	.8147	-.406	-.225
	SPD4	Design for environment (DFE)	3.841	.9404	-.563	-.045
	SPD5	Use of Life cycle assessment (LCA)	3.661	1.0192	-.392	-.555
	SMPD1	Minimizing waste during machining process	4.017	.8625	-.662	.254

SMPD	SMPD2	Energy efficiency during production process	3.980	.8402	-.878	1.104
	SMPD3	Improve resources utilisation (materials, water, manpower) on shop floor	4.035	.9456	-.900	.459
	SMPD4	Use of efficient and clean technology to reduce carbon di oxide foot print	4.043	.8359	-.743	.755
	SMPD5	Improving the utilisation of vegetable oil based metalworking fluids/cryogenic machining	3.942	.8641	-.622	.120
	SMPD6	Use of additive Manufacturing	3.652	1.0290	-.728	.232
LP	LP1	Value Stream Mapping (VSM)	3.559	.9261	-.584	.167
	LP2	Continuous improvement/ Kaizen/ Pokayoke/Mistake proofing	3.974	.8970	-.800	.608
	LP3	5S	3.878	.9259	-.728	.393
	LP4	Total productive maintenance (TPM)	3.806	.9118	-.717	.643
	LP5	Just-in-Time (JIT)	3.623	.9660	-.489	.053
	LP6	Kanban/Pull Production	3.696	.9539	-.470	-.160
APC	APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	3.959	.9173	-.965	.909
	APC2	Use of Automation System (CNC, DNC & Robotics)	3.991	.9985	-.975	.813
	APC3	Use of Information Technology (ERP, MRP, SAP)	4.032	.9533	-.995	.715
	APC4	Quickly respond to customer	4.119	.8215	-.856	.757
	APC5	Flexibility to change volume as per customer demand	4.168	.9026	-.884	2.237
	APC6	Product variety without increasing cost and sacrificing quality	4.078	.8157	-.856	.878
SSOD	SSOD1	Cooperation with suppliers for environmental objectives	3.797	.8173	-.542	.610
	SSOD2	Second-tier supplier environmentally friendly practice evaluation	3.707	.8238	-.321	-.042
	SSOD3	Cooperation with customers for green packaging	3.777	.8790	-.453	-.050
	SSOD4	Supplier’s advances in developing environmentally friendly packages	3.716	.9057	-.495	.159
	SSOD5	Investment recovery (sale) of excess inventories/ materials	3.765	.8793	-.685	.707
	SSOD6	Sale of scrap material, used materials and excess capital equipment	3.942	.8156	-.734	.996
PRRP	PRRP1	Reduce resource utilisation (Energy and water)	3.768	.8584	-.561	.203
	PRRP2	Recycle of returned product/material	3.655	.9492	-.534	.054
	PRRP3	Reusability of returned product/material	3.542	.9789	-.212	-.657
	PRRP4	Recover of returned product/material for further processing	3.586	.9082	-.280	-.393

	PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	3.788	.9111	-.798	.841
	PRRP6	Redesign post-use processes and products	3.568	.8804	-.376	-.008
SHC	SHC1	Environmental compliances as per governmental policies are strictly adhered	3.945	1.0810	-.946	.288
	SHC2	Cross-functional cooperation for sustainable manufacturing	3.757	.9728	-.429	-.366
	SHC3	Motivation towards Sustainability	3.765	.9971	-.683	.078
	SHC4	Emphasis on improving eco-efficiency	3.771	1.0013	-.629	-.073
	SHC5	Stakeholders Expertise	3.687	1.0176	-.724	.236
	SHC6	Total quality environmental management	4.035	.9456	-.900	.459
SMC	SMC1	Reduced product manufacturing cost	4.107	.7795	-.782	.922
	SMC2	Improvement in product and process quality	4.177	.7591	-.829	1.101
	SMC3	On time delivery of customer products	4.113	.7935	-.731	.442
	SMC4	Innovation in product and process design	4.020	.7717	-.493	.333
	SMC5	Adoption of advanced technology	4.032	.8188	-.538	-.246
	SMC6	Increase in profitability	4.104	.6993	-.454	.129
	SMC7	Improve Corporate Social Responsibility and organizational growth	4.067	.7951	-.608	.179
SPM	SPM1	Reduction of air emission, water waste and solid wastes	4.043	.8359	-.803	.768
	SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	4.043	.8393	-.883	1.237
	SPM3	Decrease of frequency for environmental accidents	3.986	.8541	-.817	.846
	SPM4	Decrease in cost of materials purchasing	3.916	.8432	-.571	.305
	SPM5	Decrease in cost of waste treatment	3.864	.8603	-.643	.345
	SPM6	Decrease in cost of energy consumption	3.954	.8478	-.574	.104
	SPM7	Provide good remunerations and wages to employee for stability	3.881	.8729	-.690	.469
	SPM8	Provide quality health and safety management practices	3.962	.9030	-.879	.948
	SPM9	Provide Employee training and career development program	4.006	.8760	-.977	1.279
	SPM10	Customer satisfaction	4.188	.7087	-.829	1.311

4.2.6.1 Normality of Data

There are number of tests available to test the normality of data set that assumes that certain variables in the study follow the condition of normality at least at approximate level. It can be observed by the frequency distribution which looks like a bell shaped curve with most of the subjects in the mid-range and smaller number of subjects are in high and low ranges (Coakes et al., 2007). The skewness and kurtosis are considered as the measure of approximate normality of the data distribution.

Leech et al. (2005) suggested that when the value of skewness is less than ±1 and the value of kurtosis is below 10, the distribution of variable is to be considered as approximately normal. In this research, it was found that most of the values of skewness and kurtosis of items were between -1 to +1 or near to zero. The result indicates that the items of the main survey are approximately normally distributed and comply with the condition for statistical test employed in this research. The highest value of skewness was 0.995 and kurtosis 1.311, which is again near to 1. Table 4.1 presents the value of skewness and kurtosis.

4.2.6.2 Reliability of Data

Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group. A "high" value of alpha is often used (along with substantive arguments and possibly other statistical measures) as evidence that the items measure an underlying or latent construct. Inter-item analysis is used to check the scales/question for internal consistency or reliability.

Flynn et al. (1990) and Malhotra and Grover (1998) recommended the value of Cronbach’s coefficient alpha greater than 0.7. In this research, the value of Cronbach’s coefficient alpha was calculated as 0.97. It is an integral part of the ideal survey research.

4.2.7 The Respondents Profile

4.2.7.1 Respondents by work experience (in years)

It is seen form Figure 4.2 that 6 respondents (1.7%) are from companies with 26 and more years of work experience. The number of respondents from companies with 21 to 25 years of work experience is 19 (5.5%). The number of respondents from companies with 11 to 15 years of experience is 46 (13.3%), while organizations with 16 to 20 years work experience have contributed 48 (13.9%) responses. The highest contribution of 135 (39.1%) respondents has 6 to 10 years of work experience.

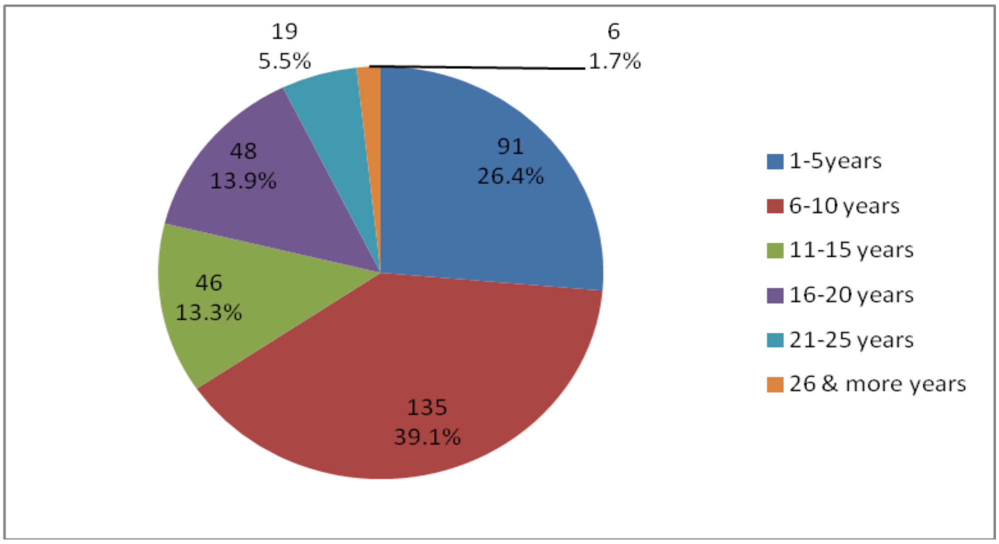


Figure 4.2: Respondents by work experience (in years)

4.2.7.2 Respondents by Position in the Company

The respondents profile by the position in the company is shown graphically in Figure 4.3. Middle Management respondents are placed the highest with 160 (46.4%) responses while junior management placed at second highest with 66 (28%) responses. The other categories of respondents in decreasing order of contribution are: senior management with 66 (19%) responses and owner/promoter/CEOs with 23 (7%) responses each. Thus the survey has received the benefit of the perceptions and opinions of a large spectrum of people with different experience in the management and outlook.

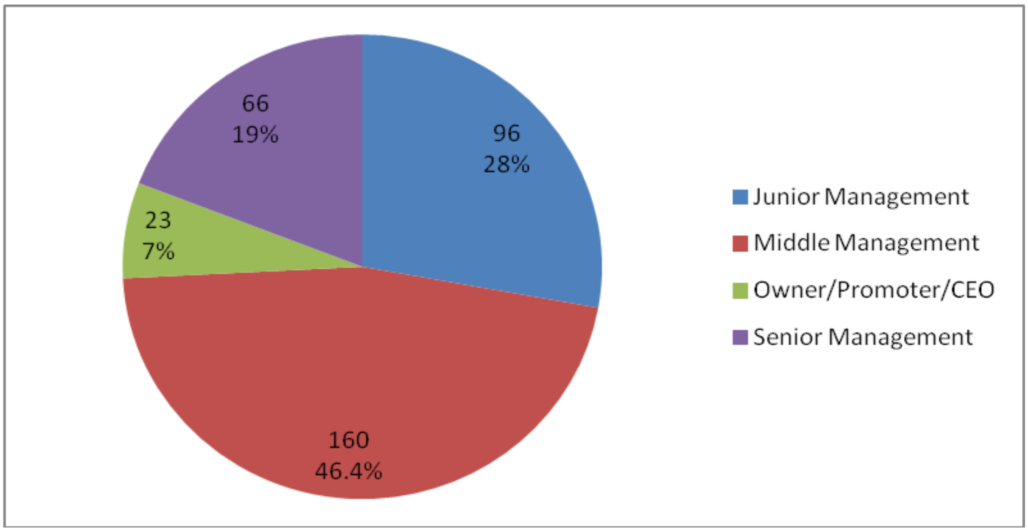


Figure 4.3: Respondents by Position in the Company

4.2.7.3 Respondents by experience in present companies

The respondents by experience in present company as shown graphically is in Figure 4.4. Respondents with experience in present company less than 3 years, 6-12 years and more than 12 years are 114 (33%), 59 (17.1%) and 32 (9.3%) respectively. Maximum numbers of respondents have 3 to 6 years of work experience in present company. Therefore, it is evident that respondents have appropriate knowledge about the company policies.

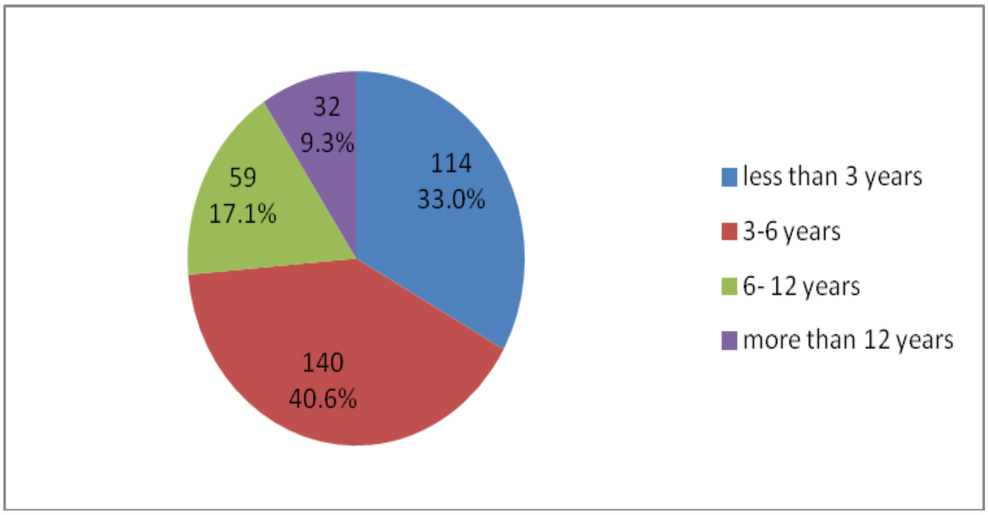


Figure 4.4: Respondents by experience in present companies

4.2.7.4 Respondents by region of parent company

A majority of the respondents 271 (78.6%) are from an Indian parent companies. The next largest category with 21 responses (6.1%) is from Japanese parent companies, whereas 19 (5.5%) respondents and 17 (4.9%) are from a US parent company and European parent company respectively. Seventeen (4.9%) responses are from other foreign parent companies. A graphical distribution of the respondents by region of parent company is shown in Figure 4.5.

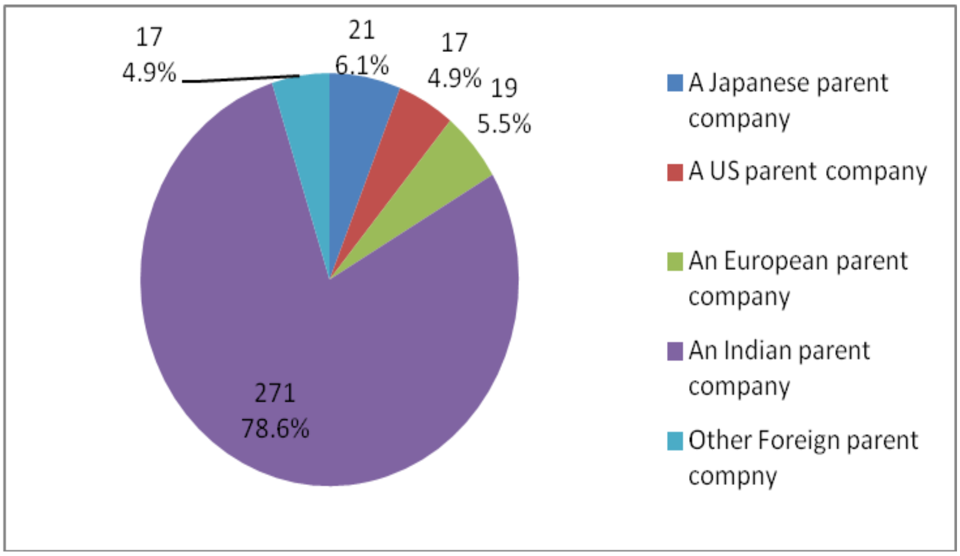


Figure 4.5: Respondents by region of parent company

4.2.8 General awareness of sustainability

In the survey questionnaire, respondent were asked about the general awareness of sustainability in terms of sustainability related program and certification. The respondents were asked to express their opinion about the *awareness of sustainability*.

Table 4.3: Statistics of general awareness of sustainability

1.2.4 General awareness of sustainability	Response of Respondents		Percentage		Total no. of Respondents = 345
	Yes	No	Yes	No	
ISO 9000 certification	341	04	98.8	1.2	
Significant environment policy	297	48	86.1	13.9	
Sustainable/Green strategy	302	43	87.5	12.5	
Energy efficiency program	279	66	80.9	19.1	
Environmental initiatives, certification programs	289	56	83.8	16.2	

The vital statistics of respondents companies is shown in Table 4.3. Surprisingly out of 345 respondents companies, 341 (98.8) are aware of ISO 900 certification and implemented. 297 (86.1%) respondents companies are aware of significant environmental policies in the company. Sustainable/green strategies being used by the 302 (87.5) companies whereas only 43 (12.5%) are not thinking about the sustainable strategies and 279 (80.99%) respondent companies are aware of the energy efficient program. Out of 345 respondent companies, 289 (83.8%) have launched environmental initiative in respective organisations and they also participated in the sustainability certificate programs.

4.2.9 Adoption of Sustainable Manufacturing Practices by Respondent companies

Out of 345 respondent companies, surprisingly 308 (89.3%) are adopted sustainable manufacturing practices. Only 37 (10.7%) respondent companies are not aware or using the sustainable manufacturing practices.

Table 4.4: Statistics of adoption of Sustainable Manufacturing Practices

Response of Respondents		Percentage
Yes	308	89.3
No	37	10.7
Total	354	100

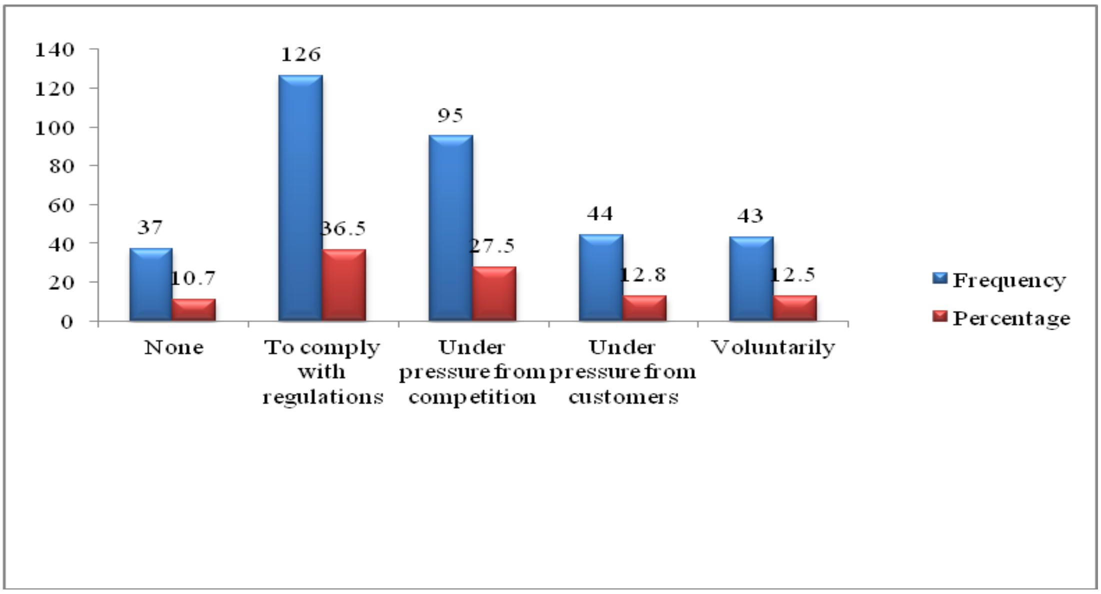


Figure 4.6: Adoptions of sustainable manufacturing practices

The statistics shown in Table 4.4 and Figure 4.6, it is clear that only 43 (12.5%) responded companies 'voluntarily' are adopting sustainable manufacturing practices whereas 44 (12.8%) and 95 (27.5%) respondent companies adopting sustainable manufacturing practices only *under pressure of customer and competition* respectively. Out of 345 respondent companies, 126 (36.5%) companies are adapting practice only to comply with regulations.

From the Table 4.5 and Figure 4.7, it is clear that 44 (38.26%) respondents from automobile sector confirmed adoption of sustainable manufacturing practices due to compliance requirement with regulations. Similarly electrical and electronics 23 (35.38%), machinery 25 (33.33%) and process industry 34 (37.77%) respondent companies adopted sustainable manufacturing practices again to comply with regulations.

Table 4.5: Sector wise frequency analysis adoptions of sustainable manufacturing practices

	Adoptions of sustainable manufacturing practices				
Type of Company	None	To comply with regulations	Under pressure from competition	Under pressure from customers	Voluntarily
Automobile (N=115)	15 (13.04%)	44 (38.26%)	27 (23.47%)	13 (11.30%)	16 (13.92%)
Electrical & Electronics (N=65)	4 (6.15%)	23 (35.38%)	21 (32.30%)	10 (15.38%)	7 (10.76%)
Machinery (N= 75)	6 (8.00%)	25 (33.33%)	22 (29.33%)	11 (14.65%)	11 (64.66%)
Process (N=90)	12 (13.33%)	34 (37.77%)	25 (27.77%)	10 (11.11%)	9 (10.00%)
Overall (N=345)	37 (10.72%)	126 (36.52%)	95 (27.53%)	44 (12.75%)	43 (12.46%)

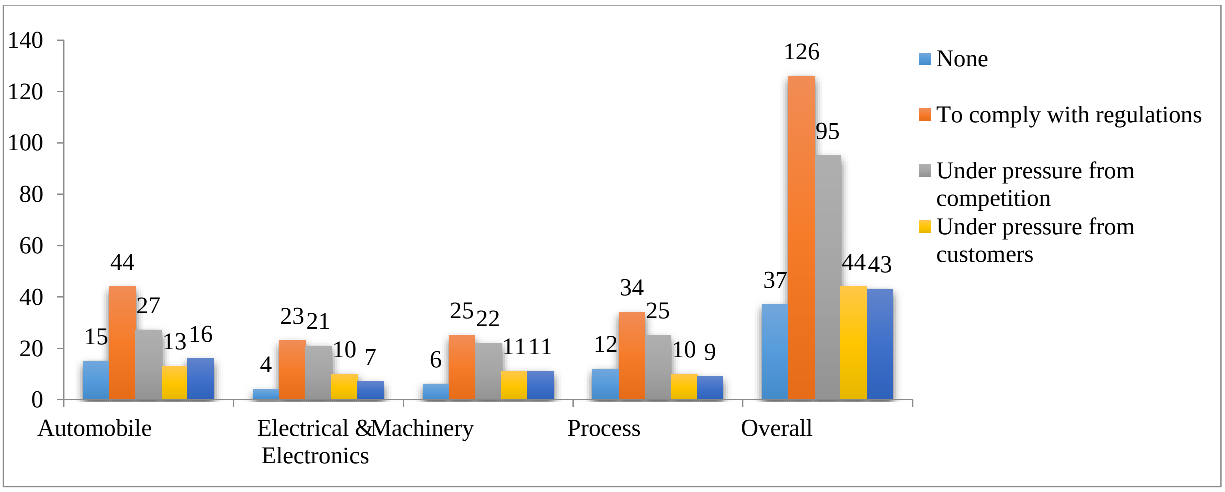


Figure 4.7: Sector wise frequency analysis of adoptions of sustainable manufacturing practices

4.3 INVESTIGATION OF ASSOCIATIONAL INFERENCE ABOUT AWARENESS OF SUSTAINABILITY

At the outset, five questions in the survey questionnaire were intended to reveal the general awareness about the sustainability (*ISO 9000 certification, significant environment policy, Sustainable/Green strategy, energy efficiency program and environmental initiatives, certification programs*) in manufacturing company's viz. automobile, electrical and electronics, machinery and process sectors. The respondents were asked if they have adopted or implemented the sustainability program and certification in their organizations.

Earlier in Table 4.4 summarizes the findings regarding awareness about sustainability in the manufacturing industry.

4.3.1 Familiar with ISO 9000 certification

Present study explores that out of 115 respondents from automobile companies 113 (98.3%) are familiar with *ISO 9000 certification*, whereas 2 (1.7%) are not familiar with ISO certification. In the case of electrical and electronics companies, out of 65 respondents, 64 (98.5%) are familiar with ISO 9000. 74 (98.7%) respondents are familiar in machinery industry. As far as process industry concerns, 90 (100%) respondents are familiar with ISO 9000 certification.

Table 4.6: Association between type of company and familiarity of ISO9000 certification

		Familiar ISO 9000 certification		
		NO	YES	Total
Type of Company	Automobile	2 (1.7%)	113 (98.3%)	115 (100%)
	Electrical & Electronics	1 (1.5%)	64 (98.5%)	65 (100%)
	Machinery	1 (1.3%)	74 (98.7%)	75 (100%)
	Process	0 (0.0%)	90 (100.0%)	90 (100%)
Total		4 (1.2%)	341 (98.8%)	345

It is evident from Table 4.6 that overall 341 (98.8%) respondents are familiar with *ISO 9000 certification* and only 4 (1.2%) have no idea about the ISO 9000 certification. To investigate if there is a significant relationship between type of firm and familiarity of ISO 9000 Companies, chi square test was carried out. It is clear from the Table 4.7 that relation between type of industry sector and familiarity of ISO 9000 certification companies is insignificant. Therefore all type industries (sectors), automobile, electrical and electronics, machinery and process invariably perceive *ISO 9000 certification* to be useful for manufacturing industry.

Table 4.7: Chi square test results for association between type of industry (Sector) and familiarity of ISO 9000 certification

	Value	Degree of freedom	Significance
Pearson Chi-Square	1.494	3	0.684
N of Valid Cases	345		

4.3.2 Adoption of environment policy

Overall 297 (86.1%) respondents think that adoption of *environmental policy* is useful in the industries. Table 4.8 shows that out of 115 respondents from the automobile companies, 98 (85.2%) believed that adoption of *environmental policies* is useful for the automobile industry. It is seen from the results that 76 (77.5%) respondents from process industries believed that environmental policies are important. Surprisingly out of 75 respondents form machinery companies, a maximum of 67 (89.3%) have adopted the environmental policies.

Table 4.8: Association between type of company and adoption of significant environment policy

		Adoption of environment policy		Total
		NO	YES	
Type of Company	Automobile	17 (14.8%)	98 (85.2%)	115 (100%)
	Electrical & Electronics	9 (13.8%)	56 (86.2%)	65 (100%)
	Machinery	8 (10.7%)	67 (89.3%)	75 (100%)
	Process	14 (15.6%)	76 (77.5%)	90 (100%)
Total		48 (13.9%)	297 (86.1%)	345

Table 4.9: Chi square test results for association between type of industries (Sector) and adoption of environment policy

	Value	Degree of freedom	Significance
Pearson Chi-Square	.935	3	.817
N of Valid Cases	345		

To investigate if there is significant relationship between type of firm and adoption of significant environmental policy in Companies, chi square test was carried out. It is clear from the Table 4.9 that relation between type of industry sector and familiarity of adoption of significant environmental policy is insignificant. Therefore, automobile, electrical and electronics, machinery and process all type industries (sectors) invariably perceive significant environment policy to be useful for manufacturing industry.

4.3.3 Perception about Sustainable/Green strategy

Out of 115 respondents from automobile companies 95 (82.6%) are familiar with *Sustainable/Green strategy*, whereas 20 (17.4%) are not familiar with *Sustainable/Green strategy*. In the case of electrical and electronics companies, out of 65 respondents, 61 (93.8%) are familiar with Sustainable/Green strategy and 64 (85.3%) respondents are familiar in machinery industry. In the process industry, 82 (78.8%) respondents out of 90 are familiar with Sustainable/Green strategy. The analysis is given in Table 4.10.

Table 4.10: Association between type of company and Perception about Sustainable/Green strategy

		Perception Sustainable/Green strategy		
		NO	YES	Total
Type of Company	Automobile	20 (17.4%)	95 (82.6%)	115 (100%)
	Electrical & Electronics	4 (6.2%)	61 (93.8%)	65 (100%)
	Machinery	11 (14.7%)	64 (85.3%)	75 (100%)
	Process	8 (8.9%)	82 (78.8%)	90 (100%)
Total		43 (12.5%)	302 (87.5%)	345 (100%)

To investigate if there is significant relationship between type of firm and perception about of *Sustainable/Green strategy*, chi square test was carried out. It is clear from the Table 4.11, that relation between type of industry sector and perception of *Sustainable/Green strategy* in companies is significant. Therefore, perception of *Sustainable/Green strategy* is significantly higher in automobile sector in comparison to electrical and electronics, machinery and process sectors. Automobile companies are more conscious about sustainable and green strategies due to heavy competition in the global market.

Table 4.11: Chi square test results for association between type of industries (Sector) and Perception about Sustainable/Green strategy

	Value	Degree of freedom	Significance
Pearson Chi-Square	7.913	3	.047
N of Valid Cases	345		

4.3.4 Participation in energy efficiency program

Overall 279 (80.9%) respondents think that *energy efficiency program* is useful in the industries. Table 4.12 shows that out of 115 respondents from the automobile companies, 88 (93.0%) believed that *energy efficiency program* is useful for the automobile industry. It is seen from the results, 73 (81.1%) respondents from process industries are believed that energy efficiency program are important. Out of 75 respondents from machinery companies 61 (81.3%) are considered that energy efficiency program is important. 57 (87.7%) respondents from electrical and electronics replied that energy efficient program beneficial for the company.

Table 4.12: Association between type of company and Participation in energy efficiency program

		Participation in energy efficiency program		Total
		NO	YES	
Type of Company	Automobile	27 (23.5%)	88 (93.0%)	115 (100%)
	Electrical & Electronics	8 (12.3%)	57 (87.7%)	65 (100%)
	Machinery	14 (18.7%)	61 (81.3%)	75 (100%)
	Process	17 (18.9%)	73 (81.1%)	90 (100%)
Total		66 (19.1%)	279 (80.9%)	345 (100%)

To investigate the relationship between type of firm and Participation in energy efficiency program in Companies, chi square test was carried out. It is clear from the Table 4.13 that relation between type of industry sector and Participation in *energy efficiency program* is insignificant. Therefore, automobile, electrical and electronics, machinery and process all type industries (sectors) invariably perceive energy efficiency program to be useful for manufacturing industry.

Table 4.13: Chi square test results for association between type of industries (Sector) and Participation in energy efficiency program

	Value	Degree of freedom	Significance
Pearson Chi-Square	3.375	3	.337
N of Valid Cases	345		

4.3.5 Participation in environmental initiatives, certification programs

Out of 115 respondents from automobile companies 91 (79.1%) are considered that *environmental initiatives, certification programs* are effectively used by the company, whereas 24 (20.9%) are not familiar with *environmental initiatives, and certification programs*. In the case of electrical and electronics companies, out of 65 respondents 57 (87.7%) are familiar with environmental initiatives, and certification programs. 66 (88.0%) respondents are familiar in machinery industry.

As far as process industry concerned, 75 (83.3%) respondents out of 90 adopted *environmental initiatives, and certification programs*. The analysis is given in Table 4.14.

Table 4.14: Association between type of company and Participation in environmental initiatives, certification programs

		Participation in environmental initiatives, certification programs		
		NO	YES	Total
Type of Company	Automobile	24 (20.9%)	91 (79.1%)	115 (100%)
	Electrical & Electronics	8 (12.3%)	57 (87.7%)	65 (100%)
	Machinery	9 (12.0%)	66 (88.0%)	75 (100%)
	Process	15 (16.7%)	75 (83.3%)	90 (100%)
Total		56 (16.2%)	289 (83.8%)	345 (100%)

It is evident from Table 4.16 that overall 289 (83.8%) responds replied that they are aware of *environmental initiatives, certification programs* and only 56 (16.2%) have not adopted the environmental initiatives. To investigate the relationship between type of firm and perception of *environmental initiatives, certification programs*, chi square test was carried out. It is clear from the Table 4.15 that relation between type of industry sector and perception of environmental initiatives, certification programs in companies is insignificant.

Table 4.15: Chi square test results for association between type of industries (Sector) and Participation in environmental initiatives, certification programs

	Value	Degree of freedom	Significance
Pearson Chi-Square	3.556	3	0.314
N of Valid Cases	345		

4.4 IDENTIFICATION OF RESEARCH CONSTRUCTS BY FACTOR ANALYSIS

Factor analysis is used to identify number of constructs that might be used to represent relationship among set of variables (Mitra & Datta, 2014). It is primarily used for dimension reduction and factor extraction. The purpose of factor extraction is to extract factor or construct, i.e. the underlying construct that describes a set of items.

In the present research, factor analysis is used to dimension reduction and identification of research constructs related to sustainable manufacturing practices, sustainable performance measures, sustainable manufacturing competitiveness and stakeholders commitment. For factor analysis, normality, linearity and homogeneity of the sample are assumed. The ratio of respondent-to- variables exceeds the minimum value of 5 (Mitra & Datta, 2014). There exist significant correlation among many of the variables. Partial correlations among most of the variables are 0.5 or less. Originally, 58 items were used to gain the insight to respondent's perception. Principle component analysis (PCA) with varimax rotation was used to identify the constructs. PCA is mostly used as a tool in exploratory data analysis. Only constructs which accounted for a variance more than one (eigenvalue >1) and cumulative percentage of total variance extracted is at least 60% were extracted (Kim and Muller, 1978). From principal component analysis and varimax rotation, eight higher level of constructs were extracted which accounted for about 61.32% of the total variance in observed rating. The various steps involved in factor analysis are described in following sections.

4.4.1 Kaiser-Mayer-Olkin (KMO) and Bartlett's test of sphericity

Field (2009), recommends that before running the factor analysis, variables should be analysed for sample adequacy through Kaiser-Mayer-Olkin (KMO) measures and Bartlett's test of sphericity. Therefore the first step running factor analysis was to carry out KMO test with sample adequacy and Bartlett's test of sphericity. KMO varies from 0 to 1 and KMO overall should be 0.60 or higher to proceed with factor analysis. In the present research, Kaiser-Mayer-Olkin (KMO) statistics was found to be 0.959.

Table 4.16: Kaiser-Mayer-Olkin (KMO) and Bartlett's test of sphericity

Test		**Statistics**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.959
Bartlett's Test of Sphericity	Approx. Chi-Square	11593.293
	Degree of freedom	1378
	Significance	0.000

Bartlett's test of sphericity examines the correlation matrix. In the present study, the Bartlett's test of sphericity was significant (0.000) as shown in Table 4.16. Thus both the test Kaiser-Mayer-Olkin (KMO) (0.959) and Bartlett's test (Sing. 0.000) indicates that the data is suitable for factor analysis.

4.4.2 Eigen value

Eigen values are the sum of square values of factor loadings relating to factors. According to Costello (2009), the factor has low Eigen value, it means that it is contributing little to the explanation of variance in the variables and may be ignored and replaced with factors that are more important. Table 4.17 illustrates the Eigen values associated with each factor. It is evident from Table 4.17, that first few constructs explain relatively large amount of variance whereas subsequent factors explain only small amount of variance. According to Kaiser's rule, all items having Eigen value less than one should be dropped.

4.4.3 Factor Loading and Rotation

It is possible to see items with large loading on several of the un-rotated factors, which can make interpretation difficult. In such cases, it can be helpful to examine a rotated solution. The varimax rotation approach simplifies the structure to maximum possible extent. It maximizes the sum of variance of the required loading of the factor matrix. According to Hair et al. (2006), only the items with factor loadings greater than 0.4 were considered for the further analysis. Initial factor rotation was applied to check the cross-loadings by removing them for better validity.

Table 4.17: Extracted sums of squared loadings

Items	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	21.057	39.730	39.730	21.057	39.730	39.730	6.492	12.250	12.250
2	2.512	4.739	44.470	2.512	4.739	44.470	5.107	9.636	21.886
3	2.293	4.326	48.796	2.293	4.326	48.796	4.114	7.762	29.648
4	1.947	3.673	52.469	1.947	3.673	52.469	3.886	7.332	36.980
5	1.525	2.877	55.346	1.525	2.877	55.346	3.781	7.134	44.114
6	1.338	2.525	57.871	1.338	2.525	57.871	3.772	7.117	51.231
7	1.195	2.255	60.127	1.195	2.255	60.127	2.917	5.504	56.735
8	1.110	2.094	62.221	1.110	2.094	62.221	2.907	5.486	62.221
9	.931	1.757	63.978						
10	.908	1.712	65.690						
11	.838	1.581	67.272						
12	.806	1.521	68.793						
13	.762	1.438	70.231						
14	.754	1.423	71.653						
15	.712	1.344	72.997						
16	.697	1.314	74.311						
17	.683	1.289	75.600						
18	.661	1.247	76.847						
19	.604	1.140	77.986						
20	.589	1.112	79.098						
21	.586	1.105	80.203						
22	.553	1.044	81.247						
23	.512	.966	82.213						
24	.506	.955	83.168						
25	.494	.932	84.100						
26	.480	.906	85.006						

27	.458	.865	85.871						
28	.438	.826	86.696						
29	.432	.815	87.511						
30	.411	.775	88.287						
31	.397	.750	89.037						
32	.383	.722	89.759						
33	.368	.694	90.453						
34	.348	.656	91.109						
35	.340	.642	91.751						
36	.339	.641	92.392						
37	.325	.613	93.005						
38	.317	.598	93.604						
39	.312	.589	94.193						
40	.307	.579	94.771						
41	.279	.526	95.298						
42	.267	.503	95.801						
43	.264	.498	96.299						
44	.260	.491	96.790						
45	.247	.467	97.257						
46	.223	.421	97.678						
47	.205	.387	98.065						
48	.199	.375	98.440						
49	.195	.368	98.808						
50	.186	.351	99.160						
51	.172	.325	99.484						
52	.163	.308	99.792						
53	.110	.208	100.000						

Table 4.18: Varimax factor rotated component matrix

	Component							
	1	2	3	4	5	6	7	8
SHC1	.781							
SHC2	.788							
SHC3	.757							
SHC4	.786							
SHC5	.761							
SPD1 (SPPD1)		.402						
SPD2 (SPPD2)		.778						
SPD3 (SPPD3)		.748						
SPD4 (SPPD4)		.447						
SMPD1 (SPPD5)		.509						
SMPD2 (SPPD6)		.525						
SMPD3 (SPPD7)		.730						
SMPD4 (SPPD8)		.578						

LP1			.622					
LP2			.721					
LP3			.670					
LP4			.648					
LP5			.652					
LP6			.483					
APC1				.616				
APC2				.546				
APC4				.455				
APC5				.644				
APC6				.537				
SSOD1					.629			
SSOD2					.639			
SSOD3					.534			
SSOD4					.623			
SSOD5					.612			
SSOD6					.536			
PRRP1						.440		
PRRP2						.756		
PRRP3						.787		
PRRP4						.798		
PRRP5						.595		
PRRP6						.683		
SMC1								.436
SMC2								.473
SMC3								.555
SMC4								.431
SMC5								.427
SMC6								.544
SMC7								.479
SPM1							.523	
SPM2							.529	
SPM3							.588	
SPM4							.578	
SPM5							.693	
SPM6							.599	
SPM7							.681	
SPM8							.657	
SPM9							.653	
SPM10							.596	

After the initial rotation, rotated component matrix result in 05 cross loadings i.e. the factor being cross-loaded on original variable. These items were deleted permanently (SCH1, SPD1, SMPD5, SMPD6 and APC3) from further analysis to obtain maximum validity of the construct. Eight items were loaded on one component. These items are from *sustainable product design (SPD)* and *sustainable manufacturing process design (SMPD)*. In the survey, the respondents observed real practice of *SPD* and *SMPD* in the industries. Finally, a new construct was formed with the name of *sustainable product and process design (SPPD)* which contains eight items related to product and process design. This analysis also supporting new construct using literature review. Digalwar et al. (2013) explored the green manufacturing practices with green product and process design.

Table 4.18 lists the varimax rotation component matrix, with the items that load strongly on each of the extracted factors. The rotated component matrix for *sustainable manufacturing practices, sustainable performance measures, sustainable manufacturing competitiveness and stakeholder's commitment* with significant factor loading on their original constructs. The factor scores are ranging from 0.427 and 0.798 and there is no cross loading of factors.

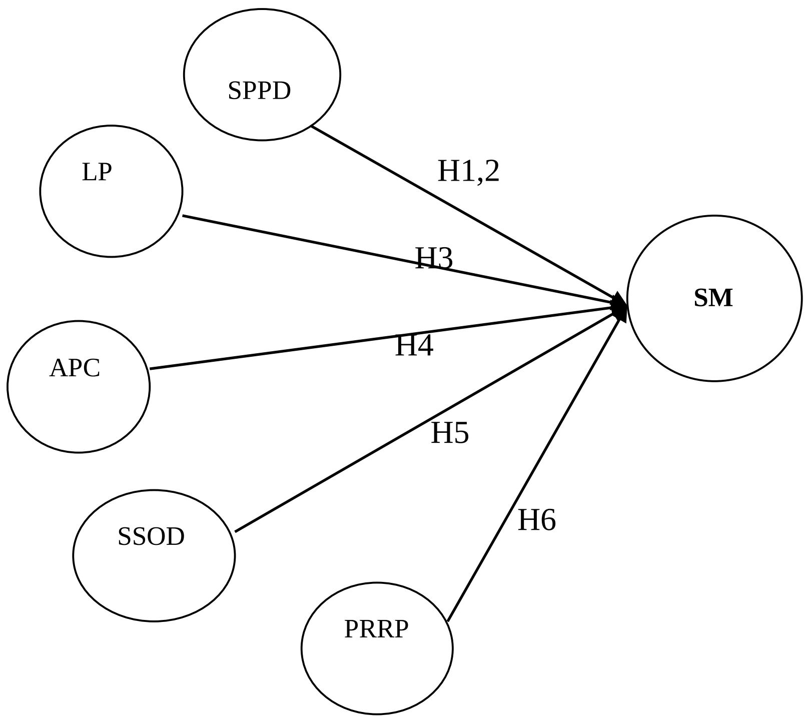


Figure 4.8: Modified Conceptual model for sustainable manufacturing

Since *sustainable product design (SPD)* and *sustainable manufacturing process design (SMPD)* loaded on one component and formed a new construct *sustainable product and process design (SPPD).* Therefore conceptual model for *sustainable manufacturing (SM)* now contains only five factors *(SPPD, LP, APC, SSOD and PRRP)* in place of six. SPD and SMPD treated as a single construct *(SPPD).* The hypotheses H1 an H2 also merged and named as H1,2. Based on the new hypothesis the modified conceptual framework for sustainable manufacturing shown in Figure 4.8.

4.4.4 Internal consistency analysis of research constructs

To measure the internal consistency, the most preferred method is to compute reliability of the constructs. It usually measures through the reliability coefficient i.e. Cronbach's alpha. The value of alpha varies from 0 to 1 and higher values indicate the higher reliability. The most preferred value of Cronbach's alpha is 0.7 (Flynn et al., 1990).

Table 4.19: internal consistency of different constructs

Constructs	Name of Construct	No. of Items	Cronbach's alpha
1	Sustainable performance measure (SPM)	10	0.908
2	Stakeholder's commitment (SHC)	5	0.907
3	Lean Practices (LP)	6	0.871
4	Sustainable Product and Process Design (SPPD)	8	0.891
5	Sustainable supply operations and distribution (SSOD)	6	0.882
6	Product recovery and recycling practices (PRRP)	6	0.847
7	Agile practices and customization (APC)	5	0.796
8	Sustainable manufacturing competitiveness (SMC)	7	0.870

Table 4.19 illustrates various higher level of constructs, number of items in them and the value of Cronbach's alpha for each construct. High value of Cronbach's alpha for each factor confirms the reliability of the instrument. In the research, value of Cronbach's alpha range from 0.796 to 0.908. On the basis of Cronbach's alpha coefficient, the study confirmed the five factors of sustainable manufacturing practices i.e. *sustainable product and process design*

(SPPD), Lean Practices (LP), Agile practices and customization (APC), Sustainable supply operation and distribution (SSOD) and Product recovery and return practices (PRRP).

The drivers of sustainable manufacturing i.e. stakeholder's commitment and the outcomes i.e. sustainable performance and sustainable manufacturing competitiveness were confirmed.

4.4.5 Validity

Validity is the extent to which two measures or set of measures correctly represent the concept of study i.e. the degree to which it is free from any systematic or non-random error (Hair et al. 2013). Three type of validity are usually considered in literature: (i) Content validity, (ii) Criteria related validity and (iii) Construct validity.

4.4.5.1 Content validity

Content validity refers to the extent to which a measure represents all factors of a given construct. Content validity cannot be determined statistically. It can be determined by experts (Flynn et al. 1990). Since the measurement items were selected after a comprehensive literature review, through evaluation by academicians and industry professionals followed by opinions of experts those who have wide experience in the field of operations management. Hence the scale represents the content validity.

4.4.5.2 Criteria related validity

The basic idea of criteria related validity is to check the performance of the measure against some criteria. Traditionally, criteria related validity is evaluated by examining the correlations of the different construct with one or more sustainable performance or manufacturing competitiveness. This investigates the empirical relationship between the scores of test instrument i.e. sustainable manufacturing practices (predictor) and an objective outcome (criteria) i.e. sustainable manufacturing competitiveness and sustainable performance measures. Table 4.20 illustrates the bivariate correlation analysis between the same and it can be seen that for both relevant criteria the correlation is high. Hence the scale represents the criteria related validity.

Table 4.20: Bi-variate Correlation between constructs

	SHC	SPPD	LP	APC	SSOD	PRRP	SPM	SMC
SHC	1							
SPPD	.688**	1						
LP	.516**	.687**	1					
APC	.509**	.645**	.646**	1				
SSOD	.588**	.707**	.657**	.635**	1			
PRRP	.404**	.566**	.474**	.492**	.600**	1		
SPM	.572**	.713**	.608**	.605**	.700**	.476**	1	
SMC	.774**	.884**	.812**	.796**	.861**	.706**	.819**	1

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

4.4.5.3 Construct Validity

To estimate that all items in scale measures the same construct, construct validity is carried out. It was estimated using principal component analysis. The matrices of different factors illustrated that they were uni-factorial with Eigen values greater than 1.

Table 4.21: Summery of factor matrices for each higher level constructs

Construct Name	KMO	% Variance	Eigen Value
Stakeholder's commitment (SHC)	0.889	73.12	3.66
Sustainable Product and Process Design (SPPD)	0.879	57.12	4.57
Lean Practices (LP)	0.875	60.91	3.65
Agile practices and customization (APC)	0.800	55.42	2.78
Sustainable supply operations and distribution (SSOD)	0.899	63.02	3.78
Product recovery and recycling practices (PRRP)	0.870	56.85	3.41
Sustainable performance measure (SPM)	0.898	56.22	3.94
Sustainable manufacturing competitiveness (SMC)	0.934	54.58	5.46

Therefore, the result of present study indicated fairly good construct validity for the developed scales. Construct validity is illustrated in Table 4.21. KMO measure of sample adequacy is >0.6 for all items of each constructs with Eigen value greater than 1, therefore the items for each construct are suitable for factor analysis.

4.5 INVESTIGATION OF STRUCTURAL EQUATION MODEL

This section focuses on the objective to identify and validate the sustainable manufacturing framework for Indian industries. The main focus is given to statistically examine the sustainable manufacturing framework and test the hypotheses which are defined in chapter 2. The causal relationship between stakeholder's commitment, sustainable manufacturing (SM), sustainable performance measures and sustainable manufacturing competitiveness are investigated with Structural equation Modeling (SEM).

4.5.1 Structural equation modeling (SEM)

SEM is a family of statistical models that seek to explain the relationship among multiple variables. It examines the structure of interrelationships expressed in a series of equations, similar to a series of multiple regression equations. These equations depict all the relationship among constructs (dependent and independent variables) involved in the analysis (Hair et al. 2013). A SEM model includes measurement model and structural model.

4.5.2 Two-step approach in structural equation modeling

It is recommended by Anderson and Garbing (1998) in two step approach, the first is the analysis of the measurement model to specify the relationship between the observed variables and latent variables or hypothetical constructs. In the present research eight constructs are studied namely *stakeholder's commitment, sustainable manufacturing practices (SPPD, LP, APC, SSOD and PRRP), sustainable performance measures and sustainable manufacturing competitiveness*. The result of this analysis identifies the measurement model properties of the observed and latent variables. This is done separately before fitting a structural model to look into the relationship between the latent variables. Measurement model is defined for all the independent and dependent latent variables (constructs). In second step, the structural model to specify the relationship among the hypothetical constructs as proposed in the research framework, is developed and verified. This systematic two step approach permits the researchers to identify sources of poor fit of a structural model also to know whether this poor fit is due to the measurement or structural model.

4.5.3 Choice of model estimation methods

It is an important part of SEM, before evaluating the final model. Structural coefficients in SEM may be computed with many of several ways. AMOS 22.0 supports maximum likelihood (ML), generalized least square (GLS), Unweighted least square (ULS), Scale free least square (SLQ) and Asymptotically distributed free (ADF) method of coefficient estimations. Maximum likelihood estimation (ML or MLE) is by the most common method.

ML is the iterative estimation procedure that estimates based on maximizing the probability (likelihood) that the observed covariances are drawn from the population assumed to be the same as that reflected in the coefficient estimates (Kline, 2005). When the condition of normality is not fulfilled weighted least square (WLS) or asymptotically distribution free (ADF) approach can be utilized. But these methods require large sample sizes (more than 2000) (Bryne, 2006).

Generalized least square (GLS) is also a very common approach when MLE is not appropriate. This also requires the need of large sample size. In this research, Maximum likelihood estimation (MLE) approach is used because the research constructs fulfill the condition of Normality (approximate).

4.5.4 Model Indices

It is important to conduct the model-fit as it indicates the goodness of the fit of research model. It is basically indicates that how well the indicators are collectively reflecting the latent constructs and how well the indicators are reliable to their constructs. However, it is viewed that chi-square (χ^2) test, associated with p value with the test statistics (χ^2) is widely accepted statistical measure, used to compare the observed and estimated covariances (Byrne, 2006; Narasimhan & Kim, 2002). Researcher suggested using at least one test of each class (absolute fit index and relative fit index) to reflect the diverse criteria.

Kline (2005) specifically recommends at least four tests such as chi square (χ^2) (CMIN), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI) and root mean square residual (RMR) for covering the divers statistical aspects.

Table 4.22: Model-fit indices summery

S. No.	Model fit indices	Abbreviations	Meaning	Acceptability Rule
1	Chi square probability with degree of freedom	(χ^2) (CMIN), df, p	Discrepancy between observed and model-implied variance covariance matrices	p>0.05
2	Chi square/degree of freedom ratio	(χ^2)/df or CMIN/df	Reduces the sensitivity of χ^2 to sample size	0.02 to 4.80
3	Goodness of fit Index	GFI	An absolute fit index that estimates the proportion of variability explained by the model (similar to R^2 in regression models)	0.75 to 0.99
4	Adjusted goodness of fit Index	AGFI	GFI penalized for model complexity	0.63 to 0.97
5	Comparative fit index	CFI	Assumes a non-central χ^2 distribution for the baseline model discrepancy	0.88 to 1.00
6	Normed fit index	NFI	The proportion of baseline (independence) model χ^2 explained by the model of interest	0.72 to 0.99
7	Root mean square residual	RMR	Difference between the observed and estimated covariance matrices	0.010 to 0.140
8	Root mean square of error approximation	RMSEA	Estimates the amount of error of approximation per model degree of freedom, correcting for sample size and penalizing model complexity	0.00 to 0.13

(Source: Mokhtarian & Meenakshisundaram, 1999; Shah & Goldstein, 2006; Ory & Mokhtarian, 2009; Gotschol et al. 2014)

The very common recommendation to report the fit indices proposes the chi square (χ^2) to degree of freedom ratio (χ^2/df) and root mean square error of approximation (RMSEA) test. Table 4.22 presents a summary of goodness-of-fit measures and presents typical values found in models from the fields of operations research (Mokhtarian & Meenakshisundaram, 1999; Shah & Goldstein, 2006).

4.5.5 The Process for SEM

An SEM model that specifies the indicators for each construct and enables and assessment of construct validity is called measurement model. Set of one or more dependent relationship linking the hypothesized model's constructs.

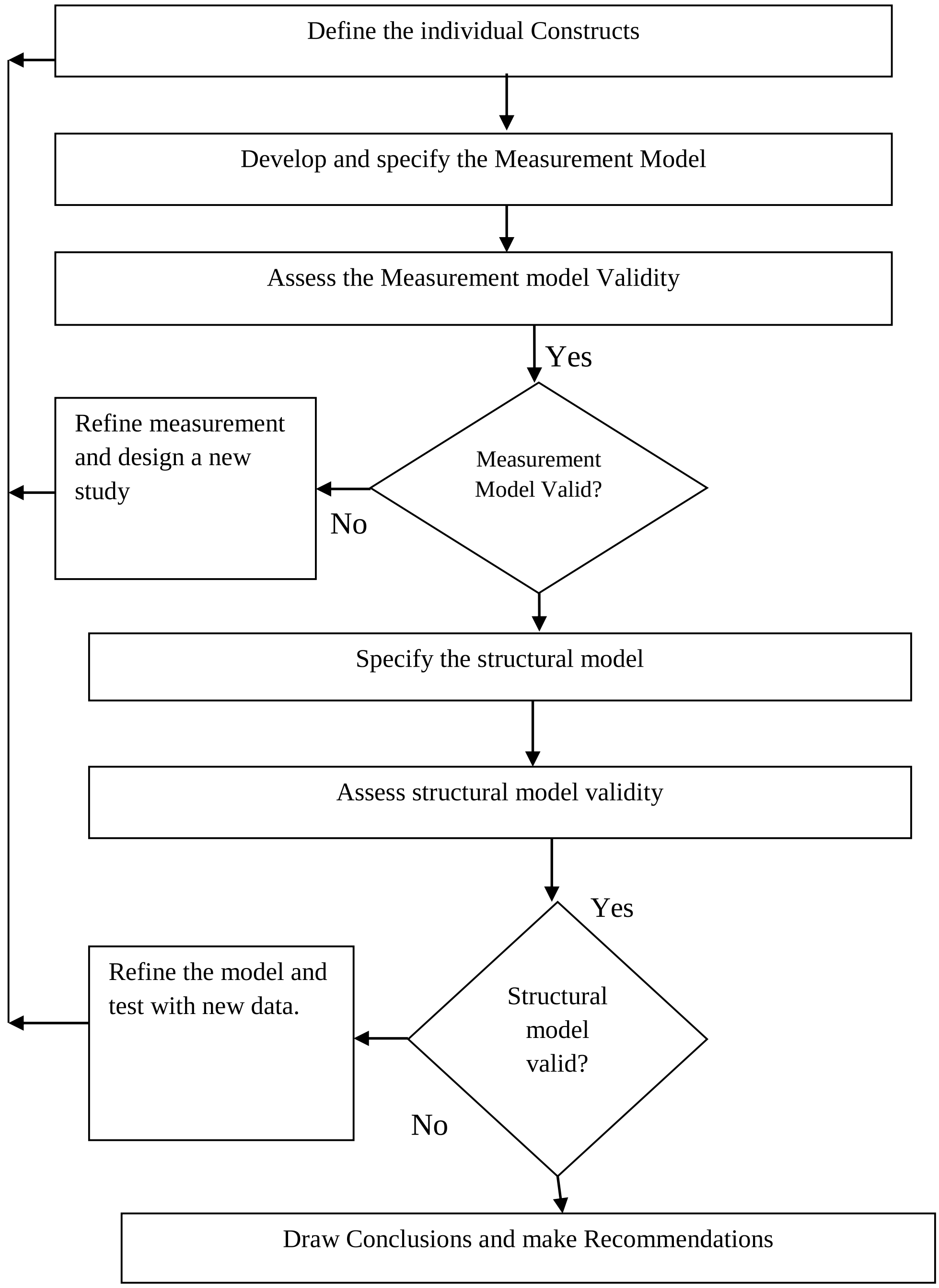


Figure 4.9: Steps in structural equation modeling (Source: Malhotra and Das, 2011)

The steps involved in conducting SEM are shown in Figure 4.9 are: (i) Define the individual constructs, (ii) specify the measurement model, (iii) assess measurement model validity and reliability, (iv) specify the structural model if the measurement model is valid, (v) assess structural model validity and (vi) draw conclusions and make recommendations if the structural model is valid. Hair et al. (2013), Byrn (2006) and Kline (2005) have also suggested the steps involved in SEM.

4.5.6 Define the individual construct

Structural equation model contains a hybrid model with multiple items (observed variables) for each latent construct (unobserved variable) which are also called constructs (Byrne, 2006). Latent constructs, which represent theoretical constructs concepts that are not directly observed. It requires items (observed variables) for measure. Items (observed) are those variables that are directly observable like the variables in a survey questionnaire. Latent constructs are operationalized in the research through the observed variables (items in questionnaire) to explore the research objectives. In chapter 2, the proposed theoretical framework including the latent constructs is discussed in detail. The framework includes total eight constructs (dependent and independent) i.e. stakeholder's commitment, sustainable manufacturing practices (SPPD, LP, APC, SSOD and PRRP), sustainable performance measures and sustainable manufacturing competitiveness. The description of latent constructs is given in Table 4.23.

Table 4.23: Description of individual constructs

S. No.	Latent Constructs (Unobserved variables)	Items (Observed variables)
1	Stakeholder's commitment (SHC)	SHC_i; Where i= 1to5
2	Sustainable Product and Process Design (SPPD)	$SPPD_i$; Where i= 1to8
3	Lean Practices (LP)	LP_i; Where i= 1to6
4	Agile practices and customization (APC)	APC_i; Where i= 1to5
5	Sustainable supply operations and distribution (SSOD)	$SSOD_i$; Where i= 1to6
6	Product recovery and recycling practices (PRRP)	$PRRP_i$; Where i= 1to6
7	Sustainable performance measure (SPM)	SPM_i; Where i= 1to10
8	Sustainable manufacturing competitiveness (SMC)	SMC_i; Where i= 1to7

4.5.7 Development of Measurement models for Research Constructs by Confirmatory Factor analysis (CFA)

The term confirmatory factor analysis (CFA) is also used to refer to the analysis of measurement of construct or model. CFA approach attempt to test the viability of selected research model and constructs, which are usually based on the theory or previous experience or as the research objectives, and to examine whether or not existing data are consistent with a proposed research model. The study assesses two types of measurement models namely the one factor congeneric models and multifactor models. One factor measurement model is used to assess item's reliability, construct validity while multifactor measurement models are more inclined to analyze the Discriminant validity of the individual scales in the construct. Together these models provide the detailed picture of the underlying constructs and associated items in the constrained model using the statistical test.

To develop measurement model for Research constructs (sustainable manufacturing, sustainable performance measures, sustainable manufacturing competitiveness and stakeholder's commitment), the items were extracted from the literature, expert opinion and industry professionals. A five point Likert scale survey questionnaire was developed and data was collected as discussed in chapter 3. Total 345 responses were collected from the four sectors viz. automobile, electrical and electronics, machinery and process of Indian manufacturing industries. Furthermore, CFA was performed to create a measurement model (Narasimhan & Kim, 2002; Zhu et al. 2005; Sarkis et al. 2010). In this study AMOS 22.0 software with maximum likelihood estimation (MLE) method was used. A series of procedures were applied to verify that all the proposed measurement items represent the construct and constructs represent the model.

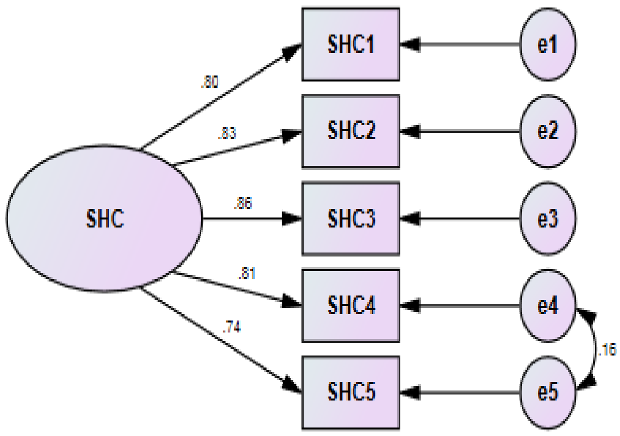
4.5.7.1 One factor congeneric model

Anderson and Gerbing (1988) argued that one factor congeneric measurement model is a model of single latent construct (unobserved variables) which is measured by several items (observed variables). Congeneric measurement models are more useful in offering precise tests convergent and Discriminant validity of construct measurement. This study contains eight constructs.

Various indices are considered based on goodness of fit for model viz. chi square (χ^2) (CMIN), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI) and root mean square residual (RMR) for covering the divers statistical aspects. The very common recommendation to report the fit indices proposes the chi square (χ^2) and root mean square error of approximation (RMSEA) tests.

4.5.7.1.1 Measurement model for Stakeholder's Commitment (SHC)

The construct of stakeholder's commitment (SHC) contains five items (observed variables) names SHC1 to SHC5. The model was found statistically significant as shown in Figure 4.10 and Table 4.24. The chi square (χ^2) value of model is 5.56 with a p-value 0.23 and degree of freedom (df) is 4, which could indicate the best fit of the data. The other model indices are (χ^2)/df = 1.39, GFI =0.993, AGFI = 0.975, RMR = 0.010, NFI = 0.995, CFI = 0.999 and RMSEA = 0.034 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.74 (standardize) which support the construct validity of SHC.



Model fit indices	Value of the model
(χ^2)/df	1.39
GFI	0.993
AGFI	0.975
RMR	0.010
NFI	0.995
CFI	0.999
RMSEA	0.034

Figure 4.10: Measurement model for Stakeholder's commitment (SHC)

Table 4.24: Regression weights for Stakeholder's commitment (SHC)

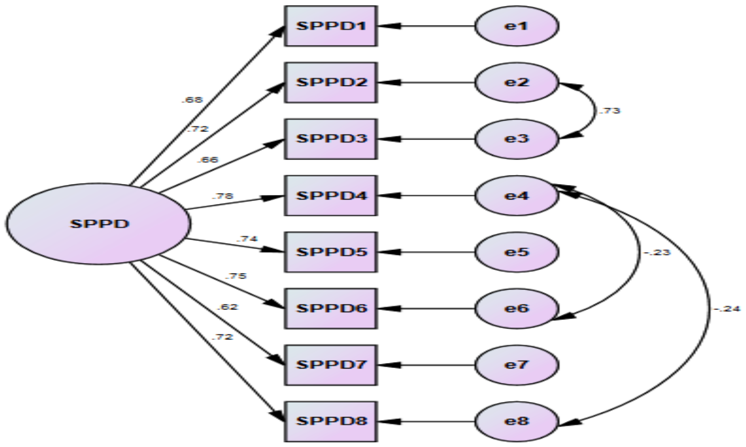
			Estimate (Unstandardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
SHC1	<---	SHC	1	0.804			
SHC2	<---	SHC	0.934	0.834	0.054	17.245	***
SHC3	<---	SHC	0.989	0.862	0.055	17.966	***
SHC4	<---	SHC	0.934	0.811	0.057	16.498	***
SHC5	<---	SHC	0.87	0.743	0.059	14.69	***

***P≤0.001

4.5.7.1.2 Measurement model for Sustainable Product and Process Design (SPPD)

The construct of Sustainable product and process design (SPPD) contains eight items (observed variables) names SPPD1 to SPPD8. The model was found statistically significant as shown in Figure 4.11 and Table 4.25.

The chi square (χ^2) value of model is 22.458 with a p-value 0.168 and degree of freedom (df) is 17 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.321, GFI = 0.984, AGFI = 0.966, RMR = 0.017, NFI = 0.985, CFI = 0.996 and RMSEA = 0.031 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.62 (standardize) which support the construct validity of SPPD.



Model fit indices	Value of the model
(χ^2)/df	1.321
GFI	0.984
AGFI	0.966
RMR	0.017
NFI	0.985
CFI	0.996
RMSEA	0.031

Figure 4.11: Measurement model for Sustainable product and process design (SPPD)

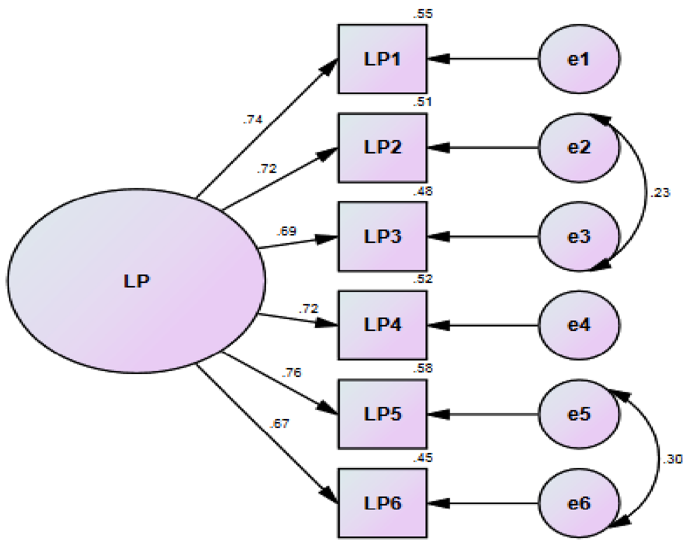
Table 4.25: Regression weights for Sustainable product and process design (SPPD)

			Estimate (Unstandardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
SPPD1	<---	SPPD	1	0.677			
SPPD2	<---	SPPD	1.102	0.721	0.092	12.02	***
SPPD3	<---	SPPD	0.978	0.662	0.088	11.13	***
SPPD4	<---	SPPD	1.334	0.783	0.108	12.307	***
SPPD5	<---	SPPD	1.157	0.74	0.094	12.304	***
SPPD6	<---	SPPD	1.141	0.749	0.094	12.078	***
SPPD7	<---	SPPD	1.062	0.619	0.101	10.486	***
SPPD8	<---	SPPD	1.087	0.717	0.093	11.642	***

***P≤0.001

4.5.7.1.3 Measurement model for Lean Practices (LP)

The construct of Lean Practices (LP) contains six items (observed variables) names LP1 to LP8. The model was found statistically significant as shown in Figure 4.12 and Table 4.26. The chi square (χ^2) value of model is 7.353 with a p-value 0.393 and degree of freedom (df) is 7 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.051, GFI = 0.993, AGFI = 0.979, RMR = 0.012, NFI = 0.992, CFI = 1.00 and RMSEA = 0.012 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.67 (standardize) which support the construct validity of LP.



Model fit indices	Value of the model
(χ^2)/df	1.051
GFI	0.993
AGFI	0.979
RMR	0.012
NFI	0.992
CFI	1.00
RMSEA	0.012

Figure 4.12: Measurement model for Lean Practices (LP

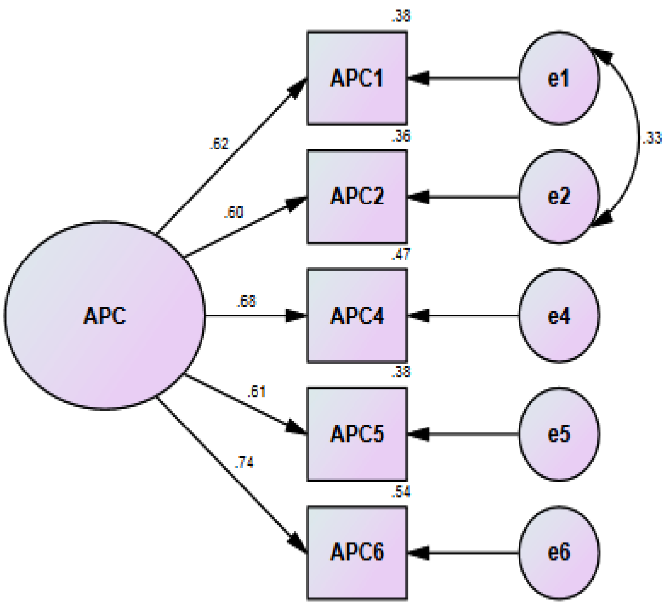
Table 4.26: Regression weights for Lean Practices (LP)

			Estimate (Un standardized)	Estimate (Standardize d)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
LP1	<---	LP	1	0.743			
LP2	<---	LP	0.933	0.716	0.078	12.008	***
LP3	<---	LP	0.928	0.69	0.08	11.615	***
LP4	<---	LP	0.955	0.721	0.078	12.225	***
LP5	<---	LP	1.067	0.76	0.082	12.953	***
LP6	<---	LP	0.927	0.669	0.083	11.2	***

***P≤0.001

4.5.7.1.4 Measurement model for Agile Practices and Customization (APC)

The construct of Agile Practices and Customization (APC) contains five items (observed variables) names APC1, APC2, APC4, APC5 and APC6. The model was found statistically significant as shown in Figure 4.13 and Table 4.27. The chi square (χ^2) value of model is 8.336 with a p-value 0.080 and degree of freedom (df) is 4 which indicates the best fit of the data. The other model indices are (χ^2)/df = 2.084 (permissible for fit), GFI = 0.990, AGFI = 0.964, RMR = 0.018, NFI = 0.983, CFI = 0.991 and RMSEA = 0.052 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.60 (standardize) which support the construct validity of APC.



Model fit indices	Value of the model
(χ^2)/df	2.084
GFI	0.990
AGFI	0.964
RMR	0.018
NFI	0.983
CFI	0.991
RMSEA	0.052

Figure 4.13: Measurement model for Agile Practices and Customization (APC)

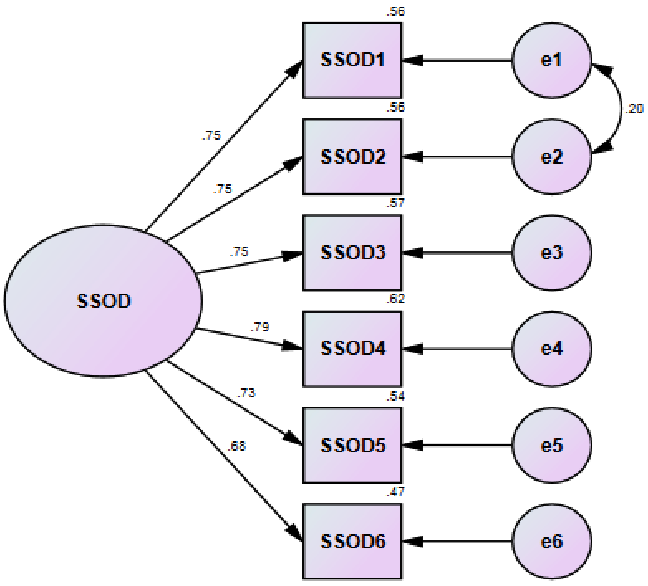
Table 4.27: Regression weights for Agile Practices and Customization (APC)

			Estimate (Un standardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
APC1	<---	APC	1	0.616			
APC2	<---	APC	1.059	0.6	0.102	10.391	***
APC4	<---	APC	0.992	0.683	0.111	8.921	***
APC5	<---	APC	0.979	0.614	0.115	8.484	***
APC6	<---	APC	1.064	0.738	0.114	9.312	***

***P≤0.001

4.5.7.1.5 Measurement model for Sustainable Supply Operation and Distribution (SSOD)

The construct of sustainable supply operation and distribution (SSOD) contains six items (observed variables) names SSOD1 to SSOD6. The model was found statistically significant as shown in Figure 4.14 and Table 4.28. The chi square (χ^2) value of model is 8.678 with a p-value 0.370 and degree of freedom (df) is 8 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.085, GFI = 0.992, AGFI = 0.979, RMR = 0.011, NFI = 0.991, CFI = 0.999 and RMSEA = 0.016 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.68 (standardize) which support the construct validity of SSOD.



Model fit indices	Value of the model
(χ^2)/df	1.085
GFI	0.992
AGFI	0.979
RMR	0.011
NFI	0.991
CFI	0.999
RMSEA	0.016

Figure 4.14: Measurement model for sustainable supply operation and distribution (SSOD)

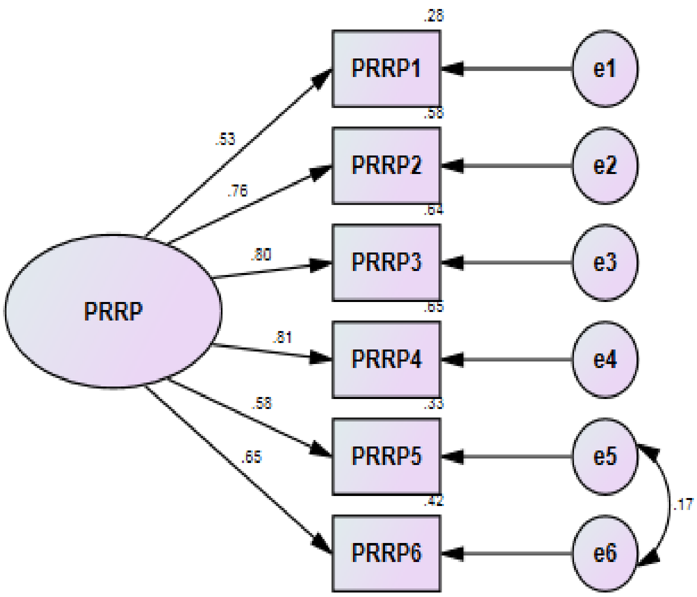
Table 4.28: Regression weights for sustainable supply operation and distribution (SSOD)

			Estimate (Un standardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
SSOD1	<---	SSOD	1	0.747			
SSOD2	<---	SSOD	1.009	0.747	0.067	14.997	***
SSOD3	<---	SSOD	1.084	0.752	0.082	13.213	***
SSOD4	<---	SSOD	1.166	0.785	0.084	13.88	***
SSOD5	<---	SSOD	1.057	0.734	0.082	12.892	***
SSOD6	<---	SSOD	0.916	0.685	0.076	12.044	***

****P≤0.001*

4.5.7.1.6 Measurement model for Product recovery & return practices (PRRP)

The construct of Product recovery & return practices (PRRP) contains six items (observed variables) names PRRP1 to PRRP6. The model was found statistically significant as shown in Figure 4.15 and Table 4.29. The chi square (χ^2) value of model is 13.829 with a p-value 0.086 and degree of freedom (df) is 8 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.729, GFI = 0.986, AGFI = 0.964, RMR = 0.017, NFI = 0.982, CFI = 0.992 and RMSEA = 0.046 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.58 (standardize) which support the construct validity of PRRP.



Model fit indices	Value of the model
(χ^2)/df	1.729
GFI	0.986
AGFI	0.964
RMR	0.017
NFI	0.982
CFI	0.992
RMSEA	0.046

Figure 4.15: Measurement model for Product recovery & return practices (PRRP)

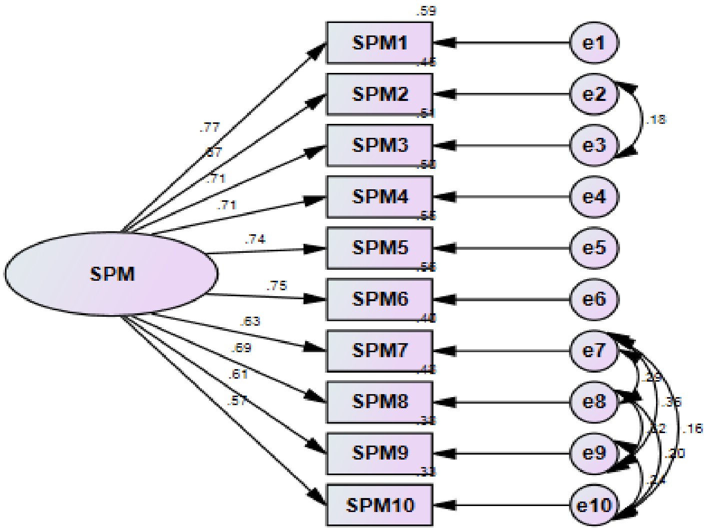
Table 4.29: Regression weights for Product recovery & return practices (PRRP)

			Estimate (Un standardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
PRRP1	<---	PRRP	1	0.533			
PRRP2	<---	PRRP	1.583	0.763	0.168	9.426	***
PRRP3	<---	PRRP	1.706	0.797	0.179	9.554	***
PRRP4	<---	PRRP	1.6	0.806	0.166	9.625	***
PRRP5	<---	PRRP	1.146	0.575	0.144	7.981	***
PRRP6	<---	PRRP	1.247	0.648	0.145	8.581	***

***P≤0.001

4.5.7.1.7 Measurement model for Sustainable Performance Measures (SPM)

The construct of Sustainable Performance Measures (SPM) contains ten items (observed variables) names SPM1 to SPM6. The model was found statistically significant as shown in Figure 4.16 and Table 4.30. The chi square (χ^2) value of model is 34.762 with a p-value 0.177 and degree of freedom (df) is 28 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.242, GFI = 0.980, AGFI = 0.961, RMR = 0.014, NFI = 0.979, CFI = 0.992 and RMSEA = 0.026 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.57 (standardize) which support the construct validity of SPM.



Model fit indices	Value of the model
(χ^2)/df	1.242
GFI	0.980
AGFI	0.961
RMR	0.014
NFI	0.979
CFI	0.992
RMSEA	0.026

Figure 4.16: Measurement model for Sustainable Performance Measures (SPM)

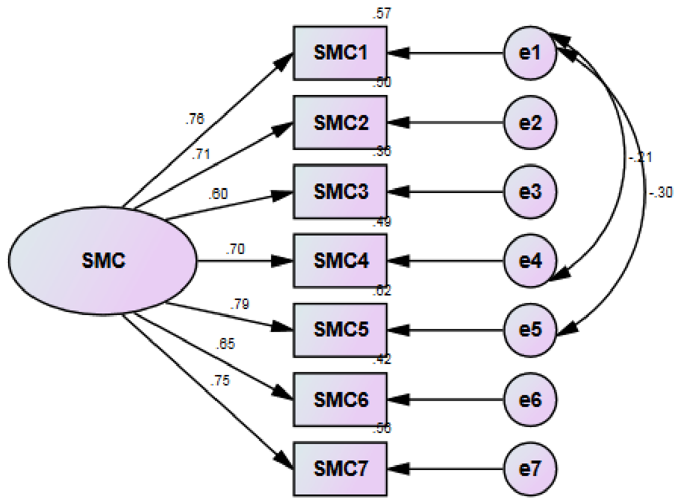
Table 4.30: Regression weights for Sustainable Performance Measures (SPM)

			Estimate (Un standardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
SPM1	<---	SPM	1	0.77			
SPM2	<---	SPM	0.872	0.668	0.07	12.372	***
SPM3	<---	SPM	0.949	0.714	0.071	13.385	***
SPM4	<---	SPM	0.93	0.709	0.071	13.075	***
SPM5	<---	SPM	0.996	0.745	0.072	13.805	***
SPM6	<---	SPM	0.99	0.751	0.07	14.056	***
SPM7	<---	SPM	0.862	0.635	0.074	11.679	***
SPM8	<---	SPM	0.968	0.69	0.076	12.733	***
SPM9	<---	SPM	0.837	0.614	0.075	11.158	***
SPM10	<---	SPM	0.632	0.574	0.061	10.311	***

***P≤0.001

4.5.7.1.8 Measurement model for Sustainable Manufacturing Competitiveness (SMC)

The construct of Sustainable Manufacturing Competitiveness (SMC) contains seven items (observed variables) names SMC1 to SMC6. The model was found statistically significant as shown in Figure 4.17 and Table 4.31. The chi square (χ^2) value of model is 14.747 with a p-value 0.256 and degree of freedom (df) is 12 which indicates the best fit of the data. The other model indices are (χ^2)/df = 1.229, GFI = 0.988, AGFI = 0.972, RMR = 0.012, NFI = 0.985, CFI = 0.997 and RMSEA = 0.026 shows the perfect acceptable model fit for further analysis. The factor loading of each variable is above 0.60 (standardize) which support the construct validity of SMC.



Model fit indices	Value of the model
(χ^2)/df	1.229
GFI	0.988
AGFI	0.972
RMR	0.012
NFI	0.985
CFI	0.997
RMSEA	0.026

Figure 4.17: Measurement model for Sustainable Manufacturing Competitiveness (SMC)

Table 4.31: Regression weights for Sustainable Manufacturing Competitiveness (SMC)

			Estimate (Un standardized)	Estimate (Standardized)	Standard Error (S.E.)	Critical Ratio (C.R.)	P
SMC1	<---	SMC	1	0.756			
SMC2	<---	SMC	0.91	0.707	0.073	12.39	***
SMC3	<---	SMC	0.801	0.596	0.077	10.442	***
SMC4	<---	SMC	0.915	0.699	0.08	11.371	***
SMC5	<---	SMC	1.091	0.786	0.088	12.381	***
SMC6	<---	SMC	0.772	0.651	0.068	11.339	***
SMC7	<---	SMC	1.01	0.75	0.079	12.841	***

***P≤0.001

One factor congeneric model for all the research constructs has been developed. From the analysis, it found that the model fit indices for all research constructs are statistically significant and these constructs are used for further analysis.

4.5.7.2 Multifactor congeneric model

The multi factor congeneric models are further developed with the prime objective to investigate the Discriminant and construct validity by confirmatory factor analysis. This technique employs the test of goodness of fit to the data to examine the measurement and structural model. Focusing on the theoretical framework as discussed in chapter -2 and the investigation of one factor congeneric model, the second step of multifactor congeneric are examined. There is total eight research construct, on the basis of research gaps identified from the literature, we proposed two frameworks: (i) Analysis of practices of sustainable manufacturing, (ii) analysis of relationships of stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness. For this purpose, two multifactor congeneric models are developed given as:

- Multifactor congeneric model to analyse sustainable manufacturing.
- Multifactor congeneric model to analyse the relationship of stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness.

Multiple fit indices are employed in reporting model fit using AMOS 22.0. various indices are considered based on goodness of fit test for predicted vs. observed covariance study like chi square (χ^2) (CMIN), ration of chi square to degree of freedom (χ^2/df) or (CMIN/df), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI) and root mean square residual (RMR) for covering the divers statistical aspects. The very common recommendation to report the fit indices proposes the chi square (χ^2) and root mean square error of approximation (RMSEA) tests.

4.5.7.2.1 Multifactor congeneric model to analyse sustainable manufacturing

Sustainable manufacturing includes *Sustainable Product and Process Design (SPPD), Lean Practices (LP), Agile practices and customization (APC), Sustainable supply operations and distribution (SSOD) and Product recovery and recycling practices (PRRP)* as discussed in the review of literature.

To investigate the behaviour of these practices, study was performed using first order measurement model and second order measurement model. In the first order model *SPPD, LP, APC, SSOD and PRRP* are correlated to each other as measurement dimensions for *Sustainable Manufacturing (SM)*. While, second order model will assess contribution level of each practice to sustainable manufacturing.

4.5.7.2.1.1 First order measurement model

Based on the analysis done using AMOS 22.0, the first order model for sustainable manufacturing is developed by first order confirmatory factor analysis as depict in Figure. 4.18. The first order model suggests that there are five practices (constructs) (i.e. SPPD, LP, APC, SSOD and PRRP) in the model. The practices are independent in their prediction of sustainable manufacturing. The construct such as SPPD, LP, APC, SSOD and PRRP are measured by eight, six, five, six and six items respectively as shown in Figure 4.18. The first order model for sustainable manufacturing passed all the required tests.

Assessment of first order measurement model

To obtain a good fit of the model, it is necessary to check the reliability and validity of the reflective constructs. There are many criteria's to check reliability and validity of the measures. First, the reliability of individual items testified by the measures consistently loading on their respective construct at nearly or greater than 0.5 (Fornell & Larcker, 1981). All of the constructs were confirmed by the significant standardised item loadings. Second, the construct validity and reliability of the all the constructs lie in the model. The values of estimates (standardized), squared multiple correlations (R^2) Average Variance Extracted (AVE) and Composite Reliability (CR) is given in the Table 4.32. The formula used for calculating AVE and CR is given below (Hair et al., 1998).

$$\text{Average Variance Extracted (AVE)} = \Sigma (\lambda^2)/ \Sigma (\lambda^2) + \Sigma e_j$$

$$\text{Composite Reliability (CR)} = (\Sigma \lambda)^2/(\Sigma \lambda)^2 + \Sigma e_j$$

Where λ = standardize factor loading

n = the number of items associated to the particular construct

Unidimensionality measures the extent to which the items in a scale measure the same construct (Venkatraman, 1989). Confirmatory factor analysis was performed to test the unidemensionality, Squared multiple correlations (R^2) is computed. Squared multiple correlations (R^2) indicate the percentage of variance in an indicator explained by a certain factor. Form the Table 4.33 it is clear that the relevant squared multiple correlations (R^2) are adequately large, ranging from 0.305 to 0.634. This confirms that a significant degree of calculated variable's variance is provided by its latent construct. Hence, all of the five constructs have good fit and thus are unidimensional.

Composite reliability (CR) was assessed in connection with internal reliability. The CR value of all of the constructs was above 0.7 (Hair et al. 2013). The value of CR of all constructs is greater than 0.7 and Cronbach’s alpha greater than 0.7 (Nunnally et al., 1967).

Convergent validity was evaluated using average variance extracted (AVE). The AVEs of all of the constructs were above 0.5, denoting a satisfactory degree of convergent validity (Fornell and Larcker 1981). In this research the value of AVE for *SPPD*, *LP*, *APC*, *SSOD* and *PRRP* is greater than 0.5 as shown in Table 4.32. It indicates that the convergent validity of the measurement constructs is acceptable.

Table 4.32: CFA results for the measurement model

Construct in model	Measurement items	Estimate (Standardized)	R^2	AVE	CR	Cronbach's alpha
SPPD	SPPD1	0.718	0.516	0.628	0.887	0.891
	SPPD2	0.712	0.507			
	SPPD3	0.662	0.438			
	SPPD4	0.752	0.566			
	SPPD5	0.743	0.552			
	SPPD6	0.723	0.523			
	SPPD7	0.634	0.402			
	SPPD8	0.692	0.479			
LP	LP1	0.722	0.521	0.667	0.872	0.872
	LP2	0.724	0.524			
	LP3	0.704	0.496			
	LP4	0.713	0.508			
	LP5	0.783	0.613			
	LP6	0.746	0.557			
APC	APC1	0.654	0.428	0.556	0.789	0.796
	APC2	0.641	0.411			
	APC4	0.697	0.486			
	APC5	0.552	0.305			
	APC6	0.743	0.552			
SSOD	SSOD1	0.783	0.613	0.661	0.884	0.882
	SSOD2	0.774	0.599			
	SSOD3	0.751	0.564			
	SSOD4	0.768	0.590			
	SSOD5	0.714	0.510			
	SSOD6	0.693	0.480			
PRRP	PRRP1	0.694	0.482	0.646	0.852	0.874
	PRRP2	0.751	0.564			
	PRRP3	0.764	0.584			
	PRRP4	0.796	0.634			
	PRRP5	0.623	0.388			
	PRRP6	0.672	0.452			

Discriminant validity was evaluated using two approaches. First, the correlation between the constructs should be less than 0.85, even some researchers recommend up to 0.90 (Kline, 2011). Second, the comparison of Cronbach's alpha of a latent construct to its mean correlations with other model latent variables (Ghiselli et al., 1981; Bagozzi et al., 1991, Hussain et al., 2016 and Ory & Mokhtarian, 2009). If the Cronbach's alpha value of a latent construct is adequately higher than the mean of its correlations with other variables, then there is a signal of discriminant validity. Table 4.33 includes the mean, standard deviation, Cronbach's alpha and correlation matrix with the mean of correlations of latent constructs (PRRP, SSOD, APC, LP and SPPD) on the diagonals.

In this research, the correlation between two constructs is not greater than 0.9 and the Cronbach's alpha is higher than the mean of correlation of latent constructs. Both analyses confirmed the discriminant validity of all constructs.

Table 4.33: Means, standard deviations, Cronbach's alpha and correlations of the constructs

Constructs	Mean	Std. Deviation	Cronbach's alpha	PRRP	SSOD	APC	LP	SPPD
PRRP	3.65	.689	0.874	**0.591**				
SSOD	3.78	.678	0.882	0.656	**0.746**			
APC	4.06	.663	0.796	0.566	0.772	**0.734**		
LP	3.76	.726	0.872	0.518	0.749	0.795	**0.712**	
SPPD	3.99	.650	0.891	0.625	0.808	0.804	0.791	**0.757**

Assessment of first order structural model

The measurement model had satisfactory results. Thereafter, the structural model was assessed as shown in Figure 4.18. The first order model suggests that there are five constructs (dimensions) (i.e. SPPD, LP, APC, SSOD and PRRP). The chi square (χ^2) value of model is 839.037 with degree of freedom (df) is 421, (χ^2)/df = 1.993, GFI = 0.866, AGFI = 0.842 (near to acceptance limit) (Ory & Mokhtarian, 2009), RMR = 0.045, NFI = 0.866, CFI = 0.928 and RMSEA = 0.54 (very close to acceptance limit).

The model fit Indies suggest an acceptable fit for the first order measurement model and perfect representation of sustainable manufacturing. Furthermore, results suggest, the factor loadings for first order construct of SPPD, LP, APC, SSOD and PRRP were ranged from 0.662 to 0.752, 0.704 to 0.783, 0.552 to .743, 0.69 to 0.783 and 0.623 to 0.794 respectively.

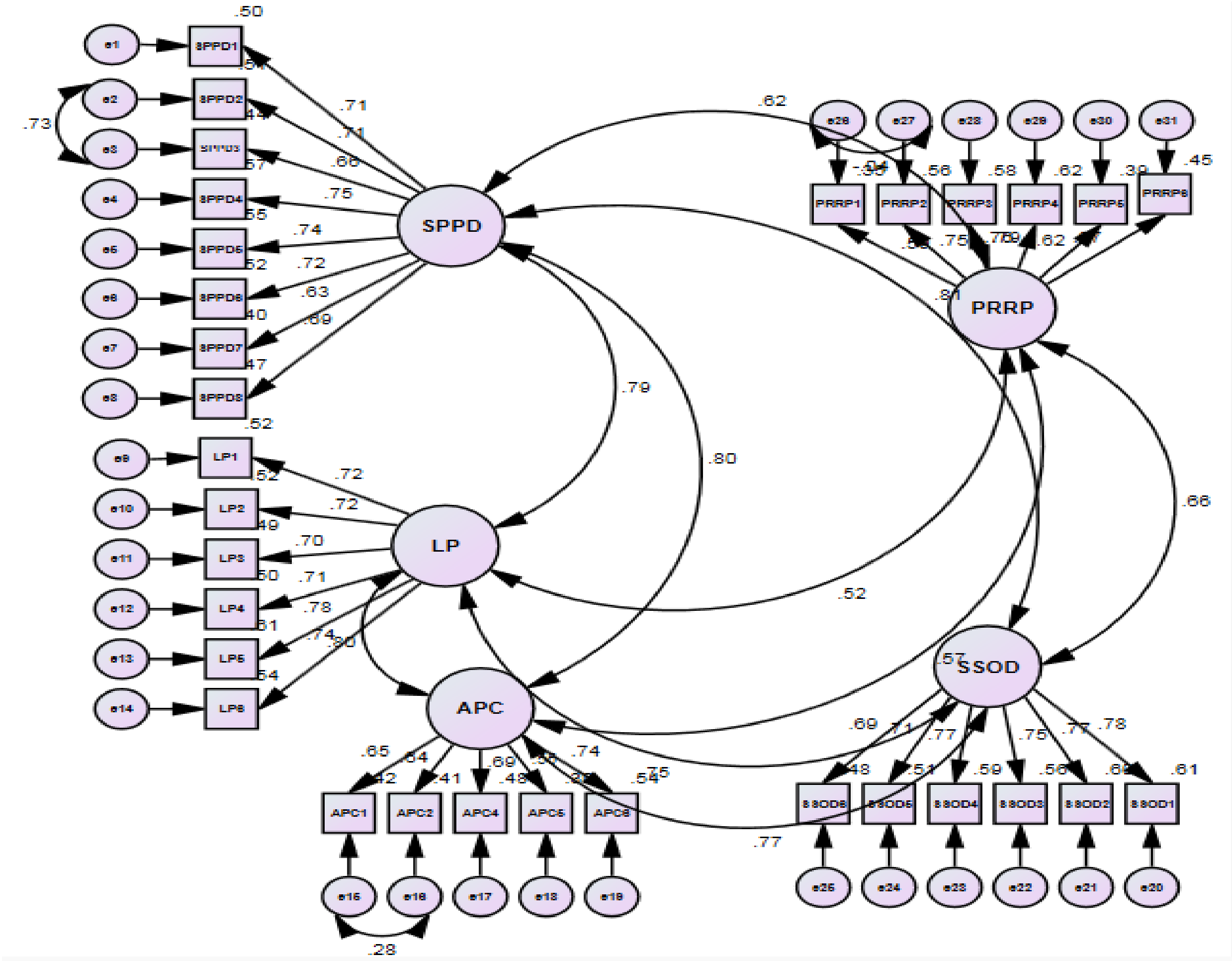


Figure 4.18: First order Measurement model

4.5.7.2.1.2 Second order measurement model

To test the second order model of sustainable manufacturing (SM), we performed second order confirmatory factor analysis, by using AMOS 22.0 software as shown in Figure-4.19. The second order model postulated a latent factor governing the correlation among SPPD, LP, APC, SSOD and PRRP. The path loading from the second order constructs (sustainable manufacturing) to all five dimensions (constructs) was significant (Zailani et al., 2015a; Yusof et al., 2016).

Assessment of second degree measurement model

Before testing the research hypotheses through structural model, a confirmatory factor analysis was run as shown in Figure 4.19 to identify a statistically suitable final model. All constructs that are kept in the model fulfil the necessary requirements and are therefore considered meaningful. The results of confirmatory factor analysis for the second order measurement model for main construct (*sustainable manufacturing*) and sub constructs/dimensions/practices (*SPPD, LP, APC, SSOD and PRRP*) were computed.

Unidimensionality

To test the unidimensionality, confirmatory factor analysis was performed. Total two measurement model were developed to analyze five constructs of sustainable manufacturing (SM). In measurement model one, all the constructs pertinent to SM were considered as first order latent constructs. In the measurement model two, the constructs of sustainable manufacturing (SM) were considered as second order latent construct, measured by first order latent constructs such as SPPD, LP, APC, SSOD and PRRP following the literature (Abdul et al., 2008; Ilgin & Gupta 2010; Siong et al., 2011; Li, 2014). The result of each measurement model with respect to Goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normed fit index (NFI), comparative fit index (CFI) root mean square residual (RMR) and root mean square error of approximation (RMSEA) are statistically significant and all the items are valid in measuring their corresponding constructs.

Efficacy test

To test the validity of the second order model In order to construct model, the efficacy can be measured by computing target (T) coefficient that demonstrate the chi-square ratio of the first order and second order (Marsh and Hocevar, 1985). The T coefficient value above 1.0 indicates more effective representation. In this research, (χ^2) value of first order model is 839.037 and for second order model 763.772. The T coefficient value is greater than 1.0. It implies that the second order constructs perfectly explained by the first order constructs model. Hence, both the models explain perfect representation of the relationship among them.

Assessment of second order structural model

Second order model for sustainable manufacturing was developed by second order confirmatory factor analysis by using AMOS 22.0 software package. The second order model postulated a latent factor governing the correlations among the five constructs (dimensions) (i.e. SPPD, LP, APC, SSOD and PRRP). The path loading from the second order constructs (SM) to all the five constructs (dimensions) was significant with $p<0.001$ as shown in Figure 4.19.

The second order loadings on SM were 0.92 for SPPD, 0.86 for LP, 0.88 for APC, 0.89 for SSOD and 0.62 for PRRP. Furthermore, the results of second order model for SM qualified all the goodness of fit parameters. The chi square (χ^2) value of model is 763.77 with degree of freedom (df) is 424, (χ^2)/df = 1.801, GFI = 0.976, AGFI = 0.855 (near to acceptance limit), RMR = .037, NFI = 0.878, CFI = 0.941 and RMSEA = 0.048. The results show that the sustainable manufacturing (SM) dimensions (Constructs) was considered as second order construct (SM) and it was also supported in the literature. For further justification, the predictive validity test was also performed as given in the next section.

Predictive validity test

Predictive validity test is used to anticipate the relationship of enabling constructs to the hypothesized dependent variables (Stratman and Rath, 2002). This also evaluates the measures behaviour accordance with the theory that separates the measurement movements. Since the implementation sustainable manufacturing (SM) in the Indian manufacturing industry improves the sustainable manufacturing competitiveness (SMC) and sustainable performance measures (SPM). In this research, we used the data of sustainable performance measures (Despeisse et al., 2010 and Joung et al., 2012) and sustainable manufacturing competitiveness (Jovane et al., 2008, Yang et al., 2010 and Hofer et al., 2012) to assess the predictive validity of the sustainable manufacturing.

Hence, the literature supports that there is positive relationship between sustainable manufacturing and sustainable performance measure. Cronbach's alpha for the sustainable performance (SPM1, SPM2, SPM3, SPM4, SPM5, SPM6, SPM7, SPM8, SPM9 and SPM10) was computed 0.906 and all these ten items were reliable. Furthermore, the Cronbac's alpha for sustainable manufacturing competiveness (SMC1, SMC2, SMC3, SMC4, SMC5, SMC6 and SMC7) was computed 0.872.

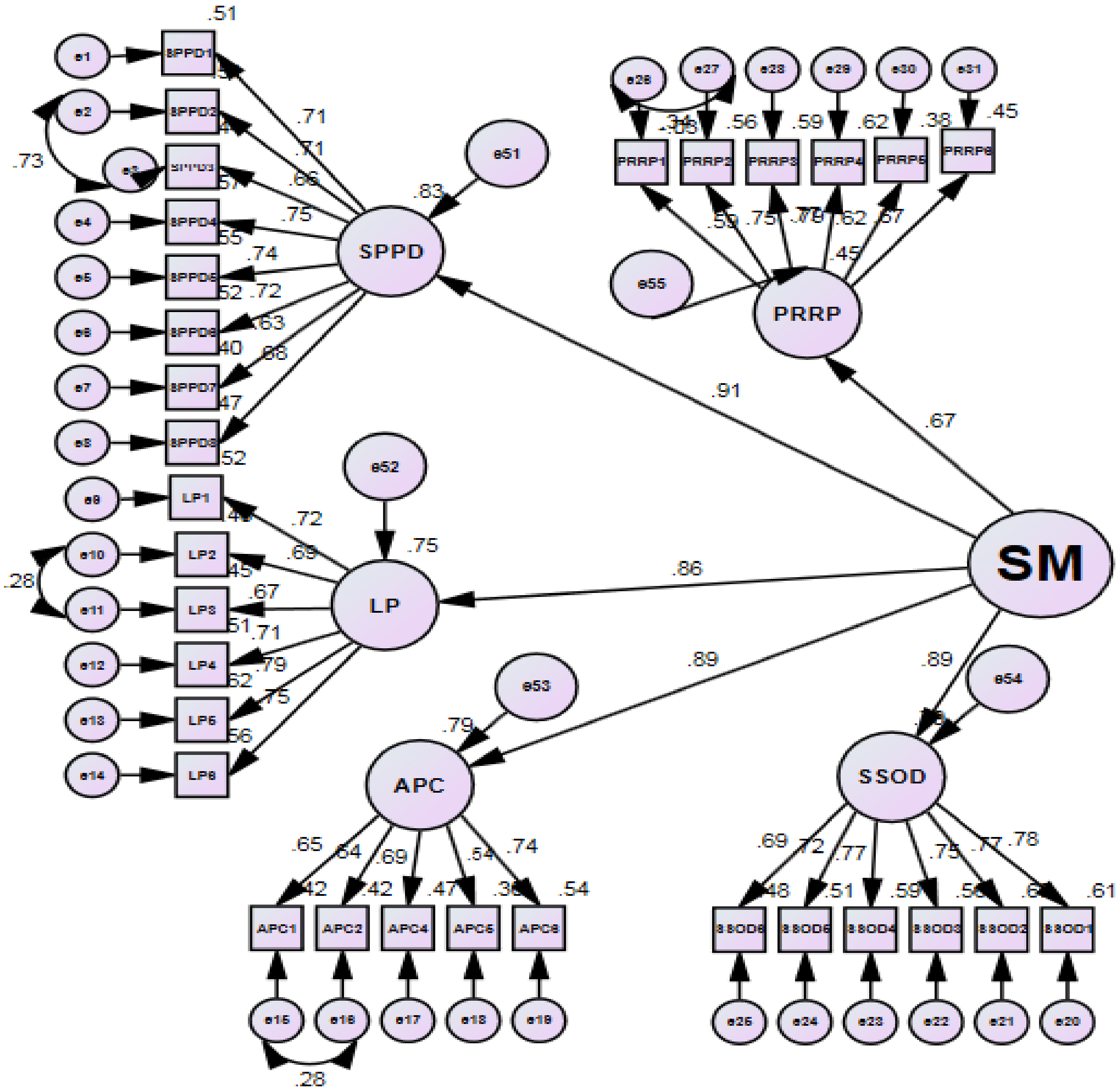


Figure 4.19: Second order Measurement model

It shows the all items were reliable. In order to validate the predictive validity, structural equation modelling was performed between SM, SPM and SMC. The result suggests the better fit with value of $\chi2$ =1736.850 with degree of freedom = 1006, (χ^2)/df = 1.629, GFI = 0.926, AGFI = 0.808 (near to acceptance limit), RMR = 0.035, NFI = 0.834, CFI = 0.928 and RMSEA = 0.043. The standard estimates for SPM = 0.838 and for SMC = 0.548, n=345, p<0.001. Thus it was concluded that the second order sustainable manufacturing model is acceptable for further analysis and passed the predictive analysis test.

4.5.7.2.2 Multifactor congeneric model to analyse the relationship of Research Constructs (SHC, SM, SPM and SMC)

In the previous section, a construct (practices) for *sustainable manufacturing (SM)*, utilizing survey instrument administered to the Indian manufacturing industry was examined and a measurement scale for evaluating the different facts of SM implementation was tested for its validity and reliability followed by confirmatory factor analysis. SM model found to be statistically fit and can be used for further analysis.

In order to investigate the relationship between *sustainable manufacturing and practices* (*SPPD, LP, APC, SSOD and PRRP*), *stakeholder's commitment (SHC), sustainable manufacturing (SMP), sustainable performance measures (SPM) and sustainable manufacturing competiveness* a measurement model for all constructs has been developed with various statistical procedures in this section.

In addition, structural model has been developed to test the relationship between *sustainable manufacturing and practices (H1,2, H3, H4, H5 and H6), stakeholder's commitment and sustainable manufacturing (H7); stakeholders commitment and sustainable performances measures(H8); stakeholder's commitment and sustainable manufacturing competitiveness (H9); sustainable manufacturing and sustainable performance measures (H10), sustainable manufacturing and sustainable manufacturing competitiveness (H11); sustainable performance measures and sustainable manufacturing competiveness (H12).*

The multifactor congeneric model provides the insight into the sustainable manufacturing implementation and its relationship with other factors (SHC, SPM and SMC). First, the items and the constructs provide direct effect and actionable information on sustainable manufacturing implementation. Second, the conceptualisation of the constructs at higher levels provides managers with an opportunity to observe sustainable manufacturing implementation at a higher level. In order to develop multifactor model and test the hypothesis proposed in chapet-2, a structural model using AMOS 22.0 software package is created with the maximum likelihood method. The two step theory given by Anderson and Garbing (1988) is used for the analysis. First, the measurement model was created for all constructs to see the model fit and their convergent and discriminant validity and second, a structural model was developed to test the proposed hypotheses as describe in the Figure 4.20.

Assessment of measurement model

In the previous section, five constructs (practices) (*SPPS, LP, APC, SSOD and PRRP*) measuring the *sustainable manufacturing* as a second order latent variable were validated. Confirmatory factor analysis (CFA) was performed to create a measurement model for the research constructs (*SM, SHC, SPM and SMC*). To check the reliability and validity of the model, we perform various tests. The results of CFA are shown in the Table 4.34.

Unidimensionality was assessed by confirmatory factor analysis. Form the Table 4.34, it is clear that the relevant squared multiple correlations (R^2) are adequately large, ranging from 0.356 to 0.869.This confirms that a significant degree of calculated variable's variance is provided by its latent construct. Hence, all of the four constructs have good fit and thus are unidimensional.

Composite reliability (CR) was assessed in connection with internal reliability. According to Hair et al. (2013), the CR of all of the constructs should be greater than 0.7. In this research, the value of CR of all constructs is greater than 0.7. The value of Cronbach’s alpha is greater than 0.7 for all constructs (Nunnally et al., 1967). The values of standardised estimates is greater than 0.5. This indicates the high convergent validity of the constructs.

Convergent validity was also confirmed by using average variance extracted (AVE). The AVEs of all of the constructs were above 0.5, denoting a satisfactory degree of convergent validity (Fornell and Larcker 1981). In this research the value of AVE for SM, SHC, SPM and SMC is greater than 0.5 as shown in Table 4.34, it indicates that the convergent validity of the measurement constructs is acceptable.

Table 4.34: CFA results for the measurement model

Construct in model	Measurement items	Estimate (Standardized)	R^2	AVE	CR	Cronbach's alpha
SHC	SHC1	0.801	0.642	0.769	0.906	0.951
	SHC2	0.828	0.686			
	SHC3	0.872	0.760			
	SHC4	0.811	0.658			
	SHC5	0.744	0.554			
SM	SPPD	0.932	0.869	0.821	0.927	0.907
	LP	0.846	0.716			
	APC	0.884	0.781			
	SSOD	0.893	0.797			
	PRRP	0.657	0.432			
SPM	SPM1	0.773	0.598	0.619	0.905	0.906
	SPM2	0.664	0.441			
	SPM3	0.707	0.500			
	SPM4	0.693	0.480			
	SPM5	0.716	0.513			
	SPM6	0.737	0.543			
	SPM7	0.676	0.457			
	SPM8	0.732	0.536			
	SPM9	0.662	0.438			
	SPM10	0.624	0.389			
SMC	SMC1	0.699	0.489	0.620	0.872	0.872
	SMC2	0.713	0.508			
	SMC3	0.597	0.356			
	SMC4	0.695	0.483			
	SMC5	0.767	0.588			
	SMC6	0.641	0.411			
	SMC7	0.777	0.604			

Discriminant validity was evaluated using two approaches. First, the correlation between the constructs should equal to 0.90 (Kline, 2011). Second, the comparison of Cronbach's alpha of a latent construct to its mean correlations with other model latent variables (Ghiselli et al., 1981; Bagozzi et al., 1991, Hussain et al., 2016 and Ory & Mokhtarian, 2009). Table 4.35 includes the mean, standard deviation, Cronbach's alpha and correlation matrix with the mean of correlations of latent constructs (SHC, SM, SPM and SMC) on the diagonals. In this research, the correlation between two constructs is not greater than 0.9 and the Cronbach's alpha is higher than the mean of correlation of latent constructs as shown in the Table 4.35. Both analyses confirmed the discriminant validity of all constructs.

Table 4.35: Means, standard deviations, Cronbach's alpha and correlations of the constructs

Constructs	Mean	Std. Deviation	Cronbach's alpha	SHC	SM	SPM	SMC
SHC	3.78	.867	0.907	**0.646**			
SM	3.85	.681	0.951	0.734	**0.826**		
SPM	3.98	.624	0.906	0.614	0.845	**0.781**	
SMC	4.09	.580	0.872	0.591	0.900	0.885	**0.792**

Discriminant validity between the constructs was also evaluated by chi square difference test between a model in which the parameter for the factor correlation was fixed at 1.0 and the original unrestricted CFA Model. The result was significant. According to the Adnderson and Gerbing, (1988), if the value of chi square difference test is significant than the model is achieved discriminant validity.

Assessment of structural model

To test the proposed hypotheses, the multifactor congneneric structural model was developed by confirmatory factor analysis using AMOS 22.0 software package as shown in Figure 4.20. A structural model has been developed to test the proposed hypothesises i.e.H1,2, H3, H4, H5, H6, H7, H8, H9, H10, H11 and H12. The structural model were analysed based on the fit between the theoretical model and the data through the goodness of fit indices. The model fit indices were computed as the values of (χ^2)/df = 1.740, GFI = 0.808, AGFI = 0.789, RMR = 0.044, NFI = 0.815, CFI = 0.911 and RMSEA = 0.046. All these values were satisfactory with respect to the recommended range value (Ory and Mokhtarian, 2009). The model fit Indies suggest an acceptable fit of structural and perfect representation of the relationship of SHC, SM, SPM and SMC.

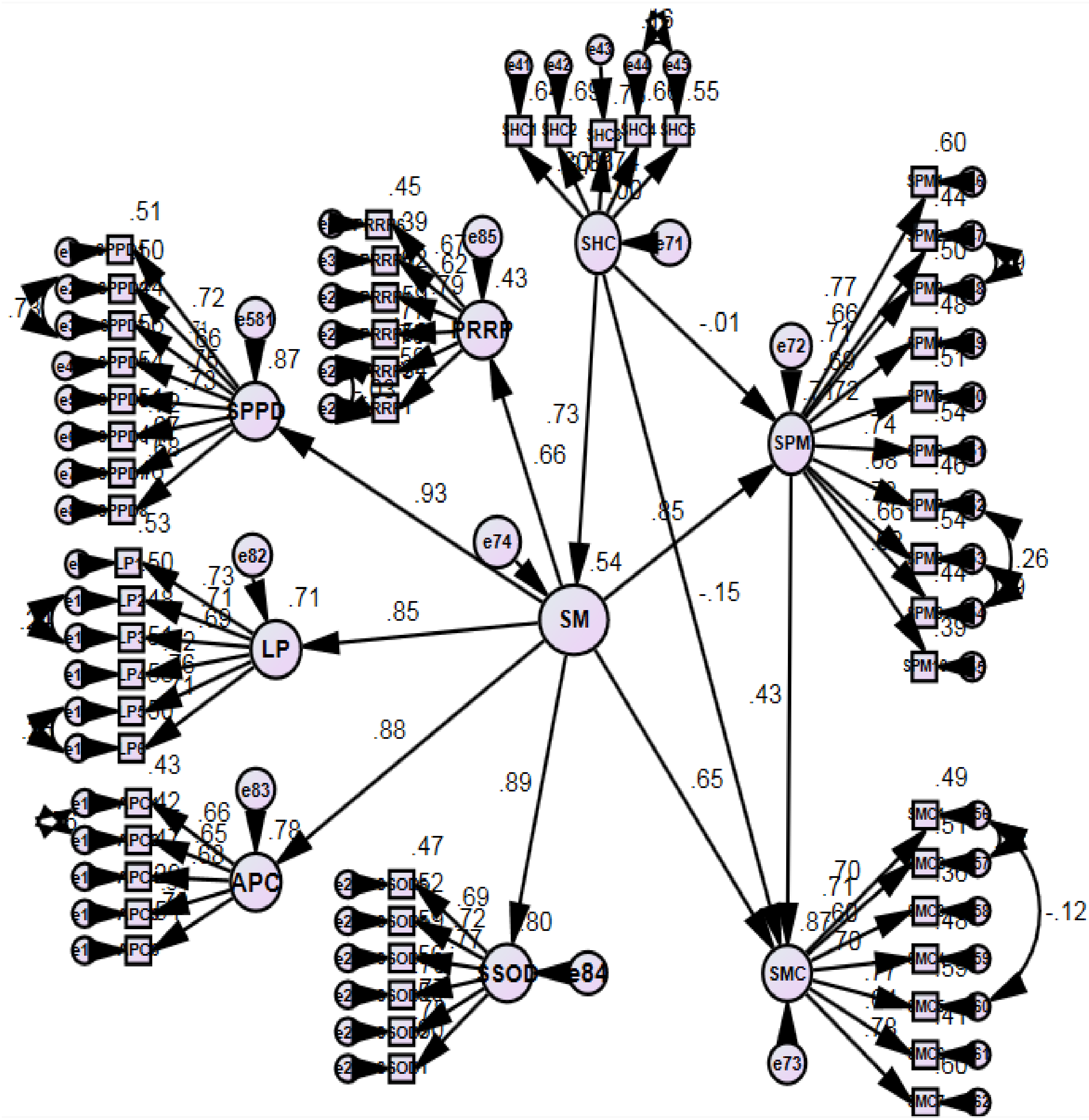


Figure 4.20: Multifactor Structural equation model

4.5.8 Discussion of hypotheses between the Research Constructs

The discussion presented in this section represent a theory driven examination of how the sustainable manufacturing, stakeholder's commitment, sustainable performance measures and sustainable manufacturing competitiveness are associated with each other in the Indian context.

Table 4.36: The results of the structural model

Hypothesis	Estimates (Standardized) (β)	Standard Error (S.E.)	Critical Ratio (CR)	P	Results
H1,2: SM → SPPD	0.932	---	---	***	Supported
H3: SM → LP	0.846	0.105	10.386	***	Supported
H4: SM → APC	0.884	0.093	10.811	***	Supported
H5: SM → SSOD	0.893	0.094	11.563	***	Supported
H6: SM → PRRP	0.657	0.088	7.938	***	Supported
H7: SHC → SM	0.734	0.043	10.356	***	Supported
H8: SHC → SPM	-0.013	0.048	-0.20	*	Not Supported
H9: SHC → SMC	-0.146	0.053	-1.735	*	Not Supported
H:10 SM → SPM	0.855	0.113	9.243	***	Supported
H11: SM → SMC	0.646	0.109	6.044	***	Supported
H12: SPM → SMC	0.431	0.068	5.267	***	Supported

Path loadings are significant at ***P<0.001; *P<0.5

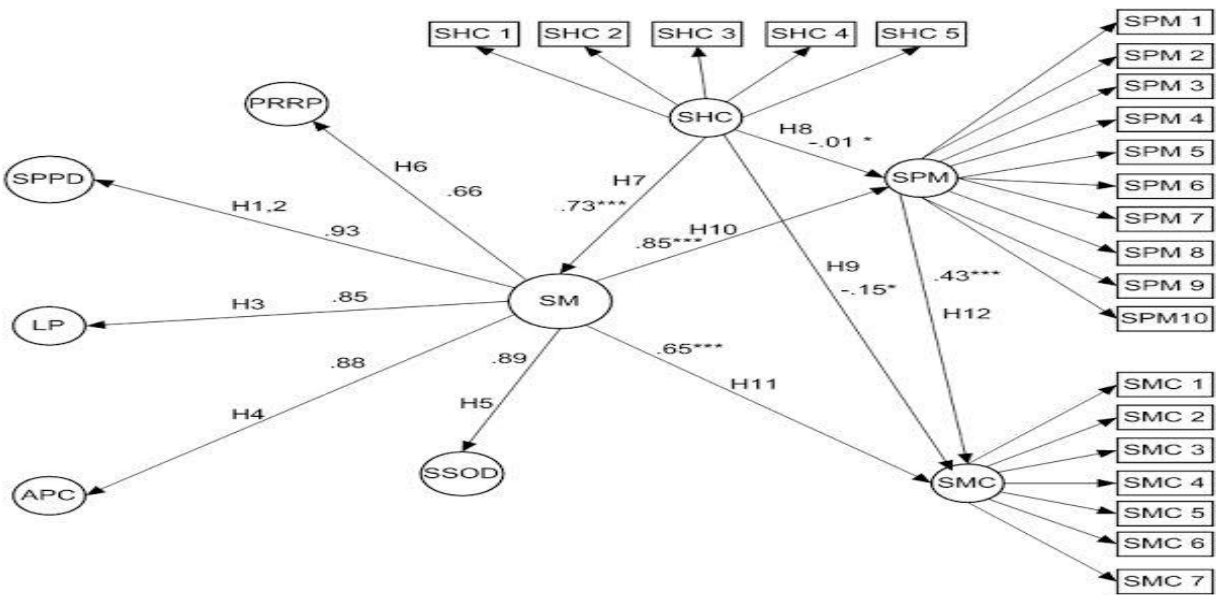


Figure 4.21: Relationships between SM, SHC, SPM and SMC

The results indicate that the scale items to measure the model's constructs are reliable and valid; and an excellent fit between the theoretical model and the data model. Table 4.36, shows the standardise estimates and result of the hypothesises.

4.5.8.1 Constitution of sustainable manufacturing through SM practices (H1,2; H3; H4; H5; H6)

The results indicate that the scale items to measure the model's constructs are reliable and valid; and an excellent fit between the theoretical model and the data model. Table 4.37, shows the standardised estimates and result of the hypothesises. The result indicates a positive and significant relationship between sustainable manufacturing (SM) and sustainable product and process design (SPPD) which support H1,2 ($\beta = 0.932$; $p<0$

$.001$). Similarly, there is a positive and significant relationship between sustainable manufacturing (SM) and lean practices (LP) ($\beta = 0.846$; $p<0.001$), sustainable manufacturing (SM) and agile practices and customization (APC) ($\beta = 0.884$; $p<0.001$), Sustainable manufacturing (SM) and sustainable supply operation and distribution (SSOD) ($\beta = 0.893$; $p<0.001$) and sustainable manufacturing (SM) and product recovery and return practices (PRRP) ($\beta = 0.657$; $p<0.001$) respectively. This supports hypotheses H3, H4, H5 and H6 respectively.

4.5.8.2 Relationship between stakeholder's commitment (SHC) with SM, SPM and SMC (H7; H8; H9)

Stakeholder's commitment (SHC) and sustainable manufacturing (SM) are positively associated and confirmed the H7 ($\beta = 0.734$; $p<0.001$). The analysis results are concerning with H8 ($\beta = -0.013$; $p<0.05$) and H9 ($\beta = -0.146$; $p<0.5$) which focus on the relationship between Stakeholder's commitment (SHC) to sustainable performance measures (SPM); Stakeholder's commitment (SHC) to sustainable manufacturing competiveness (SMC) respectively. Both hypotheses are negatively insignificant thereby providing support predominant opinion among the researcher concerning the relationship of stakeholder's commitment to sustainable performance measures and sustainable manufacturing competiveness.

4.5.8.3 Relationship between sustainable manufacturing (SM) with SPM and SMC (H10; H11)

Sustainable manufacturing (SM) is significantly linked to the sustainable performance measures (SPM) (β = 0.855; $p<0.001$) providing support to hypothesis H10. Sustainable manufacturing (SM) is positively associated with sustainable manufacturing competiveness (SMC)-thereby providing support to H11 (β = 0.656; $p<0.001$).

4.5.8.4 Relationship between sustainable performance measures (SPM) and with sustainable manufacturing competiveness (SMC) (H12)

The relationship between sustainable performance measures (SPM) and sustainable manufacturing competiveness (SMC) is positively significant which confirmed the H12 (β = 0.431; $p<0.001$). This implied that good sustainable performance of the company triggers and contributes towards the manufacturing competitiveness. In the Figure 4.21 the path loadings are shown.

4.6 PERFORMANCE INDEX

Sustainable manufacturing index, sustainable performance index and sustainable manufacturing competitiveness index calculated based on the survey on Indian manufacturing companies and on the basis of empirical results coming from the survey. These indices are calculated for all 345 responses for micro study and for the macro study the all three indexes are calculated for each sector viz. automobile, electrical & electronics, machinery and process sectors.

4.6.1 Step by step methodology to compute Indices

To calculate sustainable manufacturing index, sustainable performance index and sustainable manufacturing competitiveness index, this study uses methodology proposed by Dangayach and Deshmukh 2001. The steps involve in methodology to calculate the indices are given as:

Step-1: Administer the pre validated questionnaire (sustainable manufacturing assessment scale) in Indian manufacturing companies.

Step-2: Calculate mean response of individual items

Step-3: Estimate loadings are taken as weights of individual items from Structural equation model.

Step-4: Compute the weighted average of all individual items for respective construct to get the Index for that construct.

Hence we get the all the indices for sustainable manufacturing practices.

Index for sustainable product and process design (I_{SPPD})

$$I_{SPPD} = W_{SPPD1}\overline{SPPD1}+W_{SPPD2}\overline{SPPD2} + W_{SPPD3}\overline{SPPD3} + W_{SPPD4}\overline{SPPD4} +W_{SPPD5}\overline{SPPD5} +W_{SPPD6}\overline{SPPD6}+W_{SPPD7}\overline{SPPD7} +W_{SPPD8}\overline{SPPD8} \quad (1)$$

Index for sustainable Lean practices (I_{LP})

$$I_{LP} = W_{LP1}\overline{LP1} + W_{LP2}\overline{LP2} +W_{LP3}\overline{LP3} + W_{LP4}\overline{LP4} + W_{LP5}\overline{LP5} + W_{LP6}\overline{LP6} \quad (2)$$

Index for agile practices and customization (I_{APC})

$$I_{APC} = W_{APC1}\overline{APC1} +W_{APC2}\overline{APC2} + W_{APC4}\overline{APC4} + W_{APC5}\overline{APC5} + W_{APC6}\overline{APC6} \quad (3)$$

Index for sustainable supply operations and distribution (I_{SSOD})

$$I_{SSOD} = W_{SSOD1}\overline{SSOD1} + W_{SSOD2}\overline{SSOD2} + W_{SSOD3}\overline{SSOD3} + W_{SSOD4}\overline{SSOD4} + W_{SSOD5}\overline{SSOD5} + W_{SSOD6}\overline{SSOD6} \quad (4)$$

Index for product recovery and return practices (I_{PRRP})

$$I_{PRRP} = W_{PRRP1}\overline{PRRP1} + W_{PRRP2}\overline{PRRP2} + W_{PRRP3}\overline{PRRP3} + W_{PRRP4}\overline{PRRP4} + W_{PPRP5}\overline{PRRP5} + W_{PRRP6}\overline{PRRP6} \quad (5)$$

Step-5: Compute the weighted average of all indices calculated in step 4 using their respective estimates (standardised loadings) form SEM model to get the Index for SM

Sustainable Manufacturing Index *(SMI)* (I_{SM})

$$I_{SM} = W_{SPPD}\, I_{SPPD} + W_{LP}\, I_{LP} + W_{APC} I_{APC} + W_{SSOD} I_{SSOD} + W_{PRRP} I_{PRRP} \quad (6)$$

Step-6: Compute the Index for SPM using estimate (standardised loading) of SM from SEM model and index from SM.

Sustainable performance Index *(SPI) (I_{SPM})*

$$I_{SPM} = \beta * I_{SM} \quad (7)$$

Step-7: Compute the Index for SMC using estimates (standardised loadings) of SM and SPM from SEM model and indices of SM and SPM.

Sustainable manufacturing competitiveness *(SMCI) (I_{SMC})*

$$I_{SMC} = W_{SM}\, I_{SM} + W_{SPM}\, I_{SPM} \quad (8)$$

Form the above equations (6), (7) and (8) and structural equation (SEM) model, the sustainable manufacturing index (I_{SM}), sustainable performance index (I_{SPM}) and sustainable manufacturing competiveness Index **(**I_{SMC}**)** is computed as given in the Table 4.37.

Table 4.37: Index for SM, SPM and SMC

S. No.	Indices	Index Values
1	Sustainable Manufacturing Index	3.84
2	Sustainable Performance Index	3.28
3	Sustainable Manufacturing Competitiveness Index	3.62

From the Table 4.38, the sustainable manufacturing index ISM is computed 3.86, it means that Indian manufacturing companies are aware and adopted sustainable manufacturing practices. But still there is a need to focus various issues of sustainable manufacturing in manufacturing companies. Sustainable performance index ISPM is computed 3.78; it means there is moderately improvement in sustainable performance of the company.

Sustainable manufacturing competitiveness Index is computed 3.62; it means that Sustainable Manufacturing Competitiveness is highly achieved by implementing/adopting the Sustainable Manufacturing Practices. This supports the finding that although Indian manufacturing companies have started adoption of sustainable manufacturing practices, i.e., *SPPD, LP, APC, SSOD and PRRP*, but these are yet to be translate in term of good sustainable performance and sustainable manufacturing competitiveness in the Indian context.

4.7 SUMMARY

This chapter presents data collection from the manufacturing industries and analysis of data. The data was collected through various Indian manufacturing companies' viz. automobile, electrical & electronics, machinery and process industries. Out of 1425 sampled Indian manufacturing companies, 345 usable responses were received. The chapter starts with the descriptive statistics and analysis of respondent & company profile. Majority of respondent companies from automobile, electrical and electronics, machinery and process sectors are 115 (33.3%) maximum from automobile sector and minimum 65 (18.8%) from electrical and electronics sector. Investigation of associational inference about awareness of sustainability presents in this chapter. To investigate if there is significant relationship between type of firm and perception about of Sustainable/Green strategy, chi square test was carried out. The perception of Sustainable/Green strategy is significantly higher in automobile sector in comparison to electrical and electronics, machinery and process sectors. Automobile companies are more conscious about sustainable and green strategies due to heavy competition in the global market.

Factor analysis is used to identify number of constructs that might be used to represent relationship among set of variables (Mitra & Datta, 2014). It is primarily used just for dimension reduction and factor extraction. The purpose of factor extraction is to extract factor or construct i.e. the underlying construct that describe a set of items. In varimax rotation eight items were loaded on one component. These items are from sustainable product design (SPD) and sustainable manufacturing process design (SMPD).

In the survey, the respondents observed real practice of SPD and SMPD in the industries. Finally, a new construct was formed with the name of sustainable product and process design (SPPD) The rotated component matrix for sustainable manufacturing practices, sustainable performance measures, sustainable manufacturing competitiveness and stakeholder's commitment with significant factor loading on their original constructs.

Structural equation modelling (SEM) is used to investigate and validates the sustainable manufacturing (SM) measurement model in Indian context. SM model consists of five factors namely sustainable product and process design (SPPD), Lean practices (LP), Agile practices and customization (APC), sustainable supply operation and distribution (SSOD) and product recovery and return practices (PRRP). The multifactor cogeneric model is developed to analyze the relationship of stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness. Performance index for sustainable manufacturing, sustainable performance and sustainable manufacturing competitiveness is computed by the help of indices equations. The study reveals that the Indian manufacturing companies are adopting sustainable manufacturing but still there is need to explore. Next chapter will be further fine-grained the sector wise competitive analysis of SM practices, sustainable performance and manufacturing competiveness.

CHAPTER 5. COMPARATIVE STUDY OF FACTORS ASSOCIATED WITH SUSTAINABLE MANUFACTURING

5.1 INTRODUCTIONS

In the previous chapter, the relationship between sustainable manufacturing dimensions, stakeholder's commitment, sustainable performance measures and sustainable manufacturing competitiveness is assessed and hypotheses were tested for significance of relationship using structural equation modeling. In this chapter, the sector wise comparative analysis of sustainable manufacturing and its dimensions, stakeholder's commitment, sustainable performance measures and sustainable manufacturing competiveness will be analyzed.

5.2 TEST OF HOMOGENEITY OF VARIANCE

The tests to compare the group performance are significantly affected by the variance of group if they are substantially different, especially in terms of numbers (Leech et al. 2005). SPSS provides the Levene's test to check the homogeneity of the variance of groups to be compared (Bhanot et al. 2015a). The analysis is performed to identify the sectorial behavior of Indian manufacturing industries towards the sustainable manufacturing.

Table 5.1: Test of Homogeneity of Variances

Factors	Levene Statistic	Sig.
SHC	1.755	.156
SPPD	.914	.434
LP	1.751	.156
APC	1.464	.224
SSOD	2.350	.072
PRRP	2.034	.109
SMC	1.809	.145
SPM	1.299	.275

Conducting Levene's test of homogeneity of variance from the Table 5.1, it can be observed that the significance value of all factors is *SHC, SPPD, LP, APC, SSOD, PRRP, SPM and SMC* is greater than 0.05 and hence, it can be concluded that variances are equal.

5.3 SECTOR WISE COMPARATIVE ANALYSIS

The sample is divided into four sector i.e. automobile, electrical & electronics, machinery and process sector (Dangayach and Deshmukh, 2001). A set of activities (variables) related to the stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competiveness have been analysed. Detailed analysis of sustainable manufacturing and factors associated with it with respect to the various sectors has been outlined below. In the previous chapter, second order structural model was developed and it was statistically proved that sustainable product and process design (SPPD), Lean Practices (LP), Agile practices & Customization (APC), sustainable supply operations & distribution (SSOD) and product return & recovery practices (PRRP) are the practices of sustainable manufacturing. Overall and sector wise mean and standard deviation score is given in Table 5.2. It is noted from the Table 5.2 and Figure 5.1 that surprisingly agile practices and customization practices are being used by the Indian manufacturing industries with mean value (3.141). It is due to reason that manufacturing industries are more conscious about the manufacturing automation with on time delivery as per the customer demand.

Table 5.2: Descriptive statistics of sustainable manufacturing

	Sector	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Practices	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SM	SPPD	2.887	0.476	2.930	0.410	2.790	0.496	2.848	0.484	2.864	0.471
	LP	3. 074	0.581	2.902	0.498	2.748	0.620	2.845	0.515	2.877	0.565
	APC	**3.162**	0.510	**3.298**	0.405	**3.046**	0.518	**3.079**	0.519	**3.141**	0.502
	SSOD	2.852	0.574	3.010	0.414	2.831	0.559	2.814	0.471	2.867	0.520
	PRRP	3. 015	0.622	3.040	0.539	2.944	0.537	3.105	0.531	3.029	0.566

From the Figure 5.2, it is clear that in automobile sector used agile practice and customization with mean value of 3.162 and lean manufacturing implemented with mean value 3.074. Automobile industries are more conscious about lean practices as compared to other industry sectors.

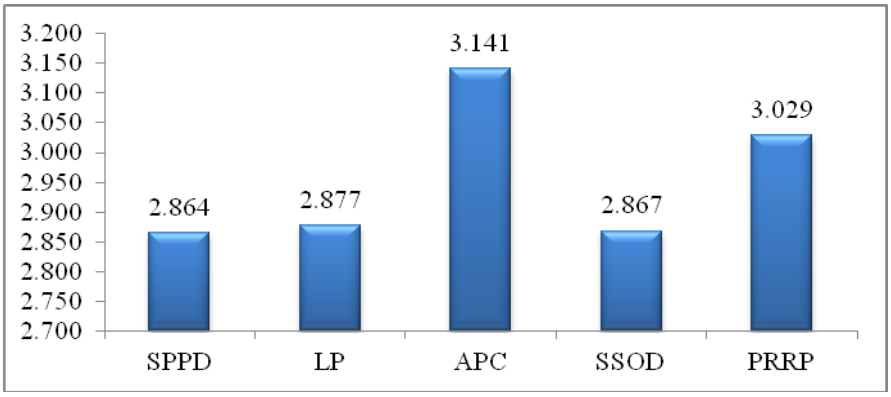


Figure 5.1: Practices (dimensions) of sustainable manufacturing

Similarly electrical and electronics, machinery and process industry also used the APC practices. However in Electrical and electronics industries, sustainable supply operations and distribution (SSOD) implemented with mean value 3.010. Machinery and process industries are using recovery practices with mean values 2.944 and 3.015 respectively. In the process industries, recovery of the products is important phenomenon, considering the steel manufacturing in India, the product returns and recovery practices are being used to produce the products.

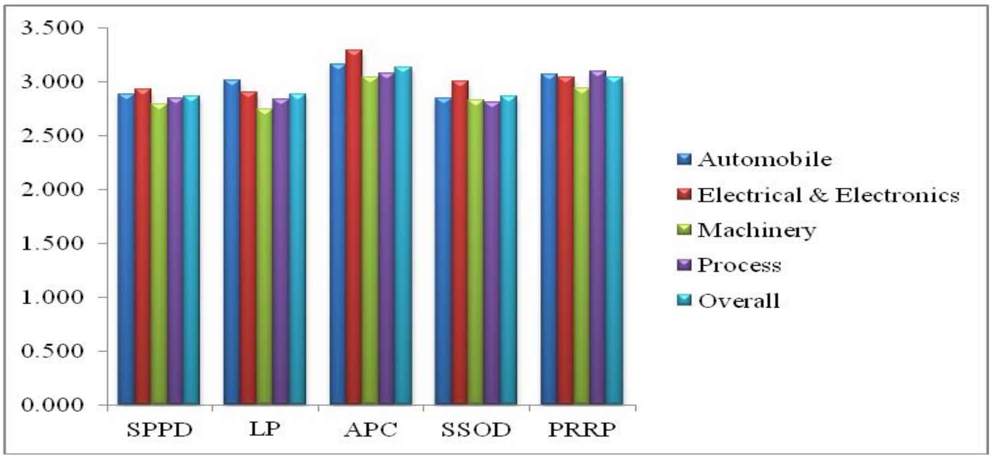


Figure 5.2: Mean Score for Practices (dimensions) of sustainable manufacturing in different sectors

5.3.1 Stakeholder's commitment

Based on the literature (Qi et al., 2010; Jayaraman et al., 2012; Hahn & Kühnen, 2013, Yu & Ramanathan, 2015), various practices in which the stakeholders commitment is explored are identified such as Environmental compliances as per governmental policies are strictly adhered, Cross-functional cooperation for sustainable manufacturing, Motivation towards Sustainability, Emphasis on improving eco-efficiency and Stakeholders Expertise, stakeholder's commitment for sustainable manufacturing are highly appreciated by the industries. Stakeholder's commitments for the sustainability of manufacturing play an important role. Respondents were asked about the level of commitment of stakeholders in their organization on five point Likert scale (where 1-very Low and 5-very high). Table 5.3 shows the sector wise mean and standard deviation of stakeholder's commitment.

Table 5.3: Descriptive statistics of stakeholder's commitment

Items	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SHC1	**3.83**	1.11	**4.26**	0.87	**3.88**	1.10	**3.91**	1.14	3.94	1.05
SHC2	3.77	0.97	3.89	0.87	3.80	0.99	3.60	1.03	3.76	0.96
SHC3	3.72	1.03	4.00	0.88	3.75	0.96	3.67	1.01	3.77	0.97
SHC4	3.77	1.02	3.95	0.96	3.75	1.08	3.67	0.94	3.77	1.00
SHC5	3.66	1.07	3.92	0.94	3.72	0.96	3.52	0.97	3.69	0.99
SHC	**3.75**	**1.04**	**4.01**	**0.90**	**3.78**	**1.02**	**3.67**	**1.02**	**3.78**	**0.99**

On five Likert scale (where 1-very Low and 5-very high).

SHC1	Environmental compliances as per governmental policies are strictly adhered
SHC2	Cross-functional cooperation for sustainable manufacturing
SHC3	Motivation towards Sustainability
SHC4	Emphasis on improving eco-efficiency
SHC5	Stakeholders Expertise

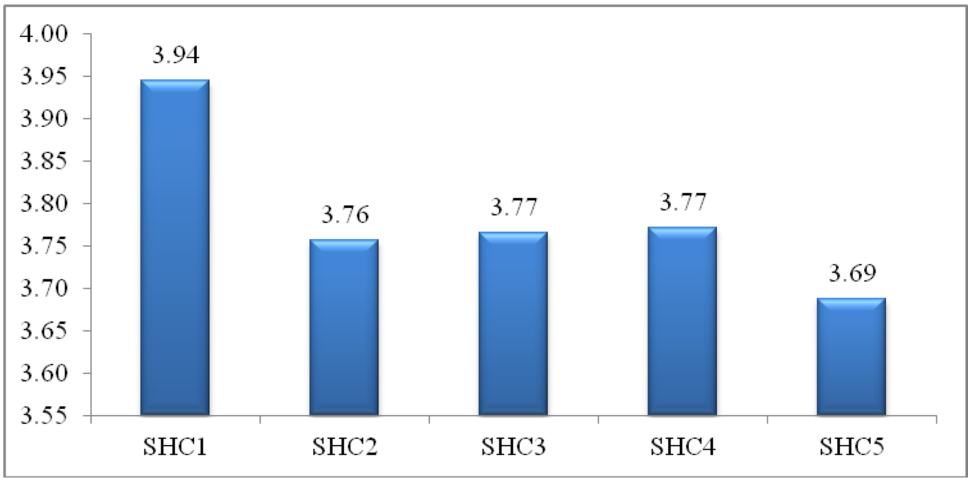


Figure 5.3: practices (items) of stakeholder's commitment

Table 5.3 summarizes the answers concerning the level of commitment of the stakeholders towards sustainable manufacturing. The result of the survey indicate that stake holders are more focused on Environmental compliances as per governmental policies are strictly adhered (SHC1) with mean 3.94 as shown in the Figure 5.3.

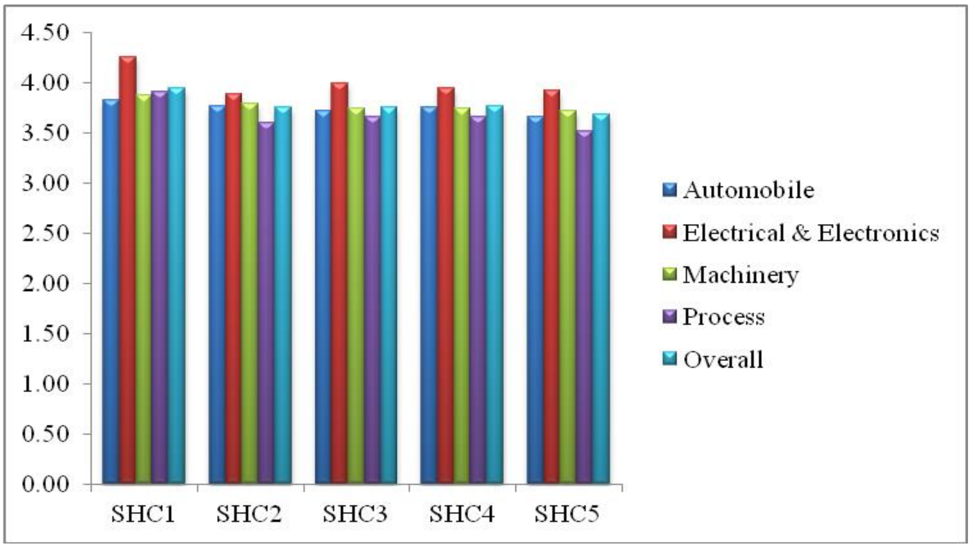


Figure 5.4: Mean Score of the elements of stakeholder's commitment for sustainable manufacturing in different sectors

It is depicted from the Figure 5.4 that in all four sectors (automobile, electrical & electronics, machinery and process), stakeholders are highly interested in Environmental compliances as per governmental due to environmental sustainability is an integral part of sustainable manufacturing.

Table 5.4: One-sample T test for stakeholder's commitment for sustainable manufacturing

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SHC1	16.237	344	.000	.9449	.830	1.059
SHC2	14.445	344	.000	.7565	.654	.860
SHC3	14.255	344	.000	.7652	.660	.871
SHC4	14.302	344	.000	.7710	.665	.877
SHC5	12.539	344	.000	.6870	.579	.795

From the Table 5.4 by one sample T test analysis, it can be clearly observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in stakeholder's commitment for sustainable manufacturing. The value of T statistics and its level of significance for SHC1 (16.237; 0.000), SHC2 (14.445; 0.000), SHC3 (14.255, 0.000), SHC4 (14.302; 0.000) and SHC5 (12.539; 0.000). From the results, it is observed that environmental compliances as per governmental policies are strictly adhered (SHC1) (T =16.237) and Cross-functional cooperation for sustainable manufacturing (SHC2) (T =14.445) are the highly significant variable of stakeholder's commitment in Indian manufacturing companies.

Table 5.5: ANOVA test for stakeholder's commitment for sustainable manufacturing

Stakeholder's Commitment	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
SHC	Automobile	115	3.751	.908	.0847	1.99	.12
	Electrical & Electronics	65	4.006	.697	.0865		
	Machinery	75	3.779	.914	.1056		
	Process	90	3.673	.867	.0914		
	Total	345	3.785	.867	.0467		

Table 5.5 illustrates that F statistics and associated p value. The result shows that the value of F = 1.99 at p value 0.12. It is clearly observed that the p value= 0.12, which is greater than the level of significance 0.05. It indicates that there is no significant difference between the sectors (automobile, electrical & electronics, machinery and process) for stakeholder' commitment. Therefore, it is concluded that stakeholders' commitment in all four sectors is significantly the same due to the environmental consciousness and government pressure.

5.3.2 Sustainable product and process design Practices

Based on the literature (Bras & McIntosh, 1999; Fai Pun, 2006; Niinimäki & Hassi, 2011; Gunasekaran & Spalanzani, 2012; Gupta et al., 2015b) and statistical analysis of the eight relevant practices of sustainable product and process design were identified for Indian manufacturing companies which provide sustainable manufacturing. The details of these practices are given below. Respondent were asked to rate the level of importance of these SPPD practices in their companies on five point Likert type scale (1-Very Low to 5-Very High).

Overall and sector wise mean and standard deviation score is given in the Table 5.6. It is observed that Indian manufacturing companies are more emphasized on design of products for reduced consumption of material and energy (SPPD1) (overall mean= 4.04) and use of efficient and clean technology to reduce carbon dioxide (CO_2) foot print (overall mean =4.04) (SPPD8) as shown in Figure 5.5.

Table 5.6: Descriptive statistics of sustainable product and process design (SPPD)

Items	Automobile (N=115)		Electrical & Electronics (N=65)		Machinery (N= 75)		Process (N=90)		Overall (N=345)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SPPD1	4.04	0.81	4.17	0.75	3.99	0.88	3.99	0.81	4.04	0.81
SPPD2	4.01	0.87	4.05	0.86	3.88	0.87	3.96	0.78	3.97	0.84
SPPD3	4.03	0.85	4.09	0.72	3.77	0.85	3.91	0.79	3.96	0.81
SPPD4	3.84	0.98	3.91	0.90	3.79	0.98	3.83	0.90	3.84	0.94
SPPD5	4.07	0.86	4.08	0.78	3.89	0.83	4.01	0.95	4.02	0.86
SPPD6	4.03	0.80	4.11	0.77	3.77	0.92	3.99	0.84	3.98	0.84
SPPD7	4.02	0.90	**4.18**	0.89	**4.09**	0.99	3.91	1.00	4.03	0.95
SPPD8	**4.08**	0.79	4.08	0.80	3.92	0.91	**4.09**	0.86	4.04	0.84
SPPD	**4.02**	**0.86**	**4.08**	**0.81**	**3.89**	**0.90**	**3.96**	**0.87**	**3.99**	**0.86**

On five Likert scale (where 1-very Low and 5-very high).

SPPD1	Design of products for reduced consumption of material and energy.
SPPD2	Design of products to reduce the use of hazardous of products and manufacturing process
SPPD3	Design for Packaging
SPPD4	Design for environment (DFE)
SPPD5	Minimizing waste during machining process
SPPD6	Energy efficiency during production process
SPPD7	Improve resources utilisation (materials, water, manpower) on shop floor
SPPD8	Use of efficient and clean technology to reduce carbon di oxide foot print

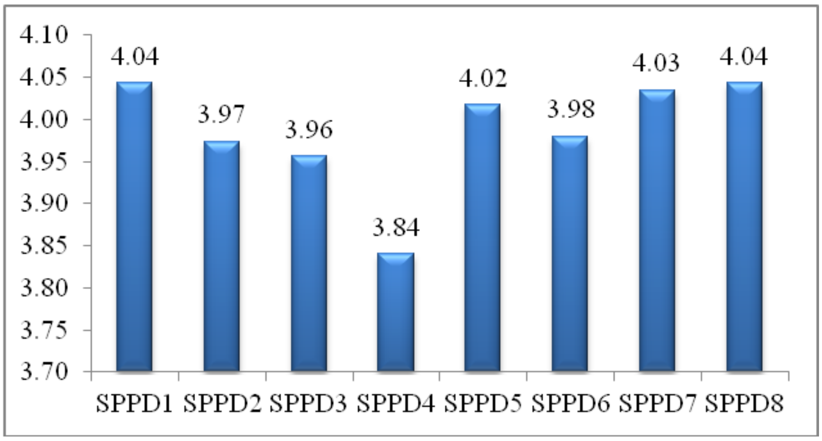


Figure 5.5: Practices (items) of sustainable product and process design (SPPD)

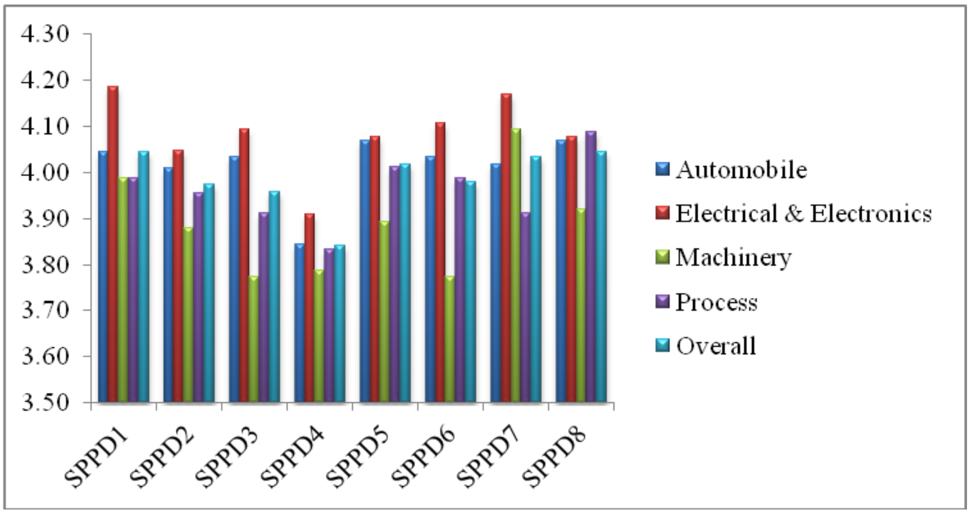


Figure 5.6: Mean Score of elements of sustainable product and process design (SPPD) in different sectors

It is depicted from the Table 5.6 and Figure 5.6 that in all the four sectors (automobile, electrical & electronics, machinery and process), the most preferred SPPD practice in automobile sector is the use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) and that of electrical & electronics and machinery companies is to Improve resources utilization (materials, water, manpower) on shop floor (SPPD7). Whereas the process industries emphasized on the use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) due to continuous type of production and high waste generation.

Table 5.7: One-sample T test for sustainable product and process design (SPPD)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SPPD1	23.789	344	.000	1.0435	.957	1.130
SPPD2	21.445	344	.000	.9739	.885	1.063
SPPD3	21.806	344	.000	.9565	.870	1.043
SPPD4	16.602	344	.000	.8406	.741	.940
SPPD5	21.910	344	.000	1.0174	.926	1.109
SPPD6	21.658	344	.000	.9797	.891	1.069
SPPD7	20.326	344	.000	1.0348	.935	1.135
SPPD8	23.187	344	.000	1.0435	.955	1.132

From the Table 5.7 by one sample T test analysis, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in sustainable product and process design (SPPD) practices. The value of T statistics and its level of significance for SPPD1 (23.789; 0.000), SPPD2 (21.445; 0.000), SPPD3 (21.806, 0.000), SPPD4 (16.602; 0.000), SPPD5 (21.910; 0.000), SPPD6 (21.658; 0.000), SPPD7 (20.326; 0.000) and SPPD8 (23.187; 0.000). From the results it is observed that the design of products for reduced consumption of material and energy (SPPD1) (T =23.789) and use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (T =23.187) are the significant practices of sustainable product & process design (SPPD).

Table 5.8: ANOVA test for sustainable product and process design (SPPD)

Sustainable Product Process Design	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
SPPD	Automobile	115	4.018	.658	.061	1.17	.32
	Electrical & Electronics	65	4.085	.560	.069		
	Machinery	75	3.891	.692	.080		
	Process	90	3.963	.662	.070		
	Total	345	3.988	.650	.035		

Table 5.8 illustrates that F statistics and associated p value. The result shows that the value of F = 1.17 at p value 0.32. It is clearly observed that the p value= 0.32, which is greater than the level of significance 0.05. It indicates that there is no significant difference between the sectors (automobile, electrical & electronics, machinery and process) for sustainable product and process design (SPPD). Therefore, it is concluded that sustainable product and process design (SPPD) practices in all four sectors are significantly same; reduction in consumption of material and energy, and utilization of efficient and clean technology to reduce carbon dioxide foot print.

5.3.3 Lean Practices

Based on the literature (de Ron, 1998; Lewis, 2000 and Dües et al. 2013 and Gupta et al., 2015a) the six relevant practices of Lean were identified for Indian manufacturing companies which provide sustainable manufacturing. The details of these practices are given below. Respondents were asked to rate the level of implementation of these Lean practices in their companies on five point Likert type scale (1-Very Low to 5-Very High).

Table 5.9: Descriptive statistics of Lean Practices

Items	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
LP1	3.62	1.01	3.66	0.82	3.41	0.97	3.53	0.84	3.56	0.93
LP2	**4.17**	0.84	**4.03**	0.93	**3.77**	0.97	3.86	0.84	3.97	0.90
LP3	4.16	0.85	3.85	0.83	3.61	0.98	3.77	0.95	3.88	0.93
LP4	3.95	0.89	3.65	0.91	3.63	0.96	**3.89**	0.88	3.81	0.91
LP5	3.82	1.00	3.66	0.87	3.44	0.98	3.50	0.95	3.62	0.97
LP6	3.84	0.98	3.75	0.85	3.59	1.03	3.56	0.91	3.70	0.95
LP	**3.92**	**0.93**	**3.77**	**0.87**	**3.58**	**0.98**	**3.68**	**0.90**	**3.76**	**0.93**

On five Likert scale (where 1-very Low and 5-very high).

LP1	Value Stream Mapping (VSM)
LP2	Continuous improvement/Kaizen//Pokayoke/Mistake proofing
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)
LP4	Total productive maintenance (TPM)
LP5	Just-in-Time (JIT)
LP6	Kanban/Pull Production

Overall and sector wise mean and standard deviation score is given in the Table 5.9. It is observed that Indian manufacturing companies have implemented Continuous improvement/Kaizen/Pokayoke/Mistake proofing (LP2) (overall mean=3.97), 5S (LP3) (overall mean=3.88) and Total productive maintenance (TPM) (LP4) (overall mean=3.81) as shown in the Figure 5.7.

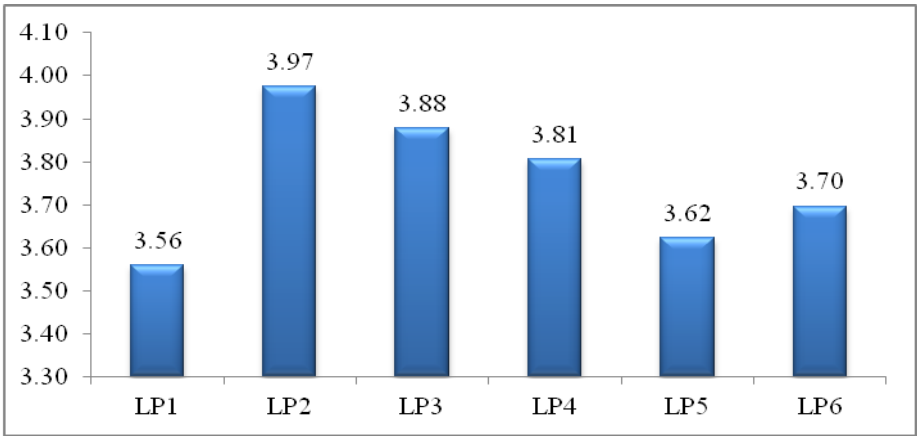


Figure 5.7: Practices (items) of Lean Practices (LP)

It is depicted from Table 5.9 and Figure 5.8 that in the all four sectors (automobile, electrical & electronics, machinery and process), the most preferred Lean Practice in automobile sector, electrical & electronics and machinery sector is Continuous improvement/Kaizen/Pokayoke/Mistake proofing (LP2). Whereas process industries have emphasized on implementation of Total productive maintenance (TPM) (LP4) with mean value (3.899) due to maintaining and improving the integrity of production and quality systems through the machines, equipment and processes.

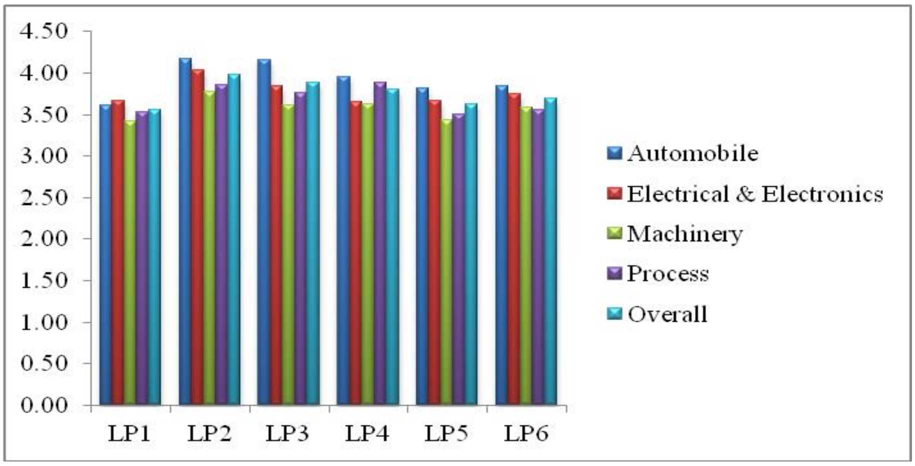


Figure 5.8: Mean Score of elements of Lean Practices (LP) in different sectors

From the Table 5.10 by one sample T test analysis, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in Lean Practices. The value of T statistics and its level of significance for LP1 (11.220; 0.000), LP2 (20.168; 0.000), LP3 (17.619, 0.000), LP4 (16.415; 0.000), LP5 (11.982; 0.000) and LP6 (13.545; 0.000). From the results it is confirmed that the Continuous improvement/Kaizen/Pokayoke/Mistake proofing (LP2) (T=20.168), 5S (LP3) (T=17.619) and Total productive maintenance (TPM) (LP4) (T=16.415) are the most significant practices of lean in Indian manufacturing companies.

Table 5.10: One-sample T test for Lean Practices (LP)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
LP1	11.220	344	.000	.559	.461	.657
LP2	20.168	344	.000	.974	.879	1.069
LP3	17.619	344	.000	.878	.780	.976
LP4	16.415	344	.000	.806	.709	.902
LP5	11.982	344	.000	.623	.521	.725
LP6	13.545	344	.000	.696	.595	.797

Table 5.11: ANOVA test for Lean Practices (LP)

Lean Practices	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
LP	Automobile	115	3.925	.734	.0685	4.028	.008
	Electrical & Electronics	65	3.767	.631	.0783		
	Machinery	75	3.575	.795	.0918		
	Process	90	3.683	.682	.0719		
	Total	345	3.756	.726	.0391		

Table 5.11 illustrates that F statistics and associated p value. The result shows that the value of F = 4.028 at p value 0.008. It is clearly observed that the p value= 0.008, which is less than the level of significance 0.05. It indicates that there is significant difference between the sectors (automobile, electrical & electronics, machinery and process) for Lean Practices. Therefore it is concluded that the implementation of Lean practices (LP) in all four sectors significantly not same there is a difference in implementation of lean practices. In the ANOVA test we found that there is a significant difference (P<0.05) in implementation of Lean practices (LP) in four Sectors, i.e., automobile, electrical & electronics, machinery and process sectors.

Table 5.12: Post hoc test for multiple comparison of sectors for Lean Practices (LP)

Factor	Sector (I)	Sector (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Lean Practices (LP)	Automobile	Electrical & Electronics	.15775	.11122	.489	-.1294	.4449
		Machinery	.34932	.10638	.006	.0747	.6240
		Process	.24174	.10087	.080	-.0187	.5022
	Electrical & Electronics	Automobile	-.15775	.11122	.489	-.4449	.1294
		Machinery	.19157	.12146	.393	-.1220	.5051
		Process	.08399	.11666	.889	-.2172	.3852
	Machinery	Automobile	-.34932	.10638	.006	-.6240	-.0747
		Electrical & Electronics	-.19157	.12146	.393	-.5051	.1220
		Process	-.10758	.11206	.772	-.3969	.1817
	Process	Automobile	-.24174	.10087	.080	-.5022	.0187
		Electrical & Electronics	-.08399	.11666	.889	-.3852	.2172
		Machinery	.10758	.11206	.772	-.1817	.3969

To find out the significance difference for implementation of lean practices, post hoc test (multiple comparison) for better understanding was conducted. From the Table 5.12 it is found that there is no significant difference in means in automobile, electrical & electronics and process sector for Lean Practice (LP) but the significant difference in means was found in automobile and machinery sectors. It is due to machinery and automobile industry sector are most aware of the implementation of lean practices.

5.3.4 Agile Practices and Customization

Based on the literature (Vinodh et al., 2012; Liao et al., 2013 and Medini et al., 2014) and statistical analysis, the five relevant practices of agile practice and customization (APC) were identified for Indian manufacturing companies which provide sustainable manufacturing. The details of these practices are given below. Respondents were asked to rate the level of level of implementation of these agile practices and customization in their companies on five point Likert type scale (1-Very Low to 5-Very High). Overall and sector wise mean and standard deviation scores are given in Table 5.13. It seems that Indian manufacturing companies are highly committed to Flexibility to change volume as per customer demand (APC5) (overall mean = 4.17) and quickly respond to customer (APC4) (overall mean = 4.12). Indian manufacturing companies are also committed to Product variety without increasing cost and sacrificing quality (APC6) as shown in the Figure 5.9.

Table 5.13: Descriptive statistics of agile practice and customization (APC)

Items	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
APC1	3.99	0.95	4.20	0.77	3.87	0.88	3.82	0.98	3.96	0.92
APC2	4.00	1.04	4.14	0.92	3.91	1.09	3.94	0.92	3.99	1.00
APC4	4.14	0.82	4.32	0.81	4.00	0.81	4.04	0.83	4.12	0.82
APC5	**4.15**	0.95	**4.45**	0.59	3.93	0.99	**4.19**	0.91	4.17	0.90
APC6	4.13	0.79	4.26	0.71	**4.01**	0.83	3.93	0.88	4.08	0.82
APC	**4.08**	**0.91**	**4.27**	**0.76**	**3.94**	**0.92**	**3.99**	**0.90**	**4.06**	**0.89**

On five Likert scale (where 1-very Low and 5-very high).

APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)
APC2	Use of Automation System (CNC, DNC & Robotics)
APC4	Quickly respond to customer
APC5	Flexibility to change volume as per customer demand
APC6	Product variety without increasing cost and sacrificing quality

It is depicted from Table 5.13 and Figures 5.10 that in the all four sectors (automobile, electrical & electronics, machinery and process), the most preferred agile practice and customization (APC) practice in automobile sector and electrical & electronics industries and process industries is Flexibility to change volume as per customer demand (APC5). Whereas machinery is emphasized on implementation of Product variety without increasing cost and sacrificing quality (APC6) with mean value (4.19) due to maintaining and improving the integrity of production and quality systems through the machines, equipment and processes.

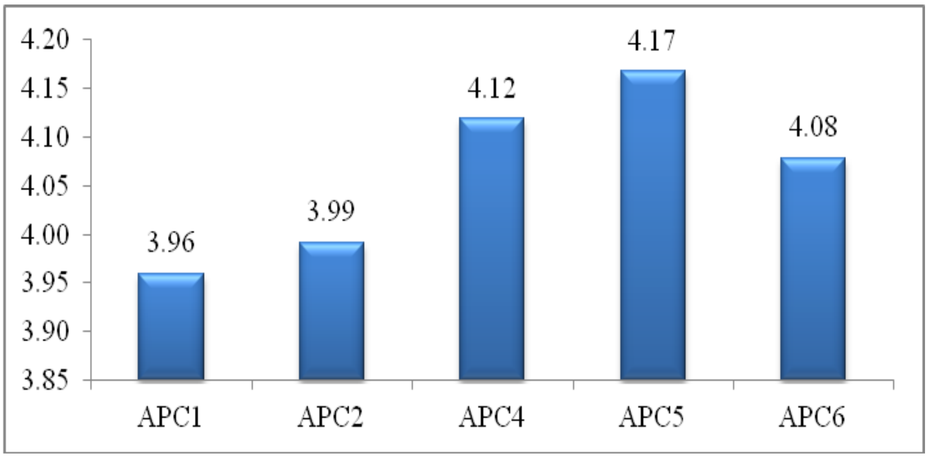


Figure 5.9: Practices (items) of Agile Practices and Customization

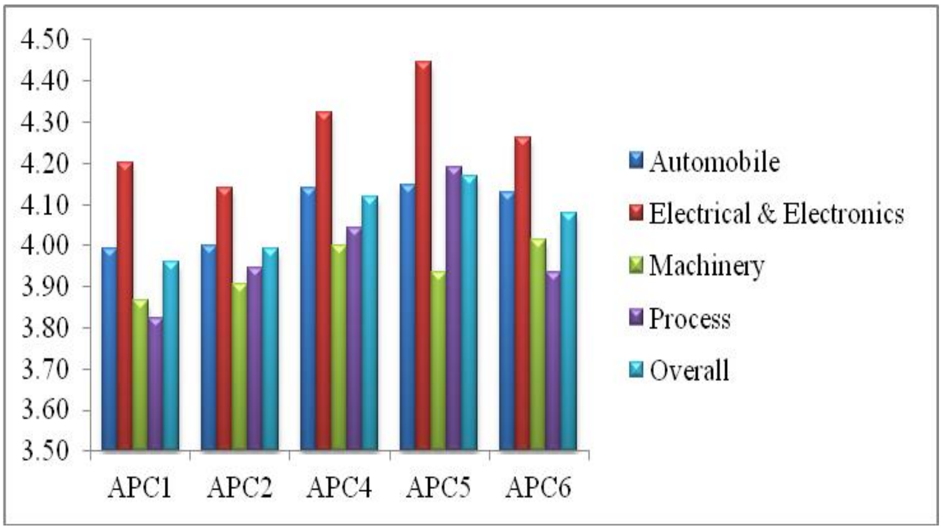


Figure 5.10: Mean Score of elements of Agile Practices and Customization in different sectors

From the Table 5.14 by one sample T test analysis, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in Lean Practices. The value of T statistics and its level of significance for APC1 (19.428; 0.000), APC2 (18.440; 0.000), APC4 (25.298, 0.000), APC5 (24.038; 0.000), and APC6 (24.553; 0.000).

Table 5.14: One-sample T test for Agile Practices and Customization

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
APC1	19.428	344	.000	.9594	.862	1.057
APC2	18.440	344	.000	.9913	.886	1.097
APC4	25.298	344	.000	1.119	1.032	1.206
APC5	24.038	344	.000	1.168	1.073	1.264
APC6	24.553	344	.000	1.078	.992	1.165

The results are confirmed that quickly respond to customer (APC4) (T=25.298) and Product variety without increasing cost and sacrificing quality (APC6) (T =24.53) are most significant practices of agile practice and customization (APC) for sustainable manufacturing. Table 5.15 illustrates that F statistics and associated p value. The result shows that the value of F = 3.499 at p value of 0.016. It is clearly observed that the p value= 0.016, which is less than the level of significance 0.05. It indicates that there is significant difference between the sectors (automobile, electrical & electronics, machinery and process) for agile practice and customization (APC) practice. Therefore, it is concluded that the implementation of agile practice and customization (APC) in all four sectors is significantly not the same and there is difference in implementation of agile practice and customization (APC) practice.

Table 5.15: ANOVA test for Agile Practices and Customization

Agile Practice and Customization	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
APC	Automobile	115	4.082	.693	.0646	3.499	.016
	Electrical & Electronics	65	4.274	.532	.0660		
	Machinery	75	3.944	.684	.0790		
	Process	90	3.987	.664	.0700		
	Total	345	4.063	.663	.0357		

In the ANOVA test, there is a significant difference (P<0.05) in implementation of agile practice and customization (APC) practice in four Sectors i.e. automobile, electrical & electronics, machinery and process sectors. To find out the significant difference for implementation of agile practice and customization (APC) practice, post hoc test (multiple comparison) was conducted for better understanding.

Table 5.16: Post hoc test for multiple comparison of sectors for Agile Practices and Customization (APC)

Factor	Sector (I)	Sector (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
APC	Automobile	Electrical & Electronics	-.19211	.10178	.235	-.4549	.0707
		Machinery	.13774	.09735	.491	-.1136	.3891
		Process	.09507	.09231	.732	-.1433	.3334
	Electrical & Electronics	Automobile	.19211	.10178	.235	-.0707	.4549
		Machinery	.32985	.11115	.017	.0429	.6168
		Process	.28718	.10677	.037	.0115	.5628
	Machinery	Automobile	-.13774	.09735	.491	-.3891	.1136
		Electrical & Electronics	-.32985	.11115	.017	-.6168	-.0429
		Process	-.04267	.10255	.976	-.3074	.2221
	Process	Automobile	-.09507	.09231	.732	-.3334	.1433
		Electrical & Electronics	-.28718	.10677	.037	-.5628	-.0115
		Machinery	.04267	.10255	.976	-.2221	.3074

From the Table 5.16, it is found that there is a significant difference in means of electrical & electronics and machinery sectors. Also it is found that there is a significant difference in process sector and electrical & electronics sectors.

5.3.5 Sustainable supply operations and distribution (SSOD)

Based on the literature (Narasimhan & Kim, 2002; Zhu et al., 2005; Zhu & Sarkis, 2007; Gimenez et al., 2012; Mitra & Datta, 2014 and Luthra et al., 2015) and statistical analysis, the six relevant practices of Sustainable supply operations and distribution (SSOD) were identified for Indian manufacturing companies, which provide sustainable manufacturing. The details of these practices are given below. Respondents were asked to rate the level of implementation of these agile practices and customization in their companies on five point Likert type scale (1-Totally disagree to 5-Totally agree).

Overall and sector wise mean and standard deviation scores are given in Table 5.17. It is observed that Indian manufacturing companies are highly committed to Sale of scrap material, used materials and excess capital equipment (SSOD6) (overall mean = 3.94), Cooperation with suppliers for environmental objectives (SSOD1) (overall mean = 3.80) and Cooperation with customers for green packaging (SSOD3) (overall mean = 3.78) as shown in Figure 5.11.

Table 5.17: Descriptive statistics of Sustainable supply operations and distribution (SSOD)

Items	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SSOD1	3.76	0.92	3.97	0.75	3.75	0.86	**3.77**	0.67	3.80	0.82
SSOD2	3.69	0.90	**3.97**	0.71	3.60	0.89	3.63	0.71	3.71	0.82
SSOD3	3.77	0.89	3.91	0.74	3.72	0.97	3.74	0.88	3.78	0.88
SSOD4	3.71	0.93	3.83	0.78	3.64	0.97	3.70	0.91	3.72	0.91
SSOD5	3.67	0.93	4.05	0.82	3.80	0.87	3.66	0.82	3.77	0.88
SSOD6	**3.99**	0.79	4.11	0.69	**3.93**	0.89	3.77	0.85	3.94	0.82
SSOD	**3.76**	**0.90**	**3.97**	**0.75**	**3.74**	**0.91**	**3.71**	**0.81**	**3.78**	**0.85**

SSOD1	Cooperation with suppliers for environmental objectives
SSOD2	Second-tier supplier environmentally friendly practice evaluation
SSOD3	Cooperation with customers for green packaging
SSOD4	Supplier's advances in developing environmentally friendly packages
SSOD5	Investment recovery (sale) of excess inventories/ materials
SSOD6	Sale of scrap material, used materials and excess capital equipment

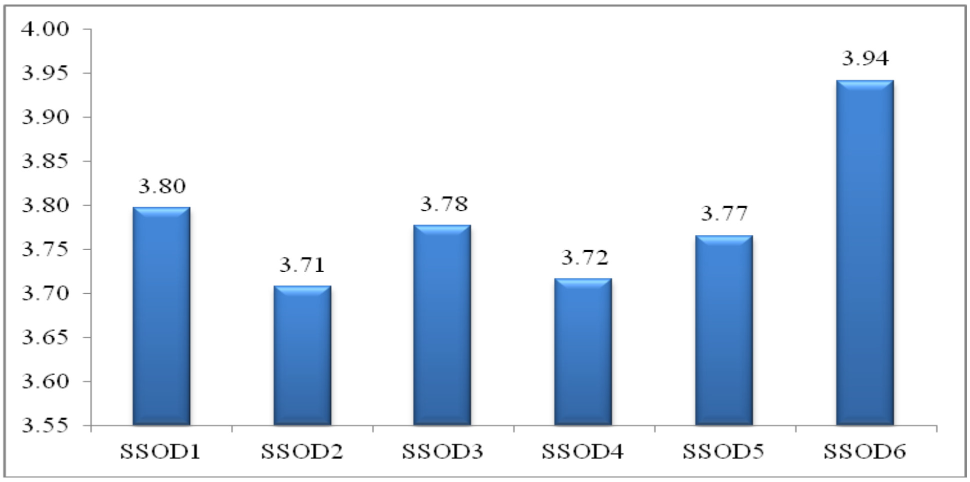


Figure 5.11: Practices (items) of Sustainable supply operations and distribution (SSOD)

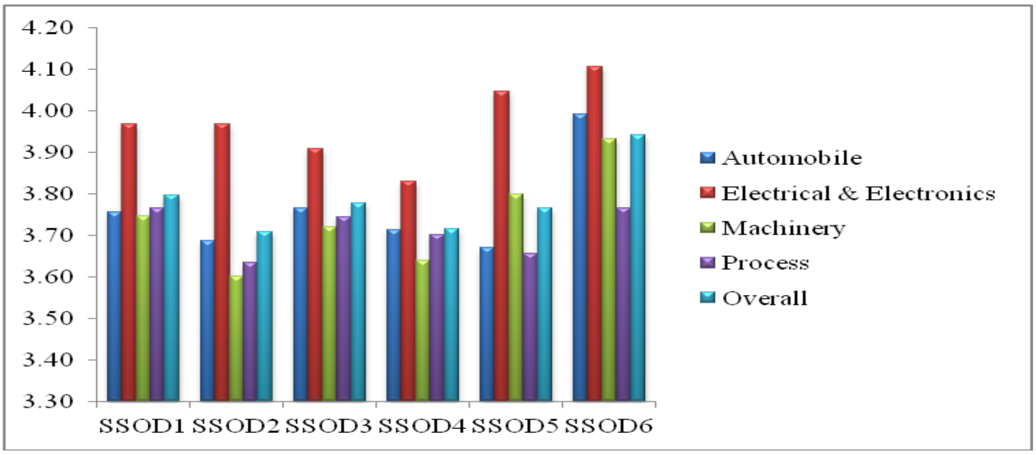


Figure 5.12: Mean Score of elements of Sustainable supply operations and distribution (SSOD) in different sectors

It is depicted from Table 5.17 and Figure 5.12 that in all four sectors (automobile, electrical & electronics, machinery and process), the most preferred Sustainable supply operations and distribution (SSOD) practice in automobile sector and machinery industries is Sale of scrap material, used materials and excess capital equipment (SSOD6), in Electrical & Electronics is Second-tier supplier environmentally friendly practice evaluation (SSOD2) and whereas in process industries Cooperation with suppliers for environmental objectives (SSOD1).

Table 5.18: One-sample T test for Sustainable supply operations and distribution (SSOD)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SSOD1	18.115	344	.000	.797	.711	.884
SSOD2	15.947	344	.000	.707	.620	.794
SSOD3	16.414	344	.000	.777	.684	.870
SSOD4	14.683	344	.000	.716	.620	.812
SSOD5	16.164	344	.000	.765	.672	.858
SSOD6	21.453	344	.000	.942	.856	1.028

By one sample T test analysis from the Table 5.18, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in supply operations and distribution (SSOD). The value of T statistics and its level of significance for SSOD1 (18.115; 0.000), SSOD 2 (15.947; 0.000), SSOD3 (16.414, 0.000), SSOD4 (14.683; 0.000), SSOD5 (16.164; 0.000) and SSOD6 (21.453; 0.000).

The results confirmed that the Cooperation with suppliers for environmental objectives (SSOD1) (T=18.115) and Sale of scrap material, used materials and excess capital equipment (SSOD6) (T =21.453) are the most significant practices of Sustainable supply operations and distribution (SSOD) for sustainable manufacturing in Indian context.

Table 5.19 illustrates F statistics and associated p value. The result shows that the value of F = 2.18 at p value 0.09. It is clearly observed that the p value= 0.09, which is greater than the level of significance 0.05. It indicates that there is no significant difference between the sectors (automobile, electrical & electronics, machinery and process) for Sustainable supply operations and distribution. Therefore, it is concluded that Sustainable supply operations and distribution (SSOD) in all four sectors significantly the same.

Table 5.19: ANOVA test for Sustainable supply operations and distribution (SSOD)

Sustainable supply operations and distribution	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
SSOD	Automobile	115	3.763	.744	.0694	2.18	.09
	Electrical & Electronics	65	3.972	.531	.0659		
	Machinery	75	3.740	.727	.0840		
	Process	90	3.711	.624	.0658		
	Total	345	3.784	.678	.0365		

5.3.6 Product recovery and return practices (PRRP)

Based on the literature (Gungor & Gupta, 1999; Fleischmann et al., 2000; Ferguson & Browne, 2001; Glavič & Lukman, 2007; Ilgin & Gupta, 2010 and Rashid et al., 2013) six relevant practices of Product recovery and return practices (PRRP) were identified for Indian manufacturing companies, which provide sustainable manufacturing. The details of these practices are given below. Respondents were asked to rate the level of agreement of these Product recovery and return practices in their companies, on five point Likert type scale (1-Totally disagree to 5-Totally agree).

Overall and sector wise mean and standard deviation score is given in Table 5.20. It is observed that the companies implemented remanufacturing of returned products as usable product (recondition and repair) (PRRP5) (overall mean = 3.79), reduced resource utilization (energy and water) (PRRP1) (overall mean = 3.77) and recycled returned product/material (PRRP2) (overall mean = 3.66) as shown in figure 5.13.

Table 5.20: Descriptive statistics of Product recovery and return practices (PRRP)

Type of Company	Automobile (N=115)		Electrical & Electronics (N=65)		Machinery (N= 75)		Process (N=90)		Overall (N=345)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
PRRP1	3.62	0.94	**3.89**	0.73	3.69	0.88	**3.93**	0.78	3.77	0.86
PRRP2	3.73	0.99	3.62	1.04	3.41	0.93	3.79	0.81	3.66	0.95
PRRP3	3.60	1.01	3.43	0.92	3.27	1.00	3.78	0.91	3.54	0.98
PRRP4	3.67	0.97	3.57	0.93	3.40	0.89	3.64	0.81	3.59	0.91
PRRP5	**3.88**	0.86	3.85	0.91	**3.75**	0.89	3.67	0.99	3.79	0.91
PRRP6	3.68	0.87	3.43	1.00	3.45	0.86	3.62	0.80	3.57	0.88
PRRP	**3.70**	**0.94**	**3.63**	**0.92**	**3.50**	**0.91**	**3.74**	**0.85**	**3.65**	**0.91**

PRRP1	Reduce resource utilisation (Energy and water)
PRRP2	Recycle of returned product/material
PRRP3	Reusability of returned product/material
PRRP4	Recover of returned product/material for further processing
PRRP5	Remanufacturing of returned products as usable product(Recondition and Repair)
PRRP6	Redesign post-use processes and products

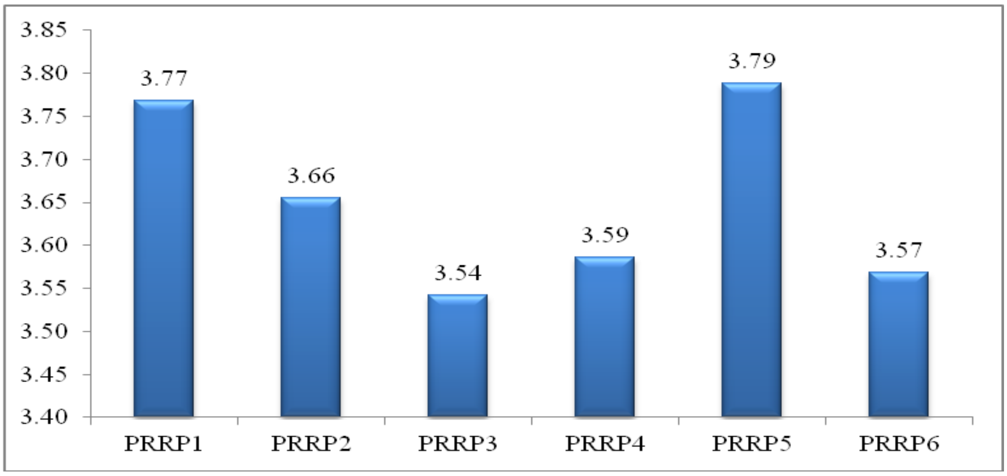


Figure 5.13: Practices (items) of Product recovery and return practices (PRRP)

It is depicted from the Table 5.20 and Figures 5.14 that in all the four sectors (automobile, electrical & electronics, machinery and process), the most preferred Product recovery and return practices (PRRP) practice in automobile and machinery sector is Remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5), in electrical & electronics and process sector is Reduce resource utilization (PRRP1).

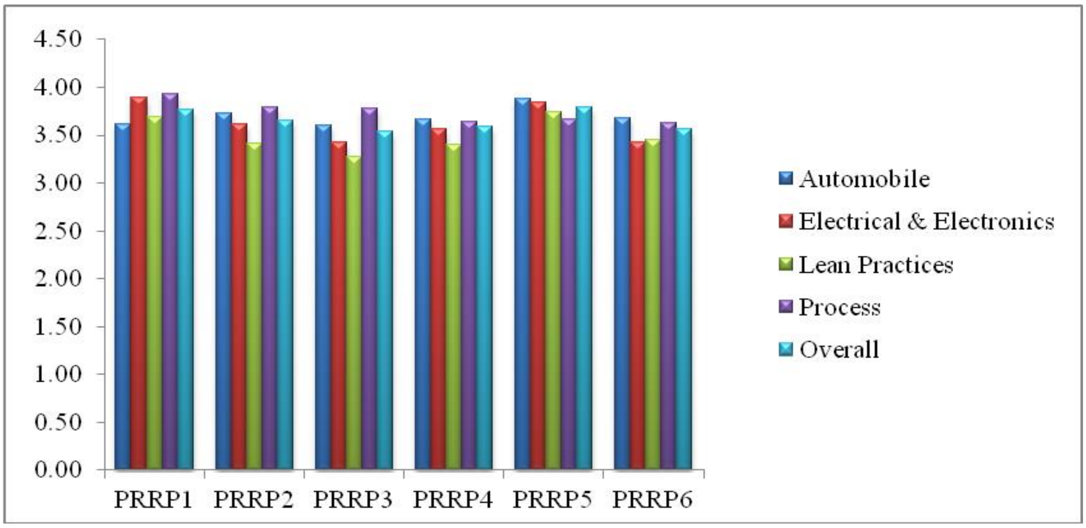


Figure 5.14: Mean Score of elements of Product recovery and return practices (PRRP) in different sectors

By one sample T test analysis from Table 5.21, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in Product recovery and return practices (PRRP). The value of T statistics and its level of significance for PRRP1 (16.621; 0.000), PRRP2 (12.818; 0.000), PRRP3 (10.285, 0.000), PRRP4 (11.975; 0.000), PRRP5 (16.073; 0.000) and PRRP6 (11.985; 0.000).

Table 5.21: One-sample T test for Product recovery and return practices (PRRP)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PRRP1	16.621	344	.000	.7681	.677	.859
PRRP2	12.818	344	.000	.6551	.555	.756
PRRP3	10.285	344	.000	.5420	.438	.646
PRRP4	11.975	344	.000	.5855	.489	.682
PRRP5	16.073	344	.000	.7884	.692	.885
PRRP6	11.985	344	.000	.5681	.475	.661

The result confirmed that the Reduce resource utilization (PRRP1) (Energy and water) (T =16.621) and Remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (T =16.073) are the most significant practices of Product recovery and return practices (PRRP) in Indian manufacturing companies.

Table 5.22: ANOVA test for Product recovery and return practices (PRRP)

Product recovery and Return Practices	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
PRRP	Automobile	115	3.6959	.75730	.07062	1.95	.12
	Electrical & Electronics	65	3.6308	.66962	.08306		
	Machinery	75	3.4960	.64316	.07427		
	Process	90	3.7389	.63374	.06680		
	Total	345	3.6514	.68875	.03708		

Table 5.22 illustrates that F statistics and associated p value. The result shows that the value of F = 1.95 at p value .12. It is clearly observed that the p value= .12, which is greater than the level of significance 0.05. It indicates that there is no significant difference between the sectors (automobile, electrical & electronics, machinery and process) for Product recovery and return practices (PRRP). Therefore, it is concluded that Product recovery and return practices (PRRP) in all four sectors is significantly same.

5.3.7 Sustainable performance measures (SPM)

Based on the literature (Sarkis, 1998; Visvanathan & Kumar, 1999; Zeng et al., 2010; Joung et al., 2012; Digalwar et al., 2013 and Li, 2014) ten relevant sustainable performance measures were identified for Indian manufacturing companies. The details of these measures are given below. Respondents were asked to rate the level of agreement of these Product recovery and return practices in their companies on five Likert type scale (1-Very Low to 5-Very High). Overall and sector wise mean and standard deviation score is given in the Table 5.23.

Table 5.23: Descriptive statistics of Sustainable performance measures (SPM)

Items	Automobile (N=115)		Electrical & Electronics (N=65)		Machinery (N= 75)		Process (N=90)		Overall (N=345)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SPM1	4.09	0.88	4.14	0.73	4.00	0.84	3.96	0.85	4.04	0.84
SPM2	4.17	0.78	4.18	0.81	3.95	0.87	3.87	0.88	4.04	0.84
SPM3	4.10	0.86	4.02	0.89	3.76	0.94	**4.01**	0.71	3.99	0.85
SPM4	4.08	0.83	4.05	0.82	3.84	0.82	3.68	0.85	3.92	0.84
SPM5	3.99	0.84	3.95	0.84	3.80	0.92	3.69	0.83	3.86	0.86
SPM6	4.01	0.86	4.06	0.81	3.91	0.89	3.84	0.82	3.95	0.85
SPM7	3.97	0.87	4.02	0.80	3.91	0.77	3.66	0.97	3.88	0.87
SPM8	4.02	0.86	4.14	0.86	3.95	0.93	3.78	0.95	3.96	0.90
SPM9	4.01	0.84	4.05	0.82	3.99	0.91	3.99	0.94	4.01	0.88
SPM10	**4.29**	0.71	**4.32**	0.59	**4.05**	0.84	**4.08**	0.64	4.19	0.71
SPM	**4.07**	**0.83**	**4.09**	**0.80**	**3.91**	**0.87**	**3.85**	**0.84**	**3.98**	**0.84**

SPM1	Reduction of air emission, water waste and solid wastes
SPM2	Decrease of consumption of hazardous/ harmful/ toxic0materials
SPM3	Decrease of frequency for environmental accidents
SPM4	Decrease in cost of materials purchasing
SPM5	Decrease in cost of waste treatment
SPM6	Decrease in cost of energy consumption
SPM7	Provide good remunerations and wages to employee for stability
SPM8	Provide quality health and safety management practices
SPM9	Provide Employee training and career development program
SPM10	Customer satisfaction

It is clear from Figure 5.15 that Indian manufacturing companies are committed to improve the Customer satisfaction (SPM10) (overall mean = 4.19), Reduction of air emission, water waste and solid wastes (SPM1) (overall mean = 4.04), Decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (overall mean = 4.04) and Decrease of frequency for environmental accidents (overall mean = 3.99).

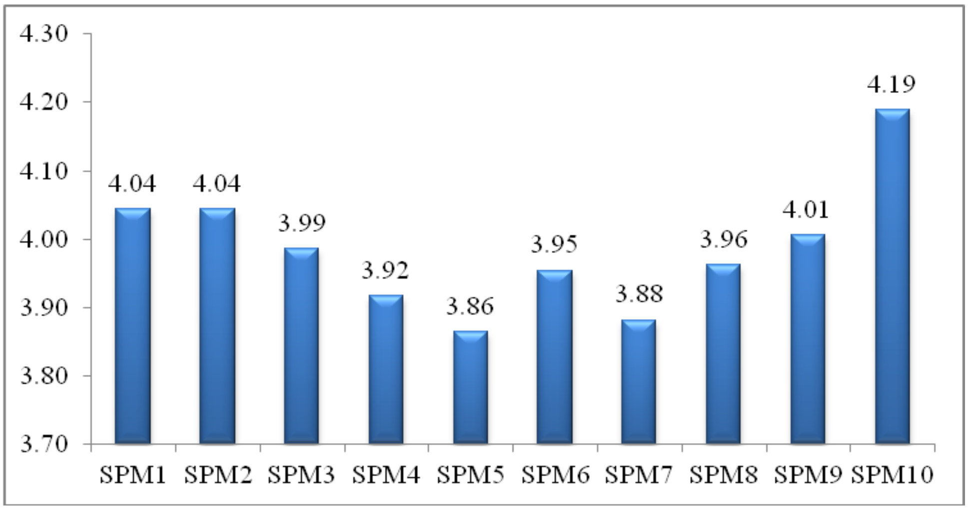


Figure 5.15: Elements of Sustainable performance measures (SPM)

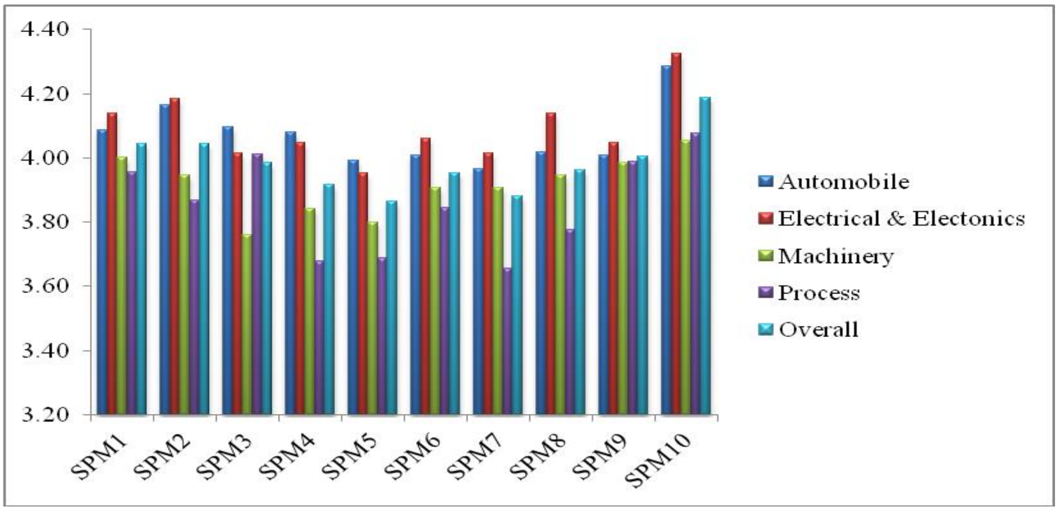


Figure 5.16: Mean Score of elements of Sustainable performance measures (SPM) in different sectors

It is depicted from Table 5.23 and Figure 5.16 that in all the four sectors (automobile, electrical & electronics, machinery and process), the most improved sustainable performance in automobile, electrical & electronics and process and machinery sector is customer satisfaction. Every company wants to satisfy their customers to remain in the market. The companies adopt sustainable manufacturing strategies to improve customer satisfaction (SPM10) with their product quality, after sale and service. On the other hand, the automobile and electrical & electronics companies are focused to decrease consumption of hazardous/harmful/toxic materials (SPM2), machinery industries are more focused to Provide Employee training and career development program (SPM9). The process industries are more focused on Decrease of frequency for environmental accidents (SPM3) due to process industries being traditional polluters and have experienced higher environmental regulatory pressure.

From the Table 5.24 by one sample T test analysis, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in Sustainable performance measures (SPM). The value of T statistics and its level of significance for SPM1 (23.187; 0.000), SPM2 (23.092; 0.000), SPM3 (21.433, 0.000), SPM4 (20.177; 0.000), SPM5 (18.649; 0.000), SPM6 (20.893; 0.000), SPM7 (18.749; 0.000), SPM8 (19.794; 0.000), SPM9 (21.326; 0.000) and SPM10 (31.149; 0.000). The results confirmed that the customer satisfaction (SPM10) (T=31.149), Reduction of air emission, water waste and solid wastes (SPM1) (T=23.187), Decrease of consumption of hazardous/ harmful/toxic materials (SPM2) (T=23.092), Decrease of frequency for environmental accidents (SPM3) (T = 21.433) and Provide Employee training and career development program (SPM9) (T = 21.326) are four performance measures that are the most significant measures in Indian manufacturing companies.

Table 5.24: One-sample T test for Sustainable performance measures (SPM)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SPM1	23.187	344	.000	1.0435	.955	1.132
SPM2	23.092	344	.000	1.0435	.955	1.132
SPM3	21.433	344	.000	.9855	.895	1.076
SPM4	20.177	344	.000	.9159	.827	1.005
SPM5	18.649	344	.000	.8638	.773	.955
SPM6	20.893	344	.000	.9536	.864	1.043
SPM7	18.749	344	.000	.8812	.789	.974
SPM8	19.794	344	.000	.9623	.867	1.058
SPM9	21.326	344	.000	1.0058	.913	1.099
SPM10	31.149	344	.000	1.1884	1.113	1.263

Table 5.25 illustrates that F statistics and associated p value. The result shows that the value of F = 3.040 at p value 0.029. It is clearly observed that the p value= 0.029 is less than the level of significance 0.05. It indicates that there is significant difference between the sectors (automobile, electrical & electronics, machinery and process) for Sustainable performance measures (SPM). Therefore, it is concluding that the Sustainable performance measures (SPM) in all four sectors significantly are not the same, and there is a difference in means of Sustainable performance measures (SPM).

Table 5.25: ANOVA test for Sustainable performance measures (SPM)

Sustainable Performance Measures	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
SPM	Automobile	115	4.070	.654	.0610	3.040	.029
	Electrical & Electronics	65	4.092	.551	.0684		
	Machinery	75	3.915	.661	.0763		
	Process	90	3.854	.581	.0613		
	Total	345	3.984	.624	.0336		

Table 5.26: Post hoc test for multiple comparison of sectors for Sustainable performance measures (SPM)

Factor	Sector (I)	Sector (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SPM	Automobile	Electrical & Electronics	-.02187	.09603	.996	-.2698	.2260
		Machinery	.15577	.09185	.327	-.0814	.3929
		Process	.21599	.08709	.045	-.0089	.4408
	Electrical & Electronics	Automobile	.02187	.09603	.996	-.2260	.2698
		Machinery	.17764	.10487	.328	-.0931	.4484
		Process	.23786	.10073	.087	-.0222	.4979
	Machinery	Automobile	-.15577	.09185	.327	-.3929	.0814
		Electrical & Electronics	-.17764	.10487	.328	-.4484	.0931
		Process	.06022	.09675	.925	-.1896	.3100
	Process	Automobile	-.21599	.08709	.045	-.4408	.0089
		Electrical & Electronics	-.23786	.10073	.087	-.4979	.0222
		Machinery	-.06022	.09675	.925	-.3100	.1896

In the ANOVA test, there is a significance difference (P<0.05) in implementation of Sustainable performance measures (SPM) in four Sectors i.e. automobile, electrical & electronics, machinery and process sectors. To find out the significant difference for implementation of Sustainable performance measures post hoc test (multiple comparison) was conducted for better understanding. From the Table 5.26, it is found that there is a significant difference in means of automobile and process sectors. It is due to process industries have continuous type of production system and process industries produce more GHG emissions.

5.3.8 Sustainable manufacturing competitiveness

Based on the literature (Jovane et al., 2008; Yang et al., 2010; Hofer et al., 2012 and Kushwaha & Sharma, 2015) seven relevant elements of Sustainable manufacturing competitiveness (SMC) were identified for Indian manufacturing companies. The details of these measures are given below. Respondents were asked to rate the level of achievement of these elements of Sustainable manufacturing competitiveness in their companies on five point type scale (1-Very Low to 5-Very High). Overall and sector wise mean and standard deviation score is given in the Table 5.27.

Table 5.27: Descriptive statistics of Sustainable manufacturing competitiveness (SMC)

Items	**Automobile (N=115)**		**Electrical & Electronics (N=65)**		**Machinery (N= 75)**		**Process (N=90)**		**Overall (N=345)**	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
SMC1	4.24	0.72	4.20	0.73	**4.05**	0.87	3.91	0.77	4.11	0.78
SMC2	**4.31**	0.65	4.18	0.70	4.01	0.88	**4.13**	0.80	4.18	0.76
SMC3	4.26	0.78	**4.32**	0.71	3.93	0.86	3.92	0.74	4.11	0.79
SMC4	4.09	0.80	4.23	0.63	3.99	0.69	3.81	0.85	4.02	0.77
SMC5	4.04	0.85	4.22	0.72	3.92	0.91	3.98	0.75	4.03	0.82
SMC6	4.14	0.71	4.29	0.63	4.00	0.70	4.01	0.71	4.10	0.70
SMC7	4.03	0.75	4.28	0.72	3.92	0.91	4.09	0.77	4.07	0.80
SMC	**4.16**	**0.75**	**4.25**	**0.69**	**3.98**	**0.83**	**3.98**	**0.77**	**4.09**	**0.77**

SMC1	Reduced product manufacturing cost
SMC2	Improvement in product and process quality
SMC3	On time delivery of customer products
SMC4	Innovation in product and process design
SMC5	Adoption of advanced technology
SMC6	Increase in profitability
SMC7	Improve Corporate Social Responsibility and organizational growth

It is depicted from Figure 5.17, that Indian manufacturing companies want to achieve Improvement in product and process quality (SMC2) (overall mean = 4.18), Reduced product manufacturing cost (SMC3) (overall mean = 4.11), on time delivery of customer products (SMC3) (overall mean = 4.11) and to increase profitability (SMC6) (overall mean = 4.10).

It is depicted in Table 5.27 and Figure 5.18 that in all the four sectors (automobile, electrical & electronics, machinery and process), achievement of manufacturing competitiveness in automobile sector by improving in product and process quality (SMC2), electrical & electronics sector by on time delivery of customer products (SMC3) and in process sector by improving in product and process quality (SMC2) and in machinery sector by reducing product manufacturing cost (SMC1).

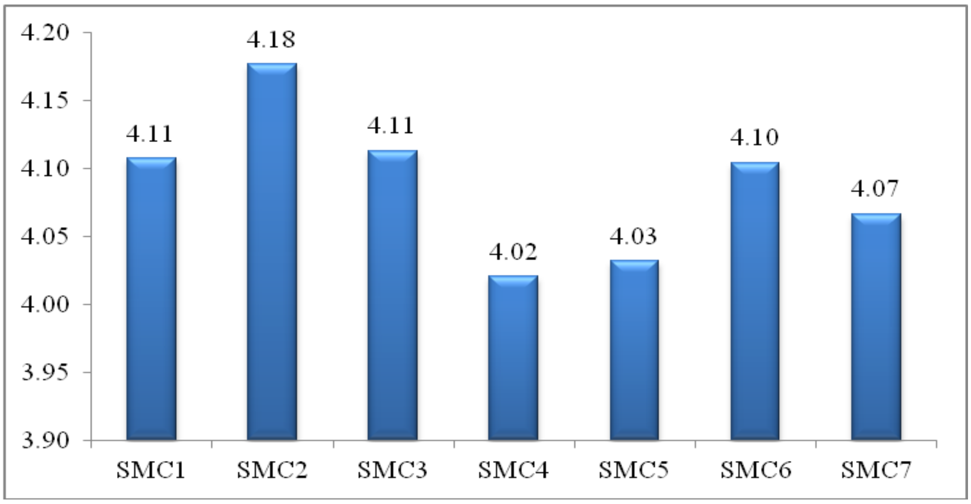


Figure 5.17: Elements of Sustainable manufacturing competitiveness (SMC)

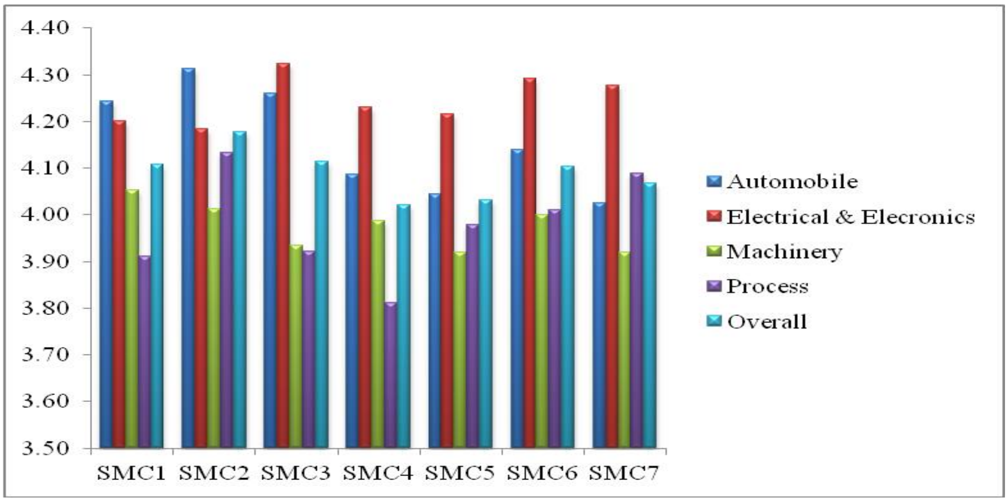


Figure 5.18: Mean Score of elements of Sustainable manufacturing competitiveness (SMC) in different sectors

From the Table 5.28 by one sample test analysis, it is observed that the p-value of the test is .000, which is less than the level of significance 0.05. It indicates that there is a significant difference in Sustainable manufacturing competitiveness (SMC).

Table 5.28: One-sample T test for Sustainable manufacturing competitiveness (SMC)

One-Sample Test						
	Test Value = 3					
	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
SMC1	26.383	344	.000	1.1072	1.025	1.190
SMC2	28.796	344	.000	1.1768	1.096	1.257
SMC3	26.054	344	.000	1.1130	1.029	1.197
SMC4	24.558	344	.000	1.0203	.939	1.102
SMC5	23.407	344	.000	1.0319	.945	1.119
SMC6	29.331	344	.000	1.1043	1.030	1.178
SMC7	24.918	344	.000	1.0667	.982	1.151

The value of T statistics and its level of significance for SMC1 (26.383; 0.000), SMC2 (28.796; 0.000), SMC3 (26.054, 0.000), SMC4 (24.558; 0.000), SMC5 (23.407; 0.000), SMC6 (29.331; 0.000) and SMC7 (24.918; 0.000). The result finds that the increase in profitability (SMC6) (t=29.331), improvement in product and process quality (SMC2) (T = 28.796) and on time delivery of customer products (SMC3) (T = 26.054) are four performance measures, which have been most achieved by Indian manufacturing companies.

Table 5.29 illustrates that F statistics and associated p value. The result shows that the value of F = 4.288 at p value .005. It is clearly observed that the p value= .005, which is less than the level of significance 0.05. It indicates that there is significant difference between the sectors (automobile, electrical & electronics, machinery and process) for Sustainable manufacturing competitiveness (SMC).

Table 5.29: ANOVA test for Sustainable manufacturing competitiveness (SMC)

Sustainable Manufacturing Competitiveness	Sector	N	Mean	Std. Deviation	Std. Error	ANOVA	
						F Value	P value
SMC	Automobile	115	4.1590	.57939	.05403	4.288	.005
	Electrical & Electronics	65	4.2458	.47207	.05855		
	Machinery	75	3.9755	.65515	.07565		
	Process	90	3.9793	.55417	.05842		
	Total	345	4.0886	.58029	.03124		

Therefore, it is concluded that the Sustainable manufacturing competitiveness in all four sectors is significantly not the same and there is a difference in means of Sustainable manufacturing competitiveness (SMC).

In the ANOVA test there is a significant difference (P<0.05) in implementation of Sustainable manufacturing competitiveness (SMC) in all four Sectors, i.e. automobile, electrical & electronics, machinery and process sectors. To find out the significance difference for implementation of Sustainable manufacturing competitiveness, post hoc test (multiple comparison) was conducted for better understanding.

From Table 5.30, it is found that there is a significant difference in means of electrical & electronics and process sectors. It is also found that there is a significant difference in means of machinery and electrical & electronics companies. It is due to high competition in the market.

Table 5.30: Post hoc test for multiple comparison of sectors for Sustainable manufacturing competitiveness (SMC)

Factor	Sector (I)	Sector (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SMC	Automobile	Electrical & Electronics	-.08689	.08878	.762	-.3161	.1423
		Machinery	.18349	.08492	.136	-.0357	.4027
		Process	.17962	.08052	.117	-.0283	.3875
	Electrical & Electronics	Automobile	.08689	.08878	.762	-.1423	.3161
		Machinery	.27038	.09696	.028	.0201	.5207
		Process	.26651	.09313	.023	.0261	.5070
	Machinery	Automobile	-.18349	.08492	.136	-.4027	.0357
		Electrical & Electronics	-.27038	.09696	.028	-.5207	-.0201
		Process	-.00387	.08945	1.000	-.2348	.2271
	Process	Automobile	-.17962	.08052	.117	-.3875	.0283
		Electrical & Electronics	-.26651	.09313	.023	-.5070	-.0261
		Machinery	.00387	.08945	1.000	-.2271	.2348

5.4 DISCUSSION

The analysis is performed to identify the sectorial behavior of Indian manufacturing industries towards the sustainable manufacturing. Levene's test of homogeneity of variance is conducted. From this test, it is observed that the significance value of all factors is *SHC, SPPD, LP, APC, SSOD, PRRP, SPM and SMC* is greater than 0.05 and hence, it can be concluded that variances are equal.

Stakeholders' commitment in all four sectors is significantly the same due to the environmental consciousness and government pressure. Sustainable product and process design (SPPD) practices in all four sectors are significantly same; reduction in consumption of material and energy, and utilization of efficient and clean technology to reduce carbon dioxide foot print. Machinery and automobile industry sector are most aware of the implementation of lean practices. They focus on Continuous improvement activities along with TPM. There is significant difference between the sectors (automobile, electrical & electronics, machinery and process) for the adoption of agile practice and customization (APC) practice of sustainability. Sustainable supply operations and distribution (SSOD) in all four sectors significantly the same. Cooperation with suppliers for environmental objectives and Sale of scrap material, used materials and excess capital equipment are the most significant practices of Sustainable supply operations and distribution (SSOD) for sustainable manufacturing in Indian context. Product recovery and return practices (PRRP) in all four sectors is significantly same. Reduce resource utilization and Remanufacturing of returned products as usable product are the most significant practices of Product recovery and return practices (PRRP) in Indian manufacturing companies. Sustainable performance measures (SPM) in all four sectors significantly are not the same, and there is a difference in means of Sustainable performance measures (SPM). Decrease of frequency for environmental accidents and Provide Employee training and career development program are the most significant measures in Indian manufacturing companies. There is a significant difference in means of electrical & electronics and process sectors. Product and process quality and on time delivery of customer products are two performance indicator, which have been most achieved by Indian manufacturing companies. Thus, it is conclude that Indian manufacturing companies can be achieve manufacturing sustainability by adopting/implementing the sustainable manufacturing practice.

5.5 SUMMARY

This chapter discussed about the sector wise comparative analysis of sustainable manufacturing practices, sustainable performance measures and sustainable manufacturing competitiveness. The study found significant SM practices, performance measures and manufacturing competitiveness in Indian manufacturing companies. The result suggests that the automobile and machinery industries are highly aware of the sustainable manufacturing practices.

Indian manufacturing industries have initiated certain practices of sustainable manufacturing including SPPD, LP, APC, SSOD and PRRP but from the results it is found that agile practices and customization (APC) practices are highly adapted by the Indian companies. After globalization, Indian manufacturing companies are more focused on advanced manufacturing practices and Indian manufacturing companies gradually established close relationship with customers and suppliers, to put greater pressure for adopting environmentally sound management practices. The stakeholders of the company place greater emphasis on Environmental compliances as per governmental policies.

Due to stakeholder's commitment and pressure for sustainable manufacturing, the manufacturing companies are beginning to accept their responsibilities for protecting the environment by developing more sustainable products, process and clean technologies by adopting various sustainable manufacturing practices. Market forces and environmental regulations have also played an important role in manufacturing sustainability to achieve competiveness.

The next chapter provides the in-depth study through case studies. Four cases one from each sector automobile, electrical & electronics, machinery and process will be discussed in the next chapter. A step wise methodology is proposed for the development of cases in Indian manufacturing companies.

CHAPTER 6. DEVELOPMENT OF CASES

6.1 INTRODUCTION

To get the in-depth knowledge of the finding of the survey discussed in previous chapters four and five, a case study approach was employed. In this chapter, four case studies were developed with the aim that they will combine to lead to a better understanding of the sustainable manufacturing adoption in Indian manufacturing companies and will help to answer the research questions in the present study.

Case study method is used in conjunction with survey research to develop explanations for some of the findings on a more comprehensive basis (Gubrium, 1988; Eisenhardt, 1989; Lewis, 2000; Dangayach & Deshmukh, 2001; Bartlett & Trifilova , 2010; Niinimäki & Hassi, 2011; Wang et al., 2015). Case study approach uses the both qualitative and quantitative methods with an aim to understand the underlying phenomenon completely. According to the Gubrium (1988) case study research is a scientific approach to correct the theoretical concepts with real time events. Yin (2003) identified that case study can be employed to explain a hypothesis.

Some researchers discuss a few limitation of case study research. Meredith (1968) explains that the need of direct observations of the actual contemporary condition leads to the difficulties of cost, time and access hurdles. Case study research is also subjected to requirement of multiple methods, tools and entities within a view to triangulate the data, lack of control and the contextual and temporal dynamic complicacies. Another problem with the case study research is the limited knowledge of procedures of case methods, thus increasing the construct error and limiting the validation and generalization.

However, Eisenhardt (1989) suggested that the case study research has a number of advantages.

- It enables researchers to develop grounded theories that are practical and relevant.
- Inferences on causal relationships can be made with more validity due to the longer-term observations available.
- It provides broad holistic pattern of phenomena in real world settings.

6.2 CASE STUDY METHODOLOGY

In this research, four case studies were developed. These include one case each from automobile, electrical and electronics, machinery and process sectors. These companies are mapped for various issues of sustainable manufacturing such as *stakeholder's commitment for sustainable manufacturing, sustainable product and process design, lean practices, agile practices and customization, sustainable supply operation and distribution, product recovery and return practices, sustainable performance measures sustainable manufacturing competitiveness.*

The step wise case development methodology proposed is shown in Figure 6.1. The step wise case development methodology is divided into three sections. The first section includes three steps (Define the objectives of the study, Selection of cases and Development of questionnaire), second section includes two steps (Data collection and Data analysis) and third section includes also includes two steps (Cross comparison of Cases and Reaching Closure).

In the first step of the methodology, the objectives of the case study are defined. The primary objective of the study is to gain in-depth understanding of sustainable manufacturing issues in the manufacturing companies. The secondary objective of the study is building a meaningful and relevant theory based on the assessment of real practice.

Second step of the methodology is selection of cases. While designing the case study research, the important issue is selection of number of cases. Although, a single case better explains a well-defined established theory, to investigate the application of a new theory in a new setup, multiple case studies are preferred. Multiple case studies also facilitate cross case comparison which is deemed to be highly important for the generalisation of theories (Voss et al., 2002).

Multiple case studies are also highly useful to establish the results of exploratory analysis and to achieve deeper insight of the results achieved from a survey analysis.

Third step includes framing of case questionnaire. A structured questionnaire was used to capture the measured issues of sustainable manufacturing in order to obtain a structured response. The questionnaire used is given in Appendix-I.

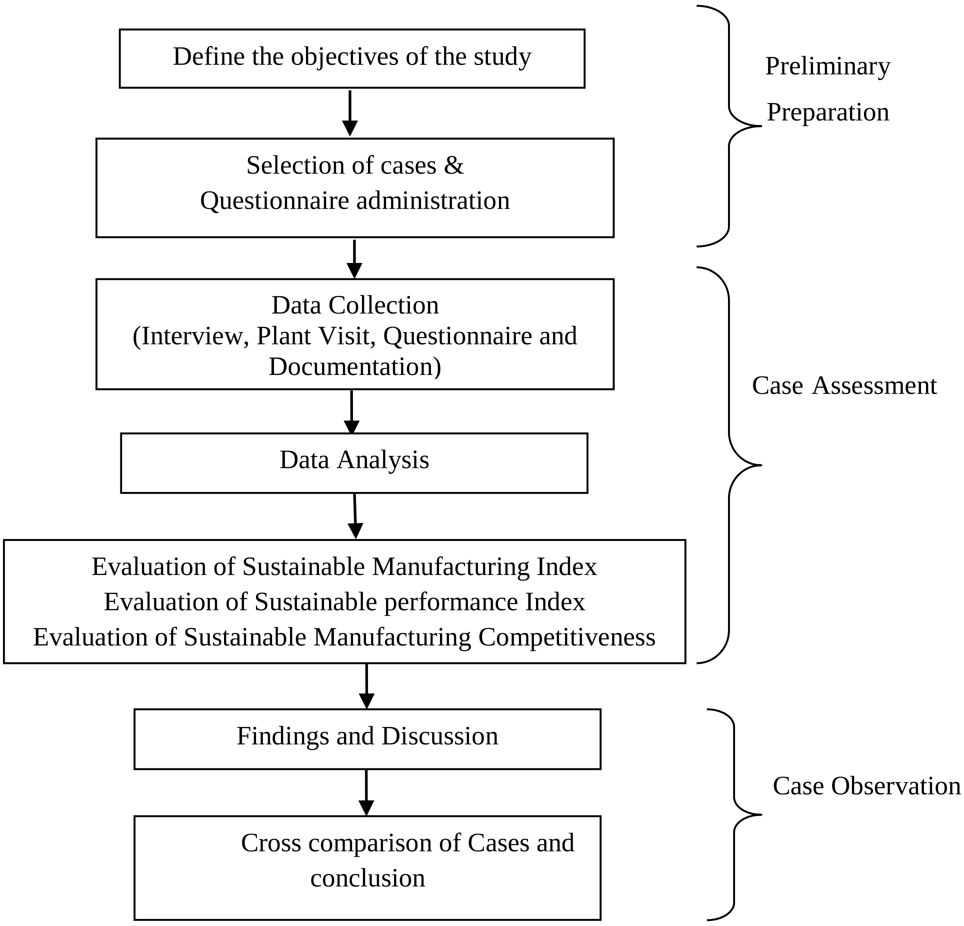


Figure 6.1: Case Development Methodology

The fourth step includes data collection process. For data collection, the author visited case companies three to, four times. Once for a general tour of operations and other visits to discuss the various issues of adoption of sustainable manufacturing in the company. In addition, several telephone communications were also made. The data collection process involved structured (survey questionnaire) and unstructured questioning followed by interviews with plant head, managers and assistant managers in each of the companies. In order to obtain a structured response, the questionnaire given in Appendix-I was used. Wherever possible or allowed, supporting documents such as plant layout, sales figures, sustainability related documents were gathered. The information collected through interviews, observations during plant visit and documents was compiled in proper format for the purpose of analysis.

Fifth step includes the data analysis. The procedure for data analysis for this study started with processing and analysing interview data, and data collected during the plant visit. Each case was analyzed comprehensively about its status of adoption of sustainable manufacturing and relevant issues.

Sustainable manufacturing index, Sustainable performance Index and Sustainable Manufacturing Competitiveness was evaluated in step six. In step seven the findings of the case studies were discussed and the observations were made. A cross comparison was conducted among the observed manufacturing companies in the step eight. The cross case comparison was carried out to assure the generalizability of the findings.

For the better understanding, the counterintuitive findings of the survey were explained with the help of case studies. The results of survey and case studies were also compared with the earlier global studies as well as studies carried out in the Indian context.

Present study involved the four multiple cases for confirmation of the results coming from the survey. The selection of case companies for the detailed cases studies were based on two criteria. First, the consent for detailed study and the second criteria was the geographical location. There is no thumb rule to decide number of cases. Therefore, keeping a balance between constraints of resource such as time and cost and the details achieved from each case, four cases one each from automobile, electrical and electronics, machinery and process sectors were selected for the study.

6.3 CASE 1: AUTOMOBILE SECTOR

A case of automobile sector company is developed. The company is labeled as ABC. The company ABC is a leading bearing manufacturing company.

6.3.1 Introduction

This company ABC is leading manufacturer of automotive components located in Greater Noida. Company with global focus, specializes in gears & transmission assemblies for recreational products, passenger cars and two wheelers. Over 90% of production is OE exports to leading automotive manufacturer of India and Japan. This has grown at an accelerated pace and marked its remarkable presence with a diverse product portfolio. Today, this Company has displayed impeccable credentials with a turnover of 80 million US$. The market share of this company is increased by 30% in last three years. There are 550 plus employees in the company.

6.3.2 Product Range

The Company ABC is manufacturing different types gears and transmission systems in its world-class plants with the most modern machinery. The company has formed joint venture from the leading companies of Japan, china and Germany to manufacture Brake Discs, Brake Drums, Cylinder block, Pressure plate and Brake plate for automotive original equipment manufacturers in the Indian and overseas market.

The company ABC secures European technology and expertise in chassis technology for small car segment in India. It is a full service supplier for car chassis technology to car makers in the high growth Indian market.

6.3.3 Vision and Mission

Deliver the best and the most cost-effective products & solutions empowered by superior technologies.

The company is committed to give best and achieve the highest standards in Performance, Quality, Systems, Care and Relationships.

6.3.4 Preliminary preparation

The company ABC is involved in the sustainability practices. The stakeholders of the company are participating in the sustainability initiatives and programmes. The main objective of this case study in automobile company is to gain the in-depth knowledge of sustainable manufacturing adoption in the company. This case company is selected on the basis of consent of detailed study about adoption of sustainable manufacturing. A structured questionnaire was developed on five point Likert scale to collect the desire information. According to Dangayach & Deshmukh, 2001, a structured questionnaire helps in data collection from the interviewees.

6.3.5 Case assessment

An assessment of sustainable manufacturing issues and practices discussed in this section. The stakeholders of the company like plant head and senior managers said that they adopted sustainable manufacturing practices to comply with regulations. The company implemented the environment policy and Sustainable/Green strategy.

6.3.5.1 Stakeholder's commitment

The assessment of stakeholder's commitment for sustainable manufacturing in the company is illustrated in table 6.1. The perceptions of manufacturing managers for the five items of stakeholder's commitment are collated on five point Likert scale.

Table 6.1 depicts that top most stakeholder's commitment for the companies are Environmental compliances as per governmental policies are strictly adhered (SCH1) (3.94), Motivation towards Sustainability (SCH3) (3.77), and Emphasis on improving eco efficiency (SHC4) (3.77). In the case of company ABC, the top three stakeholder's commitment is similar to the survey companies. Case company ABC validates the survey results. The overall mean for Survey Company and Case Company ABC for the stakeholder's commitment can be very clearly seen in the Radar chart in Figure 6.2.

Table 6.1: Assessment of Stakeholder's Commitment

Stakeholder's Commitment (SHC)		Survey (Overall Mean)	Company ABC (Overall Mean)
SHC1	Environmental compliances as per governmental policies are strictly adhered	3.94	4.20
SHC2	Cross-functional cooperation for sustainable manufacturing	3.76	3.20
SHC3	Motivation towards Sustainability	3.77	3.22
SHC4	Emphasis on improving eco efficiency	3.77	3.25
SHC5	Stakeholders Expertise	3.69	2.80

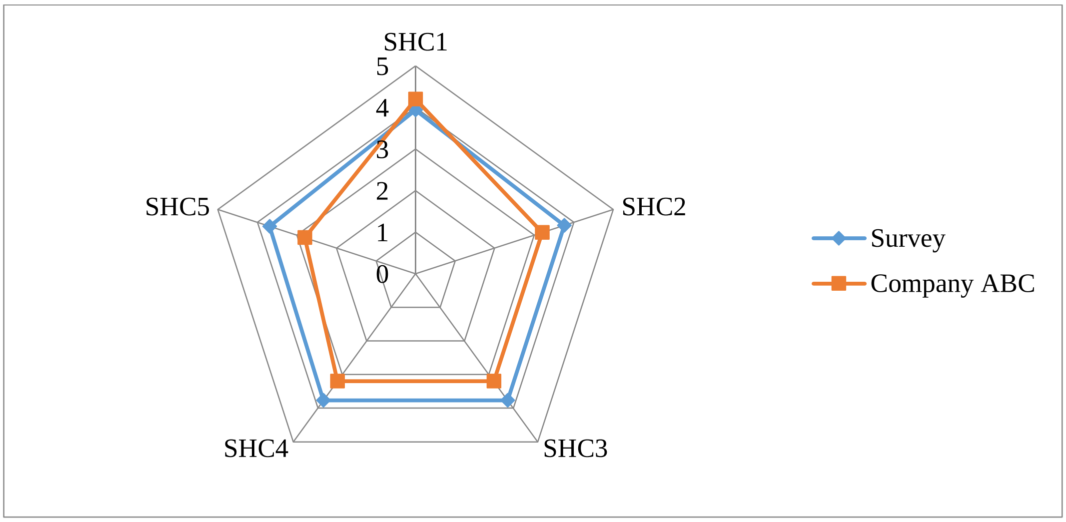


Figure 6.2: Assessment of Stakeholder's Commitment

6.3.5.2 Sustainable product and process design

The assessment of Sustainable product and process design (SPPD) in the company is illustrated in Table 6.2. The data was collected through the plant visit and interviewed of manufacturing managers for the eight items of Sustainable product and process design (SPPD) on five point Likert scale (1-Very Low to 5-Very High).

Table 6.2: Assessment of Sustainable product and process design

Sustainable product and process design (SPPD)		**Survey** (Overall Mean)	**Company ABC** (Overall Mean)
SPPD1	Design of products for reduced consumption of material and energy.	4.04	3.40
SPPD2	Design of products to reduce the use of hazardous of products and manufacturing process	3.97	3.40
SPPD3	Design for Packaging	3.96	2.80
SPPD4	Design for environment (DFE)	3.84	2.80
SPPD5	Minimizing waste during machining process	4.02	3.20
SPPD6	Energy efficiency during production process	3.98	3.40
SPPD7	Improve resources utilisation (materials, water, manpower) on shop floor	4.03	4.00
SPPD8	Use of efficient and clean technology to reduce carbon dioxide foot print	4.04	3.00

Table 6.2 depicts the top most Sustainable product and process design (SPPD) practices for the survey companies that are design of products for reduced consumption of material and energy (SPPD1) (4.04), use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (4.04) and improve resources utilisation (materials, water, manpower) on shop floor (SPPD7) (4.03).

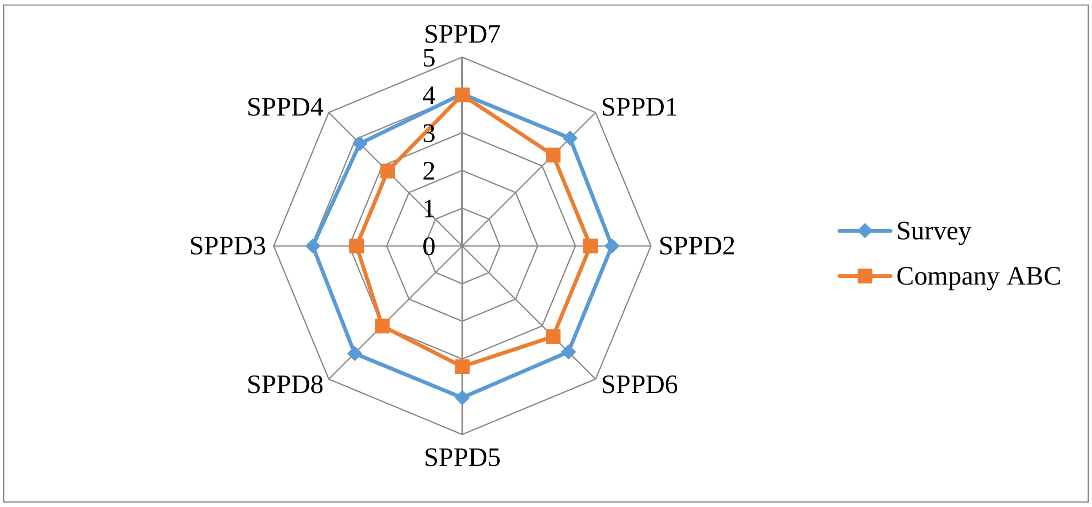


Figure 6.3: Assessment of Sustainable product and process design

In case of company ABC the top most Sustainable product and process designs practices adopted are improve resources utilisation (materials, water, manpower) on shop floor (SPPD7)

(4.00), design of products for reduced consumption of material and energy (SPPD1) (3.40) and design of products to reduce the use of hazardous of products and manufacturing process (SPPD2) (3.40). The case company results more or less are similar to survey results. The overall mean for Survey Company and Case Company ABC for Sustainable product and process design is very clearly seen in the Radar chart in Figure 6.3.

6.3.5.3 Lean Practices

The assessment of Lean Practices (LP) in the company is illustrated in Table 6.3. The data was collected through the plant visit and interviewed of manufacturing managers for the six items of Lean Practices on five point Likert scale (1-Very Low to 5-Very High). Table 6.3 depicts the top most Lean Practices for the survey companies are continuous improvement/Kaizen//Pokayoke/Mistake proofing (LP2) (3.97), 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (3.88) and Total productive maintenance (TPM) (LP4) (3.81).

In case of company ABC the top most Lean Practices adopted are Continuous improvement/Kaizen//Pokayoke/Mistake proofing (LP2) (4.60), 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (4.20) and Total productive maintenance (TPM) (LP4) (2.80). Case company ABC validates the survey results. The overall mean for Survey Company and Case Company ABC for Lean Practices (LP) can be very clearly seen in the Radar chart in Figure 6.4.

Table 6.3: Assessments of Lean Practices

Lean Practices (LP)		**Survey** (Overall Mean)	**Company ABC** (Overall Mean)
LP1	Value Stream Mapping (VSM)	3.56	2.80
LP2	Continuous improvement/Kaizen/Pokayoke /Mistake proofing	3.97	4.60
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)	3.88	4.20
LP4	Total productive maintenance (TPM)	3.81	2.80
LP5	Just-in-Time (JIT)	3.62	2.40
LP6	Kanban/Pull Production	3.7	2.60

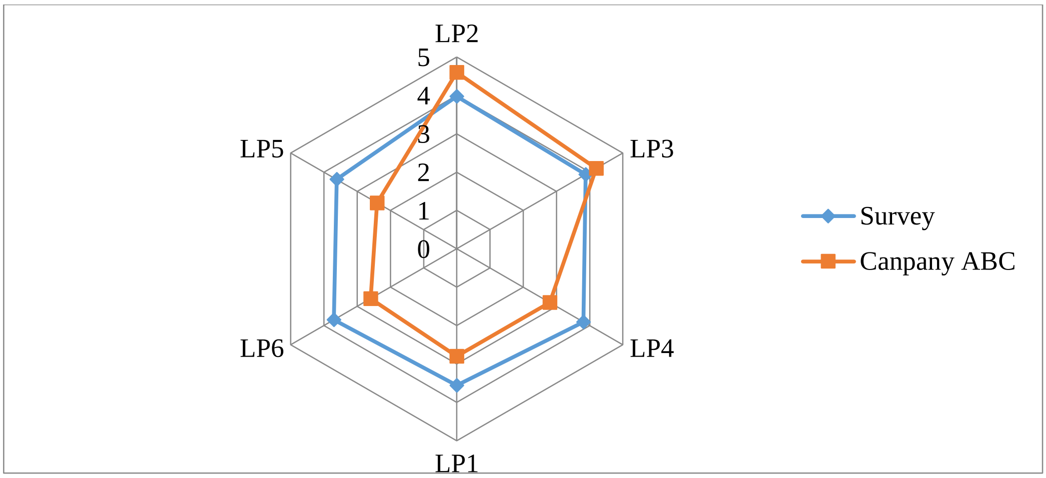


Figure 6.4: Assessments of Lean Practices

6.3.5.4 Agile practices and customization

The assessment of Agile practices and customization (APC) in the company is illustrated in table 6.4. The data was collected through the plant visit and interviews of manufacturing managers for the five items of agile practices and customization on five point Likert scale (1-Very Low to 5-Very High). Table 6.4 depicts the top most agile practices and customization for the survey companies are Flexibility to change volume as per customer demand (APC5) (4.17), quickly respond to customer (APC4) (4.12) and Product variety without increasing cost and sacrificing quality (APC6) (4.08).

In the case of company ABC, the top most agile practices and customization adopted are Flexibility to change volume as per customer demand (APC5) (4.60), quickly respond to customer (APC4) (4.20) and Use of Automation System (CNC, DNC & Robotics) (APC2) (3.60). The case company results are similar to survey results, thereby validating the results. The similarities in overall mean for Survey Company and Case Company ABC for Agile practices and customization (APC) can be very clearly seen in the Radar chart in Figure 6.5.

Table 6.4: Assessments of Agile practices and customization

Agile practices and customization (APC)		Survey (Overall Mean)	Company ABC (Overall Mean)
APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	3.96	2.60
APC2	Use of Automation System (CNC, DNC & Robotics)	3.99	3.60
APC4	Quickly respond to customer	4.12	4.20
APC5	Flexibility to change volume as per customer demand	4.17	4.60
APC6	Product variety without increasing cost and sacrificing quality	4.08	3.60

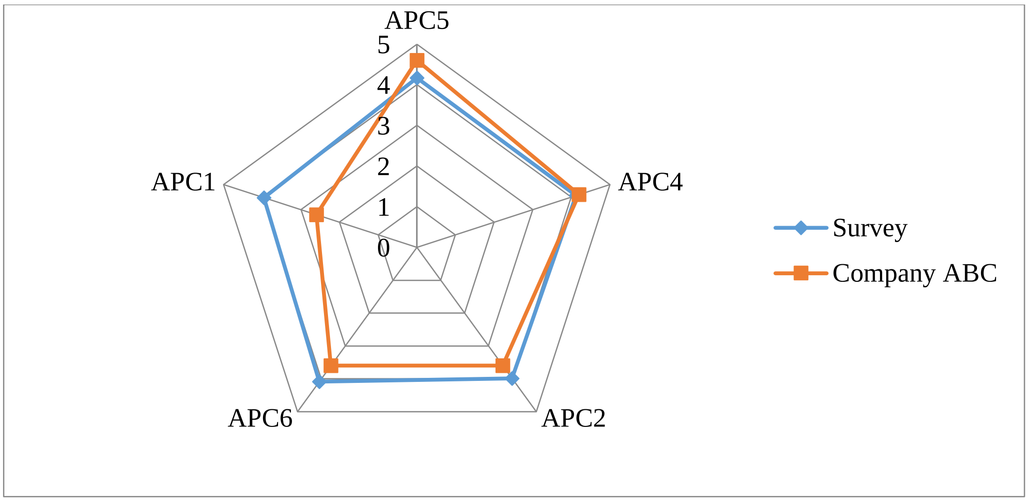


Figure 6.5: Assessments of Agile practices and customization

6.3.5.5 Sustainable supply operations and distribution

The assessment of Sustainable supply operations and distribution (SSOD) in the company is illustrated in Table 6.5. The data was collected through the plant visit and interviewed of manufacturing managers for the five items of Sustainable supply operations and distribution on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.5 depicts the top most Sustainable supply operations and distribution for the survey companies are Sale of scrap material, used materials and excess capital equipment (SSOD6) (3.94), Cooperation with suppliers for environmental objectives (SSOD1) (3.80) and Cooperation with customers for green packaging (SSOD3) (3.78). In case of company ABC the top most Sustainable supply operations and distribution are cooperation with customers for green packaging (SSOD3) (3.80), Sale of scrap material, used materials and excess capital equipment (SSOD6) (3.40) and Supplier's advances in developing environmentally friendly packages (SSOD4) (3.00).

Table 6.5: Assessments of supply operations and distribution

Sustainable supply operations and distribution (SSOD)		Survey (Overall Mean)	Company ABC (Overall Mean)
SSOD1	Cooperation with suppliers for environmental objectives	3.80	2.80
SSOD2	Second-tier supplier environmentally friendly practice evaluation	3.71	2.20
SSOD3	Cooperation with customers for green packaging	3.78	3.80
SSOD4	Supplier's advances in developing environmentally friendly packages	3.72	3.00
SSOD5	Investment recovery (sale) of excess inventories/ materials	3.77	3.00
SSOD6	Sale of scrap material, used materials and excess capital equipment	3.94	3.40

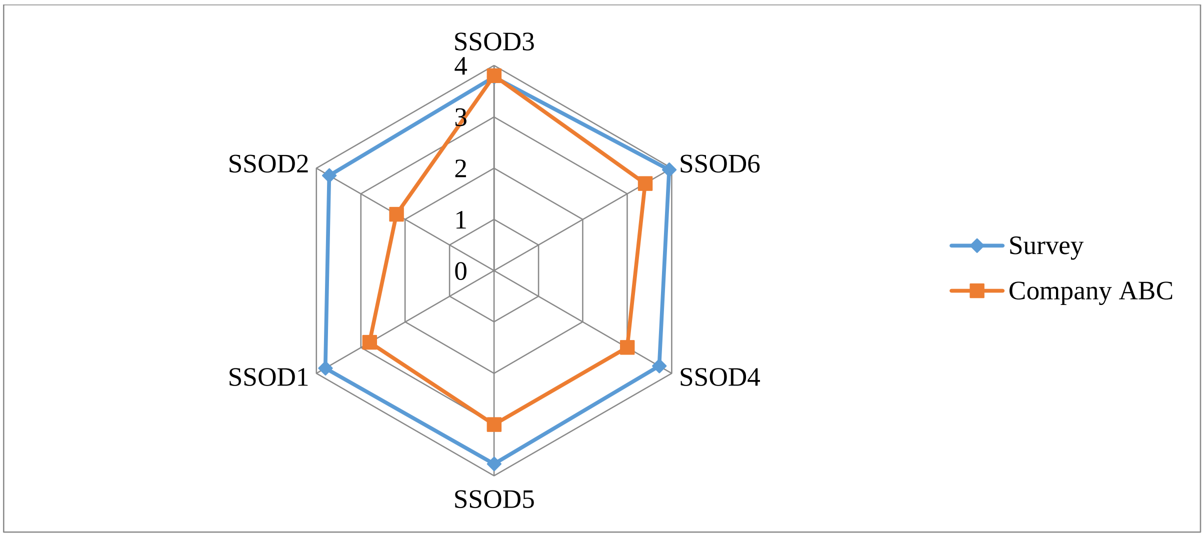


Figure 6.6: Assessments of supply operations and distribution

The case company results are similar to survey results, hence result are validated. The overall mean for Survey Company and Case Company ABC for Sustainable supply operations and distribution (SSOD) can be very clearly seen in the Radar chart in Figure 6.6.

6.3.5.6 Product recovery and return practices

The assessment of Product recovery and return practices (PRRP) in the company is illustrated in Table 6.6. The data was collected through the plant visit and interviews of manufacturing managers for the five items of Product recovery and return practices on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.6 depicts the top most Product recovery and return practices for the survey companies are Remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (3.79), Reduce resource utilisation (Energy and water) (PRRP1) (3.77) and Recycle of returned product/material (PRRP2) (3.66).

Table 6.6: Assessments of Product recovery and return practices

Product recovery and return practices (PRRP)		**Survey** (Overall Mean)	**Company ABC** (Overall Mean)
PRRP1	Reduce resource utilisation (Energy and water)	3.77	3.80
PRRP2	Recycle of returned product/material	3.66	3.00
PRRP3	Reusability of returned product/material	3.54	3.20
PRRP4	Recover of returned product/material for further processing	3.59	3.00
PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	3.79	3.20
PRRP6	Redesign post-use processes and products	3.57	2.40

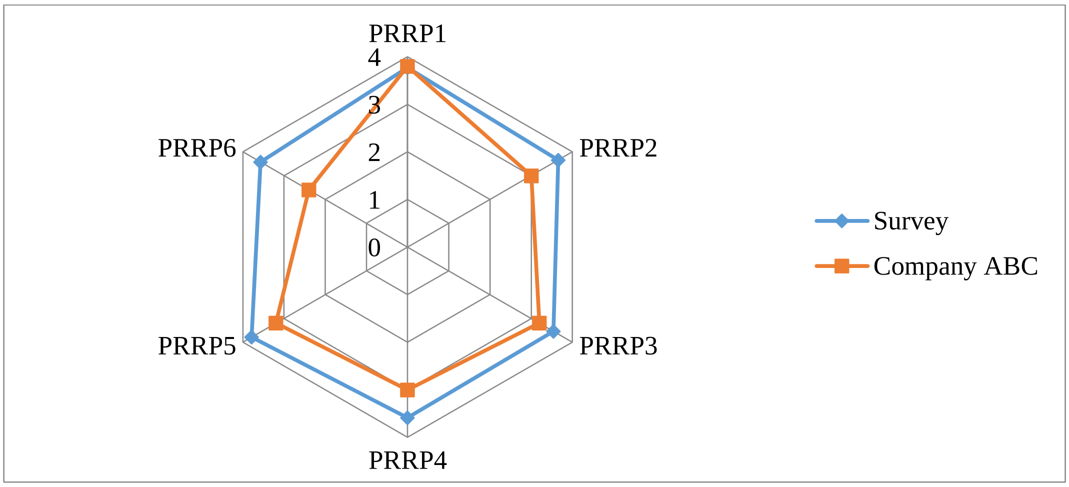


Figure 6.7: Assessments of Product recovery and return practices

In the case of company ABC, the top most Product recovery and return practices adopted are Reduce resource utilisation (Energy and water) (PRRP1) (3.80), Reusability of returned product/material (PRRP3) (3.20) and Remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5 (3.20). The case company results are similar to survey results, hence result are validated. The similarities in overall mean for Survey Company and Case Company ABC for Product recovery and return practices (PRRP) can be very clearly seen in the Radar chart in Figure 6.7.

6.3.5.7 Sustainable performance measures

The assessment of Sustainable performance measures (SPM) in the companies is illustrated in Table 6.7. The data was collected through the plant visit and interviews of manufacturing managers for the ten items of Sustainable performance measures on five point Likert scale (1-Very Low to 5-Very High). Table 6.7 depicts the top most Sustainable performance measures for the survey companies are Customer satisfaction (SPM10) (4.19), Reduction of air emission, water waste and solid wastes (SPM1) (4.04), Decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (4.04), Provide Employee training and career development program (SPM9) (4.01) and Decrease of frequency for environmental accidents (SPM3) (3.99).

Table 6.7: Assessments of Sustainable performance measures (SPM)

Sustainable performance measures (SPM)		**Survey** (Overall Mean)	**Company ABC** (Overall Mean)
SPM1	Reduction of air emission, water waste and solid wastes	4.04	3.40
SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	4.04	3.60
SPM3	Decrease of frequency for environmental accidents	3.99	3.20
SPM4	Decrease in cost of materials purchasing	3.92	4.00
SPM5	Decrease in cost of waste treatment	3.86	4.00
SPM6	Decrease in cost of energy consumption	3.95	3.80
SPM7	Provide good remunerations and wages to employee for stability	3.88	3.40
SPM8	Provide quality health and safety management practices	3.96	3.20
SPM9	Provide Employee training and career development program	4.01	3.60
SPM10	Customer satisfaction	4.19	3.60

In the case of company ABC the top most Sustainable performance measures (SPM) are Decrease in cost of materials purchasing (SPM4) (4.00), Decrease in cost of waste treatment (SPM5) (4.00), Decrease in cost of energy consumption (SPM6) (3.80), Decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (3.60) and Provide Employee training and career development program (SPM9) (3.60). The similarities overall mean for Survey Company and Case Company ABC for Product recovery and return practices (PRRP) can be very clearly seen in the Radar chart in Figure 6.8.

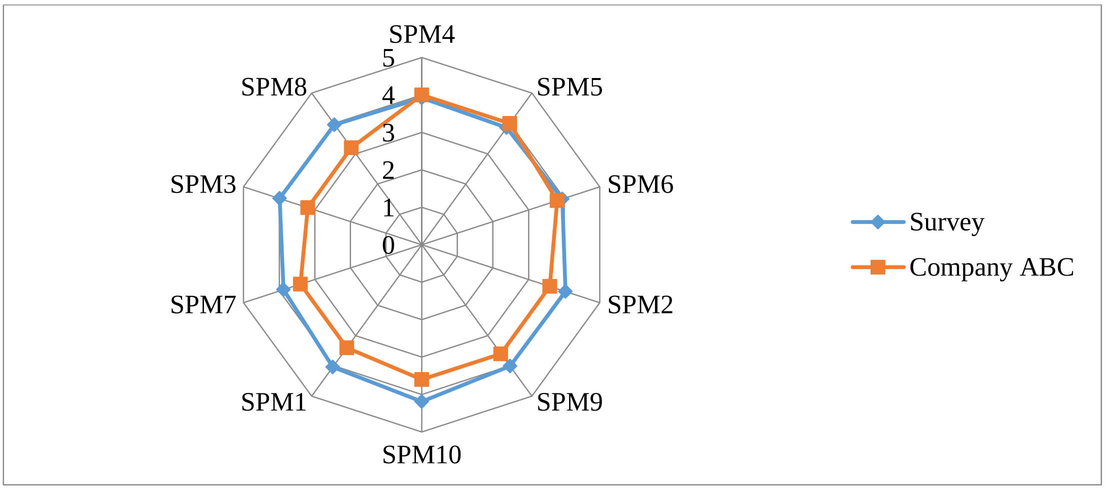


Figure 6.8: Assessments of Sustainable performance measures (SPM)

6.3.5.8 Sustainable manufacturing competitiveness

The assessment of sustainable manufacturing competitiveness (SMC) in the companies is illustrated in Table 6.8. The data was collected through the plant visit and interviews of manufacturing managers for the seven items of sustainable manufacturing competitiveness on five point Likert scale (1-Very Low to 5-Very High).

Table 6.8: Assessments of Sustainable performance measures (SPM)

Sustainable performance measures (SPM)		Survey (Overall Mean)	Company ABC (Overall Mean)
SMC1	Reduced product manufacturing cost	4.11	3.60
SMC2	Improvement in product and process quality	4.18	3.40
SMC3	On time delivery of customer products	4.11	3.60
SMC4	Innovation in product and process design	4.02	3.80
SMC5	Adoption of advanced technology	4.03	3.80
SMC6	Increase in profitability	4.1	3.60
SMC7	Improve Corporate Social Responsibility and organizational growth	4.07	3.40

Table 6.8 depicts the top most sustainable manufacturing competitiveness achieved by survey companies are Improvement in product and process quality (SMC2) (4.18), Reduced product manufacturing cost (SMC1) (4.11), on time delivery of customer products (SMC3) (4.11), Increase in profitability (SMC6) (4.10) and Improve Corporate Social Responsibility and organizational growth (SMC7) (4.07).

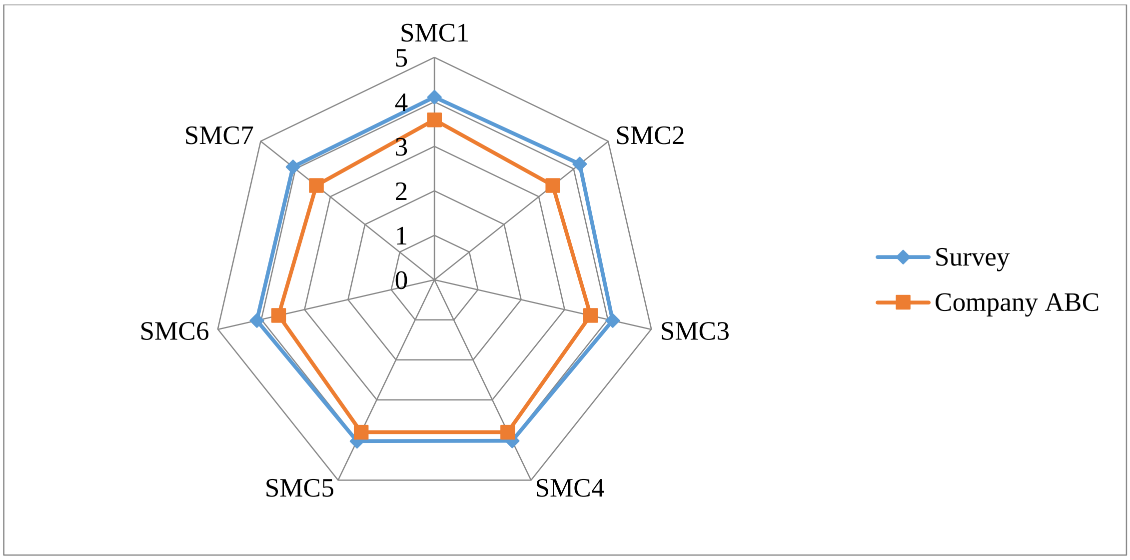


Figure 6.9: Assessments of Sustainable performance measures (SPM)

The company ABC focuses on top most sustainable manufacturing competitiveness, i.e. innovation in product and process design (SMC4) (3.80), adoption of advanced technology (SMC5) (3.8), Reduced product manufacturing cost (SMC7) (3.68), on time delivery of customer products (SMC3) (3.6) and Increase in profitability (SMC1) (3.6). The similarities in overall mean for Survey Company and Case Company ABC for Product recovery and return practices (PRRP) can be clearly seen in the Radar chart in Figure 6.9.

The company ABC Ltd. is a well-known company in automobile sector. The stakeholders of the company are conscious towards environmental and social sustainability. The company is emphasizing on improving eco efficiency, improve resources utilisation, Continuous improvement, Flexibility to change volume as per customer demand, cooperation with customers for green packaging, Reduce resource utilisation to achieve manufacturing competitiveness.

6.3.5.9 Sustainable manufacturing Index, sustainable performance Index and sustainable manufacturing competitiveness Index

Sustainable manufacturing Index (SMI)(I_{SM}), sustainable performance Index (SPI) (I_{SPM}) and sustainable manufacturing competitiveness Index (SMCI) (I_{SMC}) is computed using equation no. (6), (7) and (8) given in chapter 4. SMI, SPI and SMCI for the company ABC Ltd. are 3.26, 3.78 and 3.07 respectively.

6.3.6 Case observations

The company ABC is committed to high standards of business conduct. The company expects all its suppliers to adhere to similar good working standards and business ethics. Moreover, the company emphasis is on identify and manage the most material business conduct, social and environmental risks (also referred to as sustainability risks) associated with its procurement of goods and services, and to create a positive and constructive relationship between the company's its suppliers, and the societies in which they operate. This reinforces the company broader aim through its business activities to contribute to the wellbeing and sustainable economic development. The company has also taken a number of initiatives towards sustainable manufacturing, which include:

- Organize training sessions to enhance the understanding of Corporate Social Responsibility/Sustainability.
- Focus on conservation of energy consumption, restricted substances and chemical handling and reduce air emissions.
- Provide excellence in environment, occupational health and safety management by providing a safe and healthy work environment in entire plant.
- Develop, sustain and continually improve safe work practice and standards to safeguards environment, employees, contractors and community.
- Minimize the wastes and promote recycling of materials wherever possible.
- Periodically monitor and review environment, occupational health and safety management system and working condition.

6.4 CASE 2: ELECTRICAL AND ELECTRONICS SECTOR

A case study from electrical sector is developed. The company is labeled as EFG. The company is leading manufacturer of electrical equipment located in Greater Noida.

6.4.1 Introduction

The company EFG is the market leader in the busbar business with dominating market share in Indian market. The company is amongst the top players in the switchgear business segment. The net worth of the company is 150 million US$. The 17 world class manufacturing facilities spread over Noida, Haridwar, Pantnagar, Bhiwani, and Nantong, China and recently in Boom, Belgium. The company has 4000 employees, over 400 engineers, dedicated sales team of 250 people and millions of satisfied customers. Company invested in R&D around 2% of its total revenue. The export contributes to 30% of total turnover; the company is amongst the largest exporter of electric switchgear products from India.

6.4.2 Vision and Mission

Vision:

- To be the most trusted, respected and preferred brand
- To be closest to its customer
- To serve as role model
- To make “MADE IN INDIA” a respected label world over.

Mission

- To create a unique alchemy of outstanding products, operational excellence, path breaking customer service and compelling marketing.
- To continuously innovate, enhance our core technologies and develop new world class products.
- To be India’s largest exporter of industrial power distribution and control equipment.
- To everyday experience, the sheer joy of delighting our internal and external customers.

6.4.3 Product Range

The company EFG produces a comprehensive range of switchgear and control gear components. Company acquired sophisticated technology for these high technology products from top most company of this field from Japan Finland and France. The Company is a market Leader in the country for supply and erection of Busbar Trunking Systems Bus Duct and Busbar Riser. Company produces MV Switchgear products for Medium Voltage Switchgear in India, both for primary and secondary distribution segments.

6.4.4 Preliminary preparation

The objective of case study is to gain insight of sustainability practices adopted by the company EFG and also to investigate the results coming from survey. Company EFG is a leading manufacturer of electrical products. This case company is selected on the basis of consent of detailed study about adoption of sustainable manufacturing and also it is located in NCR region. A structured questionnaire was administered to collect case study data. Dangayach & Deshmukh, 2001, used the structured questionnaire for collection of case study data.

6.4.5 Case assessment

The assessment of adoption of sustainable manufacturing issues and practices is discussed in this section. The company adopted sustainable manufacturing practices to comply with regulations. The company implemented the ISO 14001 and green light environment initiatives and Sustainable/Green strategy. The company also participated in energy efficiency program.

6.4.5.1 Stakeholder's commitment (SHC)

The assessment of stakeholder's commitment (SHC) for sustainable manufacturing in the survey companies and case company is illustrated in Table 6.9. The perceptions of senior vice president, general manager and senior managers for the five items of stakeholder's commitment are collected on five point Likert scale. Table 6.9 depicts that top most stakeholder's commitment for the companies are Environmental compliances as per governmental policies are Environmental compliances as per governmental policies are strictly adhered (SHC1) (3.94), Motivation towards Sustainability (SHC3) (3.77) and Emphasis on improving eco-efficiency (SHC4) (3.77).

Table 6.9: Assessments of stakeholder's commitment (SHC)

Stakeholder's commitment (SHC)		**Survey (**Overall Mean)	**Company EFG (**Overall Mean)
SHC1	Environmental compliances as per governmental policies are strictly adhered	3.94	4.0
SHC2	Cross-functional cooperation for sustainable manufacturing	3.76	4.0
SHC3	Motivation towards Sustainability	3.77	4.0
SHC4	Emphasis on improving eco-efficiency	3.77	3.0
SHC5	Stakeholders Expertise	3.69	4.0

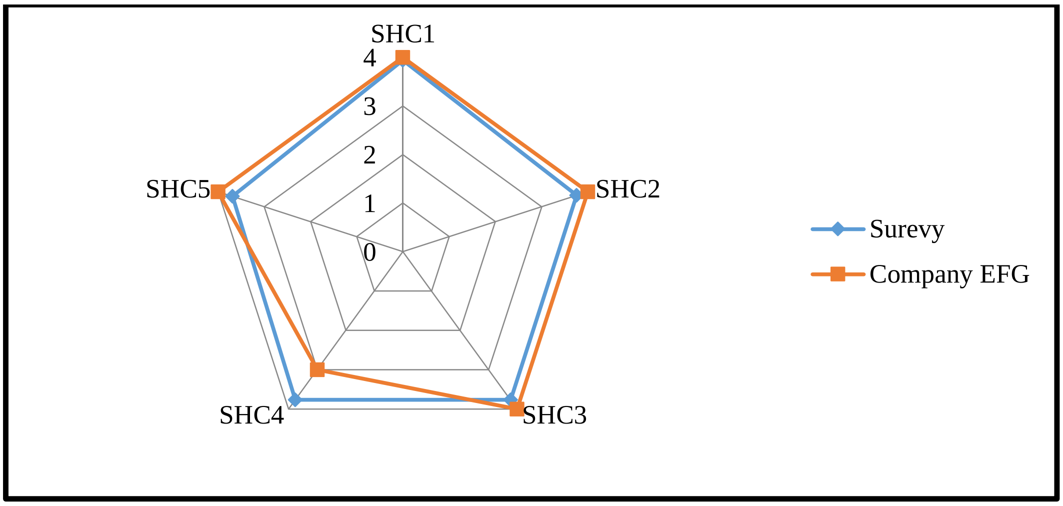


Figure 6.10: Assessments of stakeholder's commitment (SHC)

In the case of company EFG the top most stakeholder's commitment are Environmental compliances as per governmental policies are strictly adhered (SHC1) (4.0), Cross-functional cooperation for sustainable manufacturing (SHC2) (4.0) and Motivation towards Sustainability (SHC3) (4.0). SH1 is similar in survey companies and Case company EFG, that validate the survey results. The similarities in overall mean for Survey Company and Case Company EFG for the stakeholder's commitment can be very clearly seen in the Radar chart in Figure 6.10.

6.4.5.2 Sustainable product and process design (SPPD)

The assessment of Sustainable product and process design (SPPD) for sustainable manufacturing in the survey companies and case company illustrated in Table 6.10. The data was collected through the plant visit and interviews of senior vice president, general manager and senior managers for the eight items of Sustainable product and process design (SPPD) on five point Likert scale (1-Very Low to 5-Very High). Table 6.10 depicts the top most Sustainable product and process designs (SPPD) practices for the survey companies are design of products for reduced consumption of material and energy (SPPD1) (4.04), Use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (4.04) and Improve resources utilisation (materials, water, manpower) on shop floor (SPPD7) (4.03).

Table 6.10: Assessment of Sustainable product and process design

Sustainable product and process design (SPPD)		Survey (Overall Mean)	Company EFG (Overall Mean)
SPPD1	Design of products for reduced consumption of material and energy.	4.04	5.0
SPPD2	Design of products to reduce the use of hazardous of products and manufacturing process	3.97	4.0
SPPD3	Design for Packaging	3.96	4.0
SPPD4	Design for environment (DFE)	3.84	4.0
SPPD5	Minimizing waste during machining process	4.02	5.0
SPPD6	Energy efficiency during production process	3.98	5.0
SPPD7	Improve resources utilisation (materials, water, manpower) on shop floor	4.03	4.0
SPPD8	Use of efficient and clean technology to reduce carbon dioxide foot print	4.04	3.0

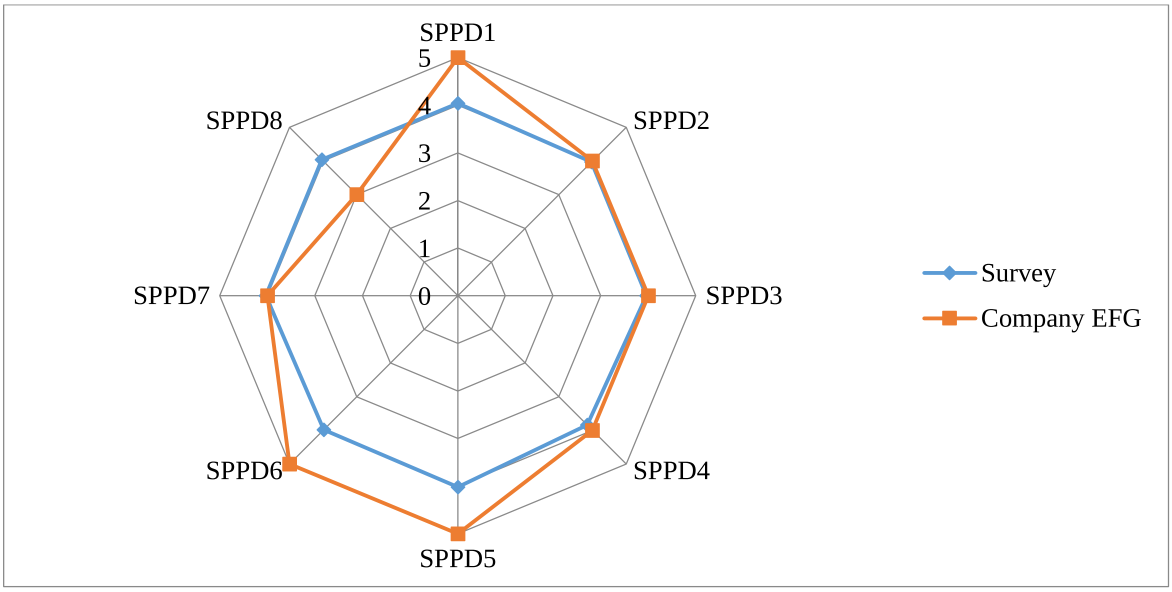


Figure 6.11: Assessment of Sustainable product and process design

In the case of company EFG the top most Sustainable product and process designs practices adopted are design of products for reduced consumption of material and energy (SPPD1) (5.0), minimizing waste during machining process (SPPD5) (5.0) and energy efficiency during production process (SPPD6) (5.0). The case company results more or less are similar to survey results. The similarities in overall mean for Survey Company and Case

Company EFG for Sustainable product and process design can be very clearly seen in the Radar chart in Figure 6.11.

6.4.5.3 Lean Practice (LP)

The assessment of Lean Practice (LP) for sustainable manufacturing in the survey companies and case company illustrated in Table 6.11. The data was collected through the plant visit and interviews of senior vice president, general manager and senior managers for the six items of Lean Practice (LP) on five point Likert scale (1-Very Low to 5-Very High). Table 6.11 depicts the top most Lean Practice (LP) practices for the survey companies are Continuous improvement/Kaizen/Pokayoke/Mistake proofing (LP2) (3.97), 5S (Sort, Shine, Set in order, Standardise, and Sustain (LP3) (3.88) and total productive maintenance (TPM) (LP4) (3.81).

Table 6.11: Assessment of Lean Practice (LP)

Lean Practice (LP)		**Survey** **(**Overall Mean)	**Company EFG** **(**Overall Mean)
LP1	Value Stream Mapping (VSM)	3.56	4.0
LP2	Continuous improvement/Kaizen/ Pokayoke/Mistake proofing	3.97	4.0
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)	3.88	3.0
LP4	Total productive maintenance (TPM)	3.81	3.0
LP5	Just-in-Time (JIT)	3.62	4.0
LP6	Kanban/Pull Production	3.7	3.0

In case of company EFG the top most Lean Practice practices adopted Continuous improvement/Kaizen/ Pokayoke/Mistake proofing (LP2) (4.0), Just-in-Time (JIT) (LP5) (4.0) and Value Stream Mapping (VSM) (LP1) (4.0).

The case company results are similar to survey results. The similarities in overall mean for Survey Company and Case Company EFG for Lean Practice can be very clearly seen in the Radar chart in Figure 6.12.

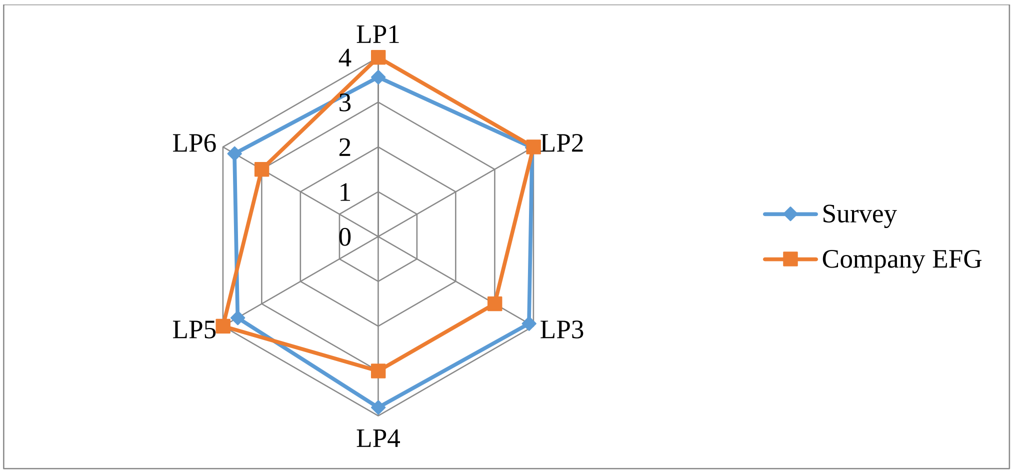


Figure 6.12: Assessment of Lean Practice (LP)

6.4.5.4 Agile Practices and Customization (APC)

The assessment of Agile Practices and Customization (APC) for sustainable manufacturing in the survey companies and case company is illustrated in Table 6.12. The data was collected through the plant visit and interviewed of senior vice president, general manager and senior managers for the six items of Agile Practices and Customization on five point Likert scale (1-Very Low to 5-Very High). Table 6.12 depicts the top most Agile Practices and Customization (APC) practices for the survey companies are flexibility to change volume as per customer demand (APC5) (4.17), Quickly respond to customer (APC4) (4.12) and Product variety without increasing cost and sacrificing quality (APC6) (4.08).

Table 6.12: Assessment of Agile Practices and Customization (APC)

Agile Practices and Customization (APC)		**Survey** (Overall Mean)	**Company EFG** (Overall Mean)
APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	3.96	5.0
APC2	Use of Automation System (CNC, DNC & Robotics)	3.99	3.0
APC4	Quickly respond to customer	4.12	4.0
APC5	Flexibility to change volume as per customer demand	4.17	3.0
APC6	Product variety without increasing cost and sacrificing quality	4.08	5.0

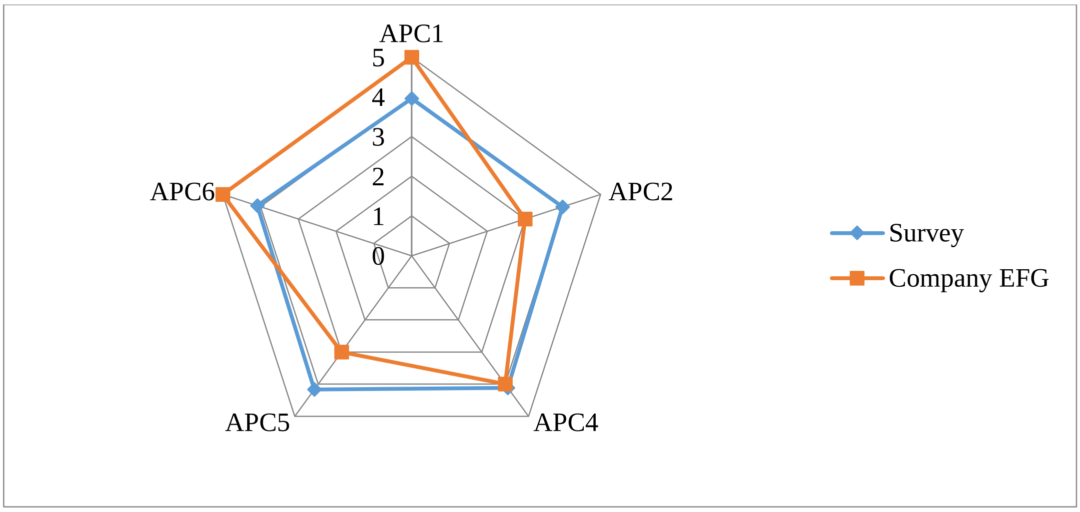


Figure 6.13: Assessments of Agile Practices and Customization (APC)

In the case of company EFG the top most Agile Practices and Customization adopted are use of flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM) (APC1) (5.0), Product variety without increasing cost and sacrificing quality (APC6) (5.0) and quickly respond to customer (APC4) (4.0). APC4 and APC6 practices are adopted by survey companies and case company EFG, that validate the results. The Similarities in overall mean for Survey Company and Case Company EFG for Agile Practices and Customization can be very clearly seen in the Radar chart in Figure 6.13.

6.4.5.5 Sustainable supply operations and distribution (SSOD)

The assessment of Sustainable supply operations and distribution (SSOD) for sustainable manufacturing in the survey companies and case company is illustrated in Table 6.13. The data was collected through the plant visit and interviewed of senior vice president, general manager and senior managers for the six items of sustainable supply operations and distribution on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.13 depicts the top most sustainable supply operations and distribution practices for the survey companies are sale of scrap material, used materials and excess capital equipment (SSOD6) (3.94), cooperation with suppliers for environmental objectives (SSOD1) (3.8) and cooperation with customers for green packaging (SSOD3) (3.78). In the case of company EFG the top most sustainable supply operations and distribution adopted are cooperation with suppliers for environmental objectives

(SSOD1) (4.0), investment recovery (sale) of excess inventories/ materials (SSOD5) (4.0) and sale of scrap material, used materials and excess capital equipment (SSOD6) (4.0). The similarities in overall mean for Survey Company and Case Company EFG for sustainable supply operations and distribution can be very clearly seen in the Radar chart in Figure 6.14.

Table 6.13: Assessments of Sustainable supply operations and distribution (SSOD)

Sustainable supply operations and distribution (SSOD)		**Survey** (Overall Mean)	**Company EFG** (Overall Mean)
SSOD1	Cooperation with suppliers for environmental objectives	3.8	4.0
SSOD2	Second-tier supplier environmentally friendly practice evaluation	3.71	3.0
SSOD3	Cooperation with customers for green packaging	3.78	3.5
SSOD4	Supplier's advances in developing environmentally friendly packages	3.72	3.0
SSOD5	Investment recovery (sale) of excess inventories/ materials	3.77	4.0
SSOD6	Sale of scrap material, used materials and excess capital equipment	3.94	4.0

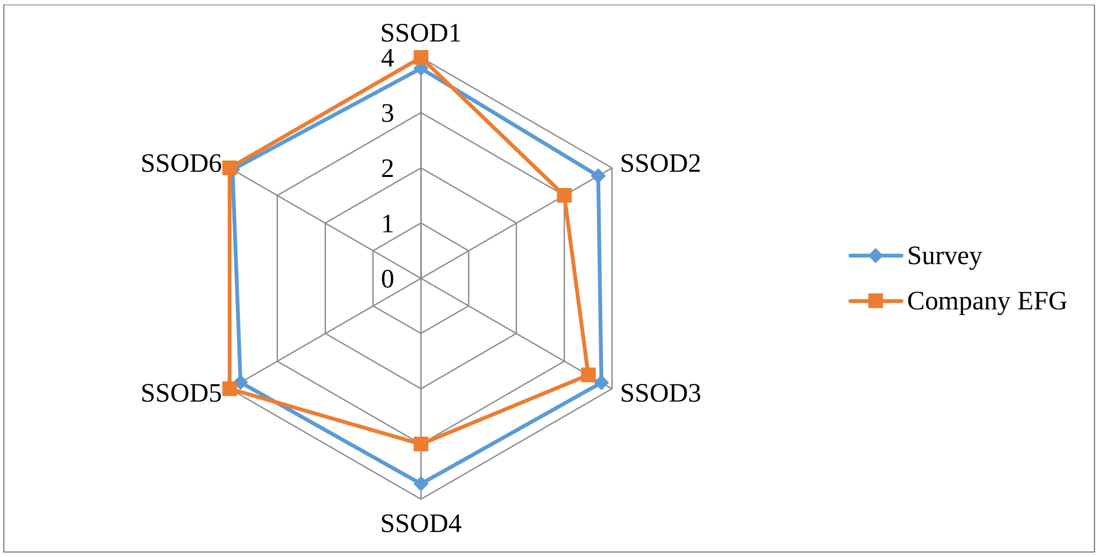


Figure 6.14: Assessments of Sustainable supply operations and distribution (SSOD)

6.4.5.6 Product recovery and return practices (PRRP)

The assessment of Product recovery and return practices (PRRP) for sustainable manufacturing in the survey companies and case company is illustrated in Table 6.14. The data was collected through the plant visit and interviewed of senior vice president, general manager and senior managers for the six items of product recovery and return practices on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.14 depicts the top most product recovery and return practices for the survey companies are remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (3.79), reduce resource utilisation (Energy and water) (PRRP1) (3.77) and recycle of returned product/material (PRRP2) (3.66)

Table 6.14: Assessments of Product recovery and return practices (PRRP)

Product recovery and return practices (PRRP)		**Survey** (Overall Mean)	**Company EFG (**Overall Mean)
PRRP1	Reduce resource utilisation (Energy and water)	3.77	4.0
PRRP2	Recycle of returned product/material	3.66	4.0
PRRP3	Reusability of returned product/material	3.54	4.0
PRRP4	Recover of returned product/material for further processing	3.59	4.0
PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	3.79	4.0
PRRP6	Redesign post-use processes and products	3.57	4.0

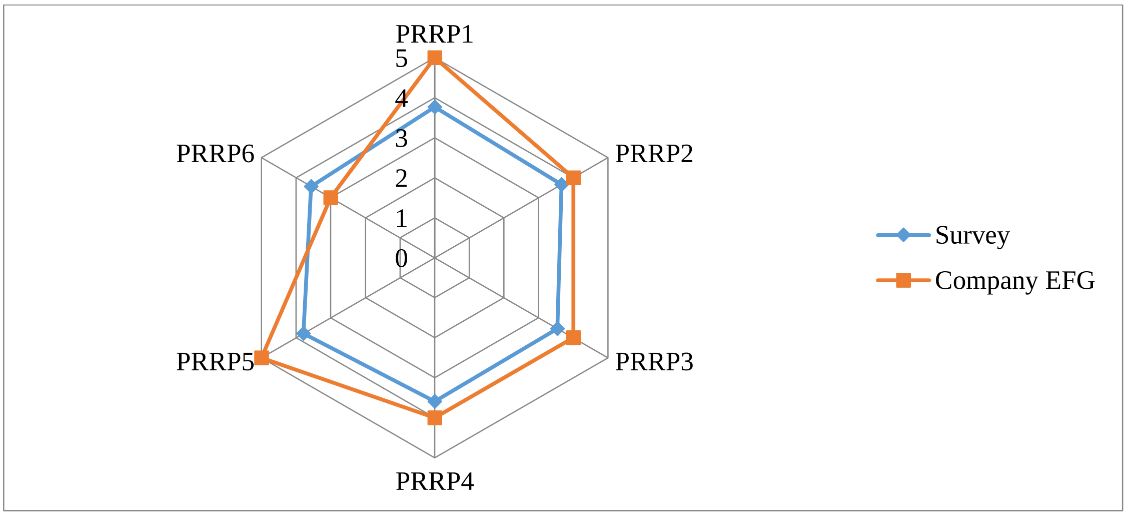


Figure 6.15: Assessments of Product recovery and return practices (PRRP)

In the case of company EFG the top most sustainable product recovery and return practices adopted are reduce resource utilisation (Energy and water) (PRRP1) (5.0), remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (5.0) and recycle of returned product/material (PRRP2) (4.0). The similarities in overall mean for Survey Company and Case Company EFG for sustainable product recovery and return practices can be very clearly seen in the Radar chart in Figure 6.15.

6.4.5.7 Sustainable performance measures (SPM)

The assessment of sustainable performance measures (SPM) in the companies of sustainable manufacturing in the survey companies and case company is illustrated in Table 6.15. The data was collected through the plant visit and interviews of senior vice president, general manager and senior managers for ten items of sustainable performance measures on five point Likert scale (1-Very Low to 5-Very High). Table 6.15 depicts the top most Sustainable performance measures for the survey companies are customer satisfaction (SPM10) (4.19), reduction of air emission, water waste and solid wastes (SPM1) (4.04), Decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (4.04), provide Employee training and career development program (SPM9) (4.01) and decrease of frequency for environmental accidents (SPM3) (3.99).

Table 6.15: Assessments of Sustainable performance measures (SPM)

Sustainable performance measures (SPM)		**Survey** (Overall Mean)	**Company EFG** (Overall Mean)
SPM1	Reduction of air emission, water waste and solid wastes	4.04	4.0
SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	4.04	5.0
SPM3	Decrease of frequency for environmental accidents	3.99	4.0
SPM4	Decrease in cost of materials purchasing	3.92	3.0
SPM5	Decrease in cost of waste treatment	3.86	4.0
SPM6	Decrease in cost of energy consumption	3.95	5.0
SPM7	Provide good remunerations and wages to employee for stability	3.88	4.0
SPM8	Provide quality health and safety management practices	3.96	4.0
SPM9	Provide Employee training and career development program	4.01	3.0
SPM10	Customer satisfaction	4.19	4.0

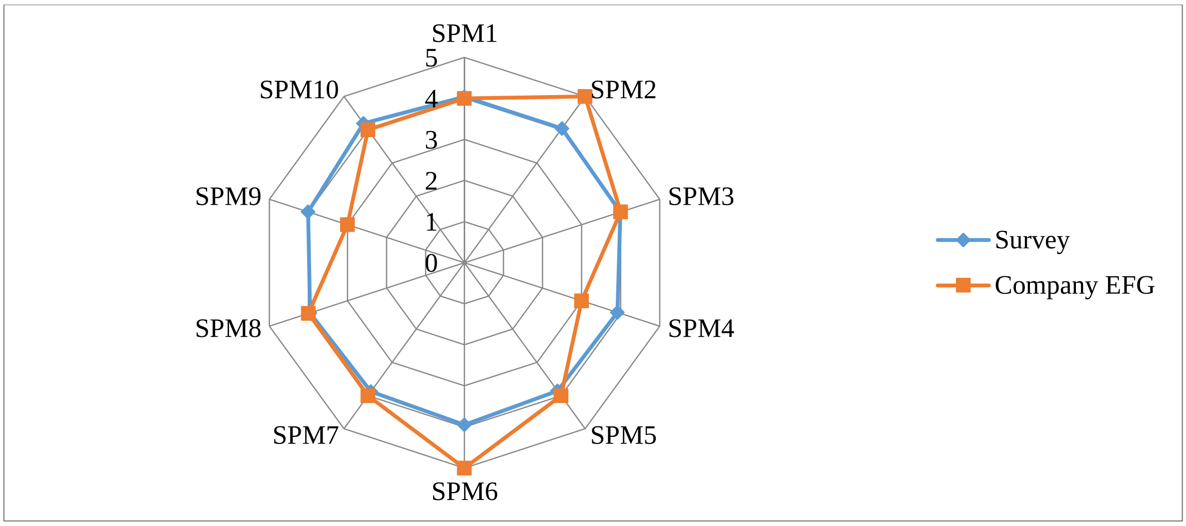


Figure 6.16: Assessments of Sustainable performance measures (SPM)

In the case of company EFG the top most Sustainable performance measures (SPM) are decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (5.0), decrease in cost of energy consumption (SPM6) (5.0), reduction of air emission, water waste and solid wastes (SPM1) (4.0), decrease of frequency for environmental accidents (SPM3) (4.0) and decrease in cost of waste treatment (SPM5) (4.0). The similarities overall mean for Survey Company and Case Company ABC for Product recovery and return practices (PRRP) can be very clearly seen in the Radar chart in Figure 6.16.

6.4.5.8 Sustainable manufacturing competitiveness

The assessment of sustainable manufacturing competitiveness (SMC) in the companies of sustainable manufacturing in the survey companies and case company is illustrated in Table 6.16. The data was collected through the plant visit and interviewed of senior vice president, general manager and senior managers for the seven items of sustainable manufacturing competitiveness on five point Likert scale (1-Very Low to 5-Very High). Table 6.16 depicts the top most sustainable manufacturing competitiveness achieved by survey companies are improvement in product and process quality (SMC2) (4.18), reduced product manufacturing cost (SMC1) (4.11), on time delivery of customer products (SMC3) (4.11) Increase in profitability (SMC6) (4.10) and improve Corporate Social Responsibility and organizational growth (SMC7) (4.07).

Table 6.16: Assessments of Sustainable performance measures (SPM)

Sustainable manufacturing competitiveness (SMC)		Survey (Overall Mean)	Company ABC (Overall Mean)
SMC1	Reduced product manufacturing cost	4.11	4.0
SMC2	Improvement in product and process quality	4.18	4.0
SMC3	On time delivery of customer products	4.11	4.0
SMC4	Innovation in product and process design	4.02	3.5
SMC5	Adoption of advanced technology	4.03	3.5
SMC6	Increase in profitability	4.1	4.0
SMC7	Improve Corporate Social Responsibility and organizational growth	4.07	3.0

The company EFG focuses on top most sustainable manufacturing competitiveness i.e. improvement in product and process quality (SMC2) (4.0), reduced product manufacturing cost (SMC1) (4.0), on time delivery of customer products (SMC3) (4.0), Increase in profitability (SMC6) (4.0) and adoption of advanced technology (SMC5) (3.5). The similarities in overall mean for Survey Company and Case Company EFG for Product recovery and return practices (PRRP) can be very clearly seen in the Radar chart in Figure 6.17.

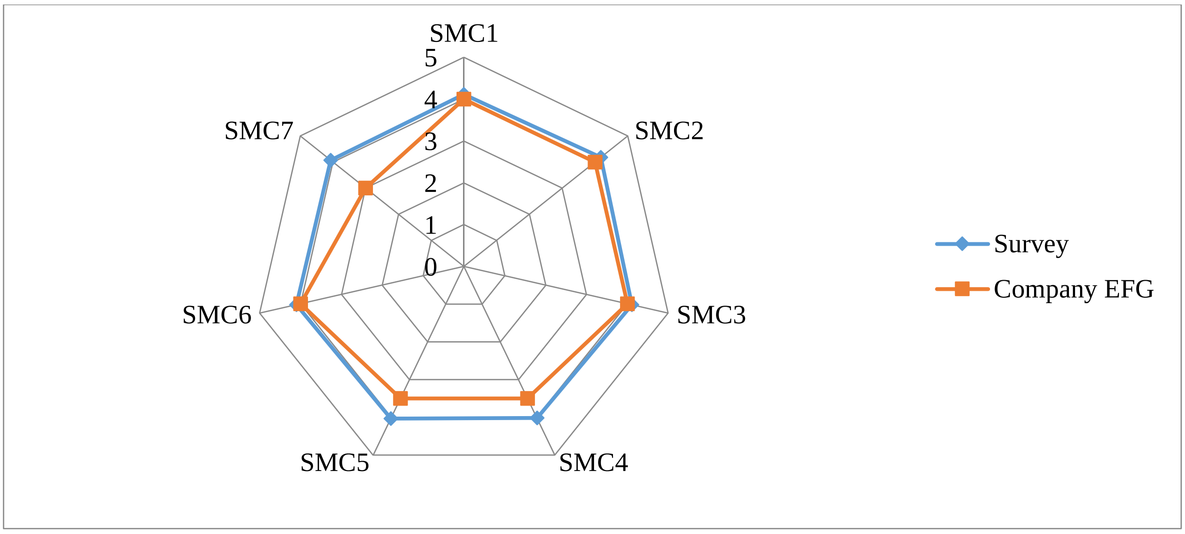


Figure 6.17: Assessments of Sustainable performance measures (SPM)

The company EFG Ltd. is a well-known company in electrical equipment manufacturing sector. The stakeholders of the company have placed emphasis on environmental and social sustainability. The company implemented various sustainable manufacturing practices in the organisation i.e. environmental compliances as per government policies, design of products for reduced consumption of material and energy, continuous improvement/Kaizen/ Pokayoke/Mistake proofing, use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM), cooperation with suppliers for environmental objectives, reduce resource utilisation (Energy and water), decrease of consumption of hazardous/ harmful/ toxic materials to Improve product and process quality.

6.4.5.9 Sustainable manufacturing Index, sustainable performance Index and sustainable manufacturing competitiveness Index

Sustainable manufacturing Index (SMI)(I_{SM})), sustainable performance Index (SPI) (I_{SPM}) and sustainable manufacturing competitiveness Index (SMCI) (I_{SMC}) is computed using equation no. (6), (7) and (8) given in chapter 4. SMI, SPI and SMCI for the company EFG Ltd. are 3.86, 3.30 and 3.64 respectively**.**

6.4.6 Case observations

The company DEF maintains leadership profile in the manufacture of a wide range of quality components in the electrical equipment manufacturing sector. It has won number of excellence awards in quality and exports in the electrical sector. The company has also taken a number of initiatives towards sustainable manufacturing, which includes:

- Ecological measurement instrument
- Cleaner production technologies
- Pollution control equipment
- Water and material consecration
- Waste exchange
- Energy conservation

6.5 CASE 3: MACHINERY SECTOR

A case study from Machinery sector is developed. The company is labeled as MNO. The company is leading manufacturer of of Earthmoving and Construction Equipment in India.

6.5.1 Introduction

The Company MNO Ltd. is a fully owned subsidiary of UK based company and has five World Class Manufacturing facilities in India. With over 400 Engineers, it also has the largest Design Centre, outside of UK in India, at Pune and the latest facility at Jaipur, a Zero Discharge, Green Facility manufactures Fabrications for the company. The company MNO has the greatest respect for the environment and its employees. The Company invested more than 300.62 Million US $ in India and today employs over 5,500 people in India. It has a network of 61 dealers and over 600 plus outlets throughout India which provide Parts and Product Support to Indian Customers. The company has remained committed to India all through; over the years it launched new India Centric products and opened new factories with Innovation and R&D. But above all Customer focus and Quality have been at the core of company's operations.

6.5.2 Vision and Mission

Vision

The company develops products and services that delight the customer and exceed their expectations. In doing this, the company recognises the potential impact on:

- The welfare of the communities in which they operate
- The health and safety of their employees
- The environmental footprint they generate

Mission

The company's Future prosperity depends not only in providing quality products and services, but understanding that quality means:

- Ensuring that the employees and the communities in which they operate are better off
- Tackling workplace and product safety responsibly

- Taking the need to operate within environmental limits seriously.

6.5.3 Product Range

The company is manufacturing the various types 2DX Backhoe Loader and takes versatility to previously inaccessible areas with its compact size. The 3DX ecoXcellence, 3DX Xtra ecoXcellence, 3DX Super ecoXcellence and 4DX ecoXcellence Backhoes are the different product that has high fuel efficiency & performance with advanced Livelink Telematics technology. Company's engine eco-MAX is an embodiment of the high levels of innovation and technological superiority. Big on fuel saving and high on performance, Engine ecoMAX is at the heart of numerous reliable equipment of the company. The powerful 3DX / 4DX / Skid Steer Loader / Excavators that come with a host of attachments, help facilitate hauling, dumping, shredding, clearing and transferring of waste conveniently saving time, energy and the Earth.

6.5.4 Preliminary preparation

The objective of case study is to evaluate sustainable manufacturing practices adopted by the company MNO and also to investigate the results coming, from survey companies. Company MNO is a leading manufacturer of agriculture and construction equipment. This case company was selected on the basis of consent of detailed study about adoption of sustainable manufacturing and also it is located in NCR region. A structured questionnaire was administered to collect case study data.

6.5.5 Case assessment

The company adopted sustainable manufacturing practices voluntarily and to complied with the regulations. The company MNO Ltd. implemented the ISO 14000, Green Lights, Eco management and audit scheme. The stakeholder of the company was willing to participate in energy efficiency program in the organization. The company participated in environmental initiatives, certification programs.

6.5.5.1 Stakeholder's commitment (SHC)

The assessment of stakeholder's commitment (SHC) for sustainable manufacturing in the survey companies and case company is illustrated in Table 6.17. The perceptions of general manager and deputy Manager and sr. engineers for the five items of stakeholder's commitment on five point Likert scale. Table 6.17 depicts that top three stakeholder's commitment are environmental compliances as per governmental policies are strictly adhered (SHC1) (3.94), motivation towards Sustainability (SHC3) (3.77) and emphasis on improving eco-efficiency (SHC4) (3.77). In the case of company MNO the top three stakeholder's commitment environmental compliances as per governmental policies are strictly adhered (SHC1) (5.00), cross-functional cooperation for sustainable manufacturing (SHC2) (4.75) and emphasis on improving eco-efficiency (SHC4) (4.75). The result of survey companies and MNO Company are same that validates the survey results. The overall mean for Survey Company and Case Company MNO for the stakeholder's commitment is very clearly seen in the Radar chart in Figure 6.18.

Table 6.17: Assessments of Stakeholder's commitment (SHC)

Stakeholder's commitment (SHC)		**Survey** (Overall Mean)	**Company MNO** (Overall Mean)
SHC1	Environmental compliances as per governmental policies are strictly adhered	3.94	5.00
SHC2	Cross-functional cooperation for sustainable manufacturing	3.76	4.75
SHC3	Motivation towards Sustainability	3.77	4.50
SHC4	Emphasis on improving eco-efficiency	3.77	4.75
SHC5	Stakeholders Expertise	3.69	4.00

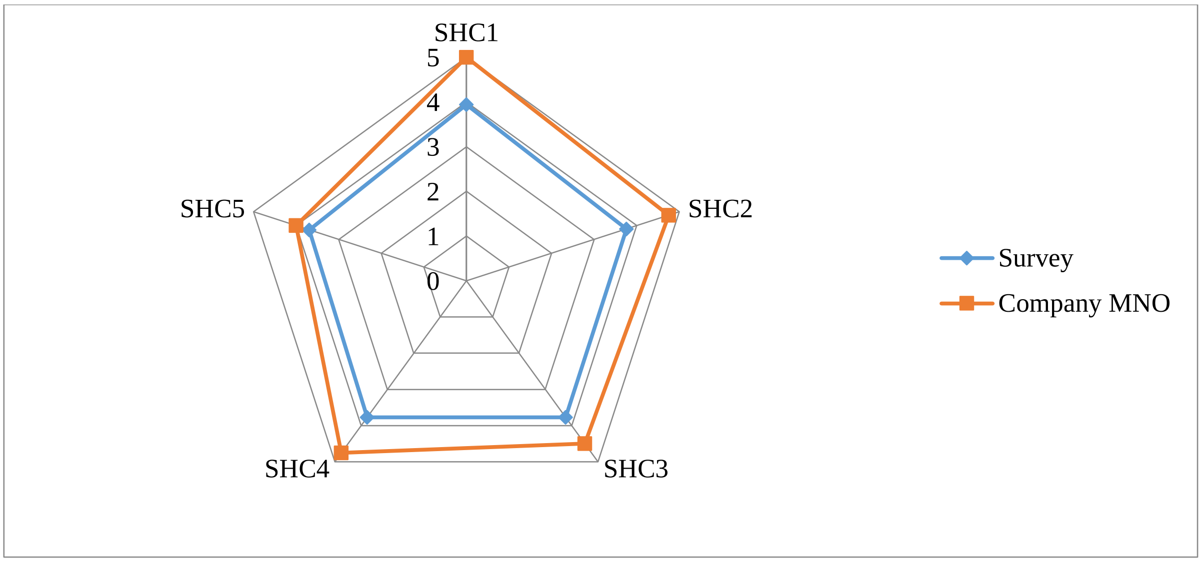


Figure 6.18: Assessments of Stakeholder's commitment (SHC)

6.5.5.2 Sustainable product and process design (SPPD)

The assessment of Sustainable product and process design (SPPD) for sustainable manufacturing in the survey companies and case company illustrated in Table 6.18. The data was collected through the plant visit and interviewed of general manager and deputy Manager and sr. engineers for the eight items of Sustainable product and process design (SPPD on five point Likert scale (1-Very Low to 5-Very High). Table 6.18 depicts the top most Sustainable product and process designs (SPPD) practices for the survey companies are design of products for reduced consumption of material and energy (SPPD1) (4.04), use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (4.04), improve resources utilisation (materials, water, manpower) on shop floor (SPPD7) (4.03) and minimizing waste during machining process (SPPD5) (4.02).

Table 6.18: Assessment of Sustainable product and process design

Sustainable product and process design (SPPD)		**Survey** (Overall Mean)	**Company MNO** (Overall Mean)
SPPD1	Design of products for reduced consumption of material and energy.	4.04	4.75
SPPD2	Design of products to reduce the use of hazardous of products and manufacturing process	3.97	4.50
SPPD3	Design for Packaging	3.96	4.25
SPPD4	Design for environment (DFE)	3.84	4.00
SPPD5	Minimizing waste during machining process	4.02	4.25
SPPD6	Energy efficiency during production process	3.98	4.25
SPPD7	Improve resources utilisation (materials, water, manpower) on shop floor	4.03	4.00
SPPD8	Use of efficient and clean technology to reduce carbon dioxide foot print	4.04	4.00

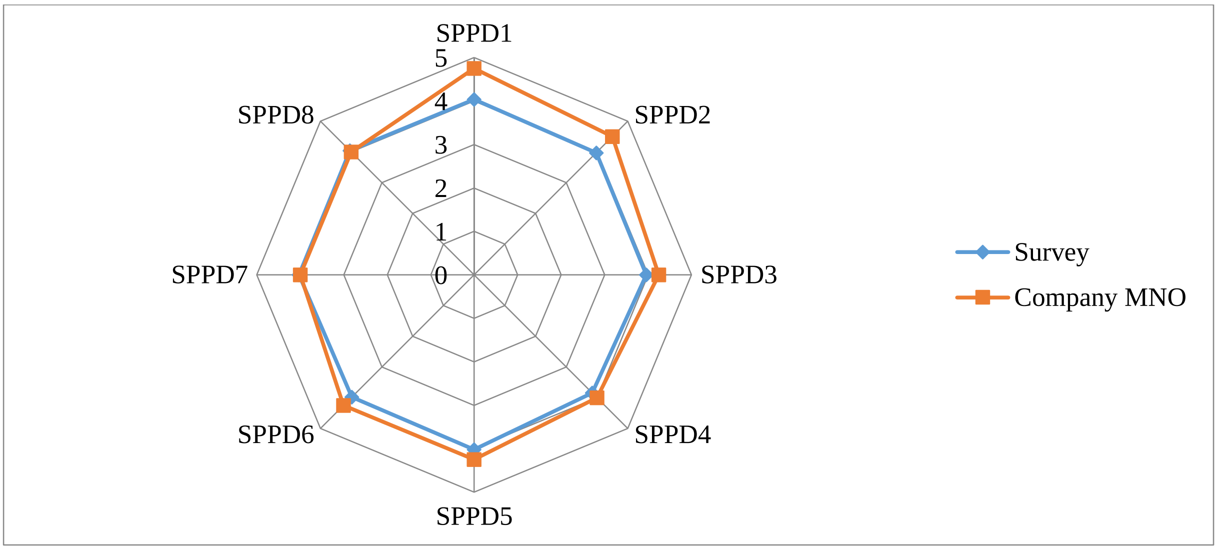


Figure 6.19: Assessment of Sustainable product and process design

In the case of company MNO the top most Sustainable product and process designs practices adopted are design of products for reduced consumption of material and energy (SPPD1) (4.75), design of products to reduce the use of hazardous of products and manufacturing process (SPPD2) (4.50), minimizing waste during machining process (SPPD5) (4.25), energy efficiency during production process (SPPD6) (4.25) and design for Packaging (SPPD3) (4.25). The case company results more or less are similar to survey results.

The similarities in overall mean for Survey Company and Case Company MNO for Sustainable product and process design can be very clearly seen in the Radar chart in Figure 6.19.

6.5.5.3 Lean Practice (LP)

The assessment of Lean Practice (LP) for sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.19. The data was collected through the plant visit and interviewed of general manager and deputy Manager and sr. engineers for the six items of Lean Practice (LP) on five point Likert scale (1-Very Low to 5-Very High). Table 6.19 depicts the top three Lean Practices (LP) practices for the survey companies are continuous improvement/Kaizen/ Pokayoke/Mistake proofing (LP2) (3.97), 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (3.88) and total productive maintenance (TPM) (LP4) (3.81).

Table 6.19: Assessment of Lean Practice (LP)

Lean Practice (LP)		**Survey** **(**Overall Mean)	**Company MNO** **(**Overall Mean)
LP1	Value Stream Mapping (VSM)	3.56	4.67
LP2	Continuous improvement/Kaizen/ Pokayoke/Mistake proofing	3.97	5.00
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)	3.88	4.50
LP4	Total productive maintenance (TPM)	3.81	4.00
LP5	Just-in-Time (JIT)	3.62	4.50
LP6	Kanban/Pull Production	3.7	4.50

In the case of company MNO, the top three Lean practices are continuous improvement/Kaizen/ Pokayoke/Mistake proofing (LP2) (5.00), Value Stream Mapping (VSM) (LP1) (4.67) and 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (4.50). The case company results are similar to survey results. The similarities in overall mean for Survey Company and Case Company MNO for Lean Practices can be very clearly seen in the Radar chart in Figure 6.20.

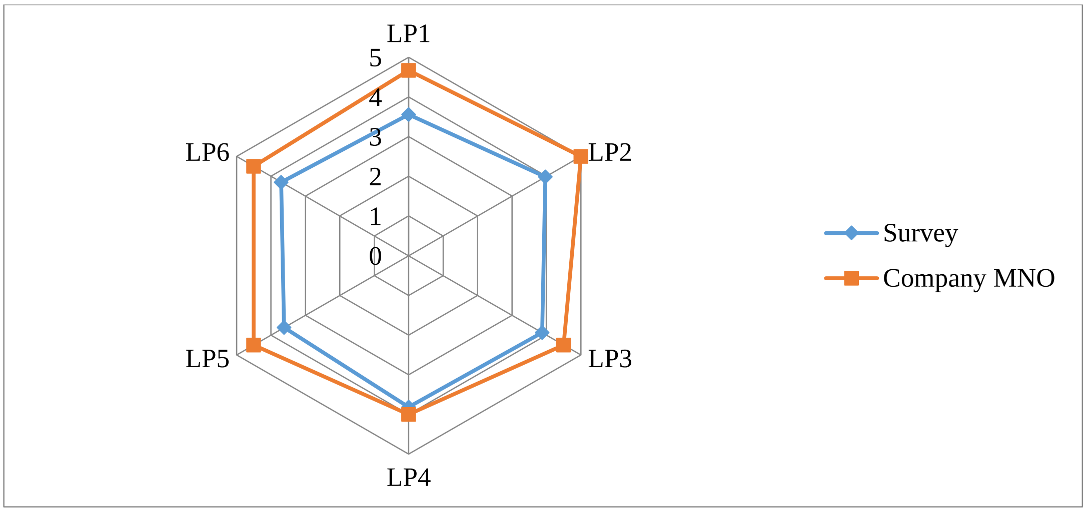


Figure 6.20: Assessment of Lean Practice (LP)

6.5.5.4 Agile Practices and Customization (APC)

The assessment of Agile Practices and Customization (APC) for sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.20. The data was collected through the plant visit and interviews of general manager and deputy Manager and sr. engineers for the six items of Agile Practices and Customization are collected on five point Likert scale (1-Very Low to 5-Very High). Table 6.20 depicts the top three Agile Practices and Customization (APC) practices for the survey companies are flexibility to change volume as per customer demand (APC5) (4.17), quickly respond to customer (APC4) (4.12) and product variety without increasing cost and sacrificing quality (APC6) (4.08).

Table 6.20: Assessment of Agile Practices and Customization (APC)

Agile Practices and Customization (APC)		**Survey** (Overall Mean)	**Company MNO** (Overall Mean)
APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	3.96	4.50
APC2	Use of Automation System (CNC, DNC & Robotics)	3.99	4.75
APC4	Quickly respond to customer	4.12	5.00
APC5	Flexibility to change volume as per customer demand	4.17	5.00
APC6	Product variety without increasing cost and sacrificing quality	4.08	4.50

In the case of company MNO, the top three Agile Practices and Customization adopted are quickly respond to customer (APC4) (5.00), flexibility to change volume as per customer demand (APC5) (5.00) and use of Automation System (CNC, DNC & Robotics) (APC2) (4.75). APC4 and APC6 practices are adopted by survey companies and case company MNO that validate the results. The similarities in overall mean for Survey Company and Case Company MNO for Agile Practices and Customization can be very clearly seen in the Radar chart in Figure 6.21.

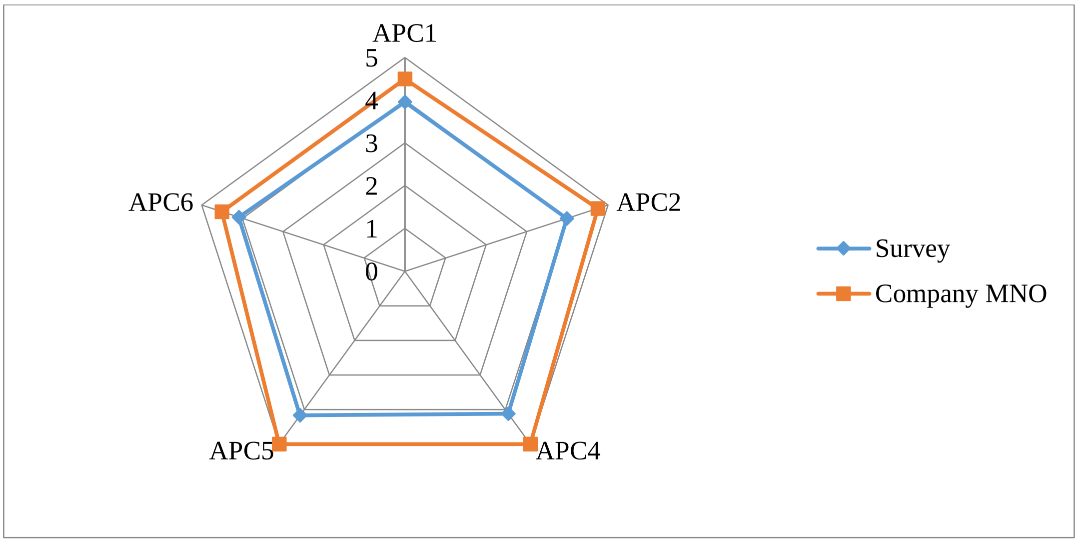


Figure 6.21: Assessments of Agile Practices and Customization (APC)

6.5.5.5 Sustainable supply operations and distribution (SSOD)

The assessment of Sustainable supply operations and distribution (SSOD) for sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.21. The data was collected through the plant visit and interviews of general manager and deputy Manager and sr. engineers for the six items of sustainable supply operations and distribution on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.21 depicts the top three sustainable supply operations and distribution practices for the survey companies are sale of scrap material, used materials and excess capital equipment (SSOD6) (3.94), cooperation with suppliers for environmental objectives (SSOD1) (3.8) and cooperation with customers for green packaging (SSOD3) (3.78).

Table 6.21: Assessments of Sustainable supply operations and distribution (SSOD)

		Survey (Overall Mean)	**Company MNO** (Overall Mean)
SSOD1	Cooperation with suppliers for environmental objectives	3.8	3.75
SSOD2	Second-tier supplier environmentally friendly practice evaluation	3.71	3.25
SSOD3	Cooperation with customers for green packaging	3.78	4.50
SSOD4	Supplier's advances in developing environmentally friendly packages	3.72	4.00
SSOD5	Investment recovery (sale) of excess inventories/ materials	3.77	2.75
SSOD6	Sale of scrap material, used materials and excess capital equipment	3.94	3.25

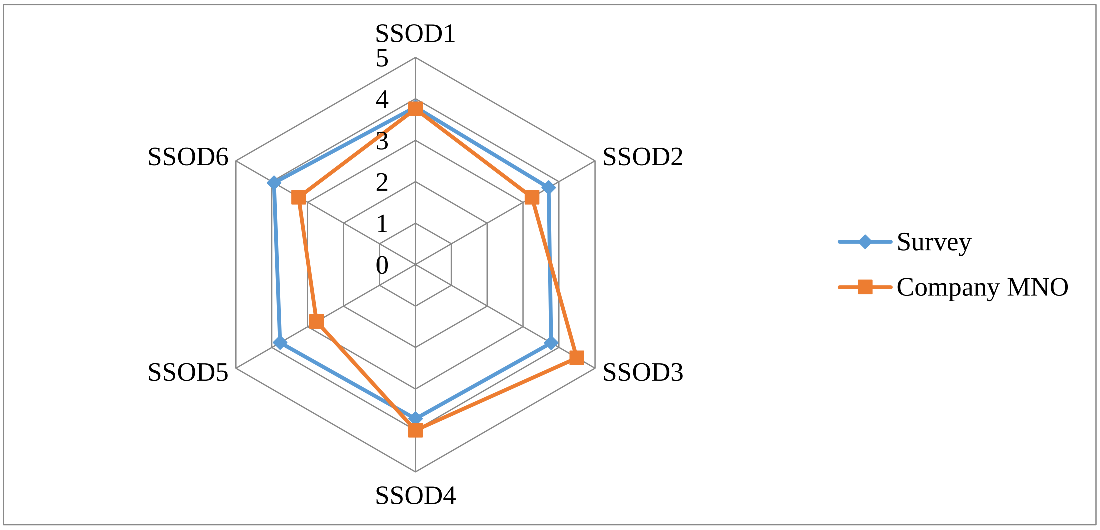


Figure 6.22: Assessments of Sustainable supply operations and distribution (SSOD)

In the case of company MNO the top three sustainable supply operations and distribution adopted are cooperation with customers for green packaging (SSOD3) (4.50), supplier's advances in developing environmentally friendly packages (SSOD4) (4.00) and cooperation with suppliers for environmental objectives (SSOD1) (3.75). SSOD3 and SSOD6 are similar practices in survey companies and case company MNO, hence that validates the results. The similarities in the overall mean for Survey Company and Case Company MNO for sustainable supply operations and distribution can be very clearly seen in the Radar chart in Figure 6.22.

6.5.5.6 Product recovery and return practices (PRRP)

The assessment of Product recovery and return practices (PRRP) for sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.22. The data was collected through the plant visit and interviews of general manager and deputy Manager and sr. engineers for the six items of product recovery and return practices on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.22 depicts the top three product recovery and return practices for the survey companies are remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (3.79), reduce resource utilisation (Energy and water) (PRRP1) (3.77) and recycle of returned product/material (PRRP2) (3.66).

Table 6.22: Assessments of Product recovery and return practices (PRRP)

Product recovery and return practices (PRRP)		**Survey** (Overall Mean)	**Company MNO** (Overall Mean)
PRRP1	Reduce resource utilisation (Energy and water)	3.77	5.00
PRRP2	Recycle of returned product/material	3.66	4.25
PRRP3	Reusability of returned product/material	3.54	4.00
PRRP4	Recover of returned product/material for further processing	3.59	3.75
PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	3.79	3.75
PRRP6	Redesign post-use processes and products	3.57	3.75

In the case of company MNO the top three sustainable product recovery and return practices adopted are reduce resource utilisation (Energy and water) (PRRP1) (5.00), recycle of returned product/material (PRRP2) (4.25) and reusability of returned product/material (PRRP3) (4.00). The similarities in overall mean for Survey Company and Case Company MNO for sustainable product recovery and return practices can be very clearly seen in the Radar chart in Figure 6.23.

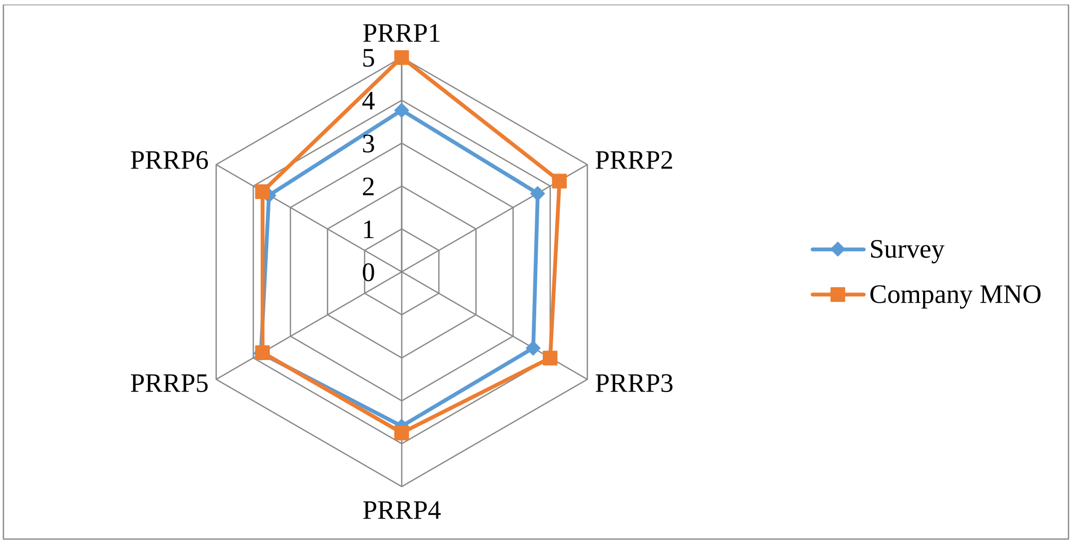


Figure 6.23: Assessments of Product recovery and return practices (PRRP)

6.5.5.7 Sustainable performance measures (SPM)

The assessment of sustainable performance measures (SPM) in the companies of sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.23. The data was collected through the plant visit and interviews of general manager and deputy Manager and sr. engineers for ten items of sustainable performance measures on five point Likert scale (1-Very Low to 5-Very High). Table 6.23 depicts the top most Sustainable performance measures for the survey companies are customer satisfaction (SPM10) (4.19), reduction of air emission, water waste and solid wastes (SPM1) (4.04), decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (4.04), provide employee training and career development program (SPM9) (4.01) and decrease of frequency for environmental accident (SPM3) (3.99).

Table 6.23: Assessments of Sustainable performance measures (SPM)

Sustainable performance measures (SPM)		Survey (Overall Mean)	Company MNO (Overall Mean)
SPM1	Reduction of air emission, water waste and solid wastes	4.04	4.75
SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	4.04	4.75
SPM3	Decrease of frequency for environmental accidents	3.99	4.75
SPM4	Decrease in cost of materials purchasing	3.92	3.25
SPM5	Decrease in cost of waste treatment	3.86	3.50
SPM6	Decrease in cost of energy consumption	3.95	4.50
SPM7	Provide good remunerations and wages to employee for stability	3.88	3.67
SPM8	Provide quality health and safety management practices	3.96	4.50
SPM9	Provide Employee training and career development program	4.01	4.25
SPM10	Customer satisfaction	4.19	4.75

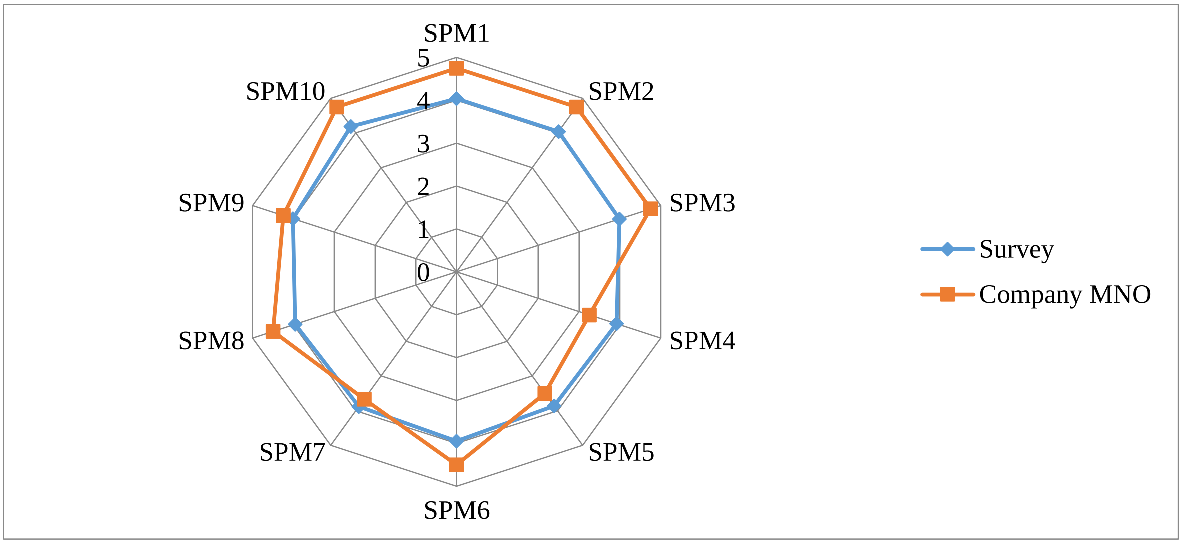


Figure 6.24: Assessments of Sustainable performance measures (SPM)

In the case of company MNO the top five Sustainable performance measures (SPM) are reduction of air emission, water waste and solid wastes (SPM1) (4.75), decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (4.75), decrease of frequency for environmental accidents (SPM3) (4.75), customer satisfaction (SPM10) (4.75) and decrease in cost of energy consumption (SPM6) (4.50). The similarities in overall mean for Survey

Company and Case Company MNO for Sustainable performance measures (SPM) can be very clearly seen in the Radar chart in Figure 6.24.

6.5.5.8 Sustainable manufacturing competitiveness

The assessment of sustainable manufacturing competitiveness (SMC) in the companies of sustainable manufacturing in the survey companies and case company MNO is illustrated in Table 6.24. The data was collected through the plant visit and interviewed of senior vice president, general manager and senior managers for the seven items of sustainable manufacturing competitiveness on five point Likert scale (1-Very Low to 5-Very High). Table 6.24 depicts the top most sustainable manufacturing competitiveness achieved by survey companies are improvement in product and process quality (SMC2) (4.18), reduced product manufacturing cost (SMC1), (4.11), on time delivery of customer products (SMC3) (4.11), increase in profitability (SMC6) (4.1) and improve corporate Social Responsibility and organizational growth (SMC7) (4.07).

Table 6.24: Assessments of Sustainable manufacturing competitiveness (SMC)

		Survey (Overall Mean)	**Company MNO** (Overall Mean)
SMC1	Reduced product manufacturing cost	4.11	4.50
SMC2	Improvement in product and process quality	4.18	4.75
SMC3	On time delivery of customer products	4.11	5.00
SMC4	Innovation in product and process design	4.02	4.75
SMC5	Adoption of advanced technology	4.03	4.50
SMC6	Increase in profitability	4.1	3.25
SMC7	Improve Corporate Social Responsibility and organizational growth	4.07	4.75

The company MNO focuses on top most sustainable manufacturing competitiveness i.e. on time delivery of customer products (SMC3) (5.00), improvement in product and process quality (SMC2) (4.75), improve Corporate Social Responsibility and organizational growth (SMC7) (4.75), innovation in product and process design (SMC4) (4.75) and reduced product manufacturing cost (SMC1) (4.50).   The similarities in overall mean for Survey Company and Case Company MNO for sustainable manufacturing competitiveness (SMC) can be very clearly seen in the Radar chart in Figure 6.25.

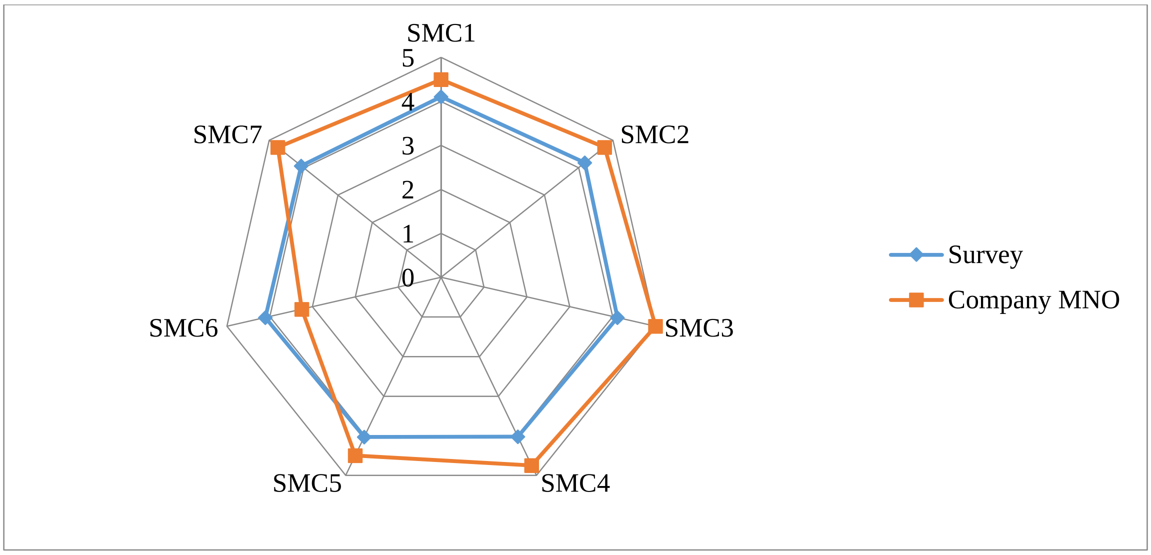


Figure 6.25: Assessments of Sustainable manufacturing competitiveness (SMC)

The company MNO Ltd. is a world's largest construction and agricultural equipment manufacture. Company MNO is highly concern with sustainability. The stakeholders of the company are motivated for sustainable development in the organisation. Company implemented various sustainable manufacturing practices i.e. environmental compliances as per governmental policies are strictly adhered, design of products for reduced consumption of material and energy, continuous improvement/Kaizen/Pokayoke/Mistake proofing, quickly respond to customer, cooperation with customers for green packaging, reduction of air emission, water waste and solid wastes, on time delivery of customer products for sustainable manufacturing competitiveness.

6.5.5.9 Sustainable manufacturing Index, sustainable performance Index and sustainable manufacturing competitiveness Index

Sustainable manufacturing Index (SMI) (I_{SM}), sustainable performance Index (SPI) (I_{SPM}) and sustainable manufacturing competitiveness Index (SMCI) (I_{SMC}) is computed using equation no. (6), (7) and (8) given in chapter 4. SMI, SPI and SMCI for the company MNO Ltd. are 4.23, 3.62and 3.99 respectively.

6.5.6 Case observations

The company MNO being the world’s leading manufacturer takes the environmental responsibilities very seriously. The company aim to eliminate pollution releases, promote high standards of energy management and to recycle and safety dispose waste. The product is designed for maximum energy efficiency and minimum environmental impact. Company has been committed to adopt, implement and achieve some of the following significant initiatives:

- Reduce in average consumption of water.
- Use of renewable energy increased.
- Reduction in specific generation of waste.

6.6 CASE 4: PROCESS SECTOR

A case study from Process sector is developed. The company is labeled as PQM. Case company is leading manufacturer of Cold Rolled Coil and Sheets in India. Company is leading the technological revolution in Indian Cold Rolled Steel Industry today and defining new frontier of customer satisfaction. Be it through technology and product upgrades, R&D efforts or stringent quality control measures, company is consistent in its pursuit of value.

6.6.1 Introduction

Company PQM Ltd is one of the prominent players in the Indian Steel industry. It is India’s 3rd largest Secondary Steel Producing Company with an existing steel production capacity of 5.6 million ton per annum. Being amongst the prime movers of the technological revolution in Indian Cold Rolled Steel Industry, This company has emerged as the country's largest and the only Cold Rolled Steel Plant with an independent line for manufacturing Cold Rolled Coil and Sheet up to a width of 1700 mm. Along with this Company has a Galvanized Coil and Sheet line up to a width of 1350 mm. The annual turnover of the company is 1265 million US$.

6.6.2 Vision and Mission

"Diversity enriches any large organization and enhances its collective capabilities. A clear, shared vision is a key requisite to successful diversity management." The Company PQM Ltd. believe in the power of five – People, Products, Customers, Culture and Values.

PQM LTD. envisions a future that puts company in the lead role in this dynamic Indian steel industry and amongst the top key steel players globally. Company is always adding more value to our products and services through innovations. The company foremost priority is pioneering the product market with best quality and price offerings, along with attainment of highest level of customer satisfaction. The values and culture at PQM Ltd. will stand tall to ensure a thriving working environment that is safe, healthy and clean. It is a company that cares about its people, its environment and its community.

6.6.3 Product Range

Company PQM Ltd. has world class testing equipment to compete with rapid change in technology. As one of the largest integrated steel players in India, company is a source for vivid variety of products such as Hot Rolled Coil,CRCA,CRFH,Galvanized Coil and Sheet, Galume Coil and Sheet, Color Coated Coils, Color Coated Tiles, High Tensile Steel Strips, Hardened & Tempered Steel Strips, Precision Tubes, HFW/ERW Pipe (API Grade),3LP Coated Pipes, Billets and Sponge Iron.

6.6.4 Preliminary preparation

The objective of case study is exploring the adoption of sustainable manufacturing practices by company PQM and also to investigate the results coming from survey. Company PQM is a leading manufacturer of Cold Rolled Coil and Sheets products. This case company is selected on the basis of consent of detailed study about adoption of sustainable manufacturing and also it is located in NCR region. A structured questionnaire was developed on five point Likert scale to collect case study data

6.6.5 Case assessment

The Company PQR adopted sustainable manufacturing issues and practices to comply with regulations. The company implemented the ISO 14001 and Green strategy. The company also participate in energy efficiency programs and also participates in environmental initiatives, and certification programs. Company PQR uses environment policy to ensure clean, green and healthy environment, efficient use of natural resources, energy, plant and equipment, reduction in emissions, noise, waste and greenhouse gases continual improvement in environment management and compliance of relevant environmental legislations.

6.6.5.1 Stakeholder's commitment (SHC)

The assessment of stakeholder's commitment (SHC) for sustainable manufacturing in the survey companies and case company illustrated in Table 6.25. The perceptions of vice president and general managers for the five items of stakeholder's commitment were collated on five point Likert scale. Table 6.25 depicts the top three stakeholder's commitment for the companies are environmental compliances as per governmental policies (SHC1) (3.94), motivation towards Sustainability (SHC3) (3.77) and emphasis on improving eco-efficiency (SHC4) (3.77).

Table 6.25: Assessments of Stakeholder's commitment (SHC)

Stakeholder's commitment (SHC)		**Survey (Overall Mean)**	**Company PQR (Overall Mean)**
SHC1	Environmental compliances as per governmental policies are strictly adhered	3.94	4.33
SHC2	Cross-functional cooperation for sustainable manufacturing	3.76	3.67
SHC3	Motivation towards Sustainability	3.77	3.67
SHC4	Emphasis on improving eco-efficiency	3.77	3.33
SHC5	Stakeholders Expertise	3.69	2.00

In the case of company PQR the top three stakeholder's environmental compliances as per governmental policies are strictly adhered (SHC1) (4.33), motivation towards Sustainability (SHC3) (3.67) and cross-functional cooperation for sustainable manufacturing (SHC2) (3.67). The result of survey companies and PQR Company are similar that validate the survey results.

The similarities in overall mean for Survey Company and Case Company MNO for the stakeholder's commitment can very clearly seen in the Radar chart in Figure 6.26.

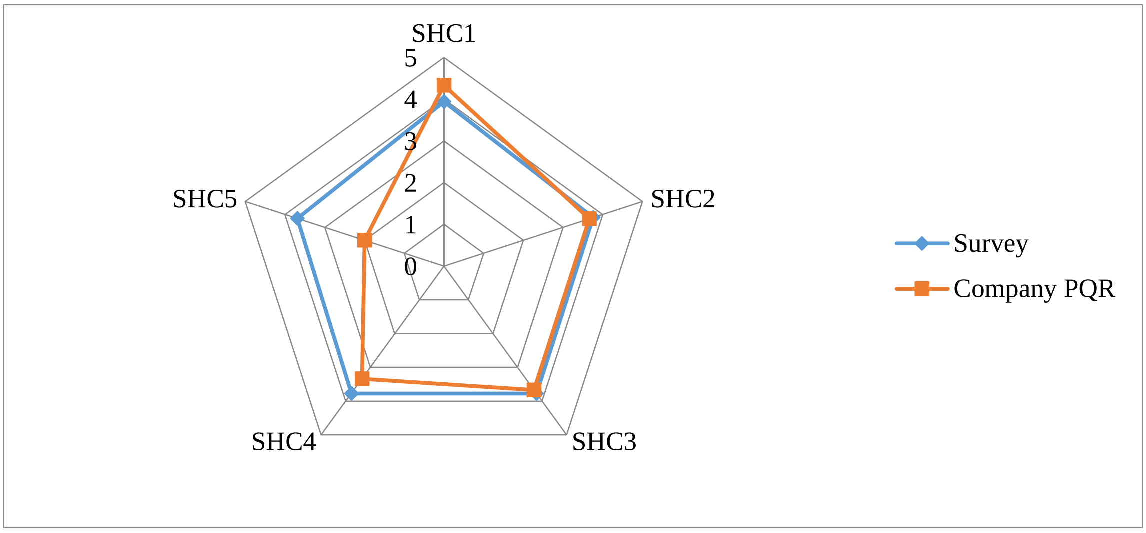


Figure 6.26: Assessments of Stakeholder's commitment (SHC)

6.6.5.2 Sustainable product and process design (SPPD)

The assessment of Sustainable product and process design (SPPD) for sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.26. The data was collected through the plant visit and interviews of vice president and general managers for the eight items of Sustainable product and process design (SPPD) on five point Likert scale (1-Very Low to 5-Very High). Table 2.6 depicts the top most Sustainable product and process designs (SPPD) practices for the survey companies are design of products for reduced consumption of material and energy (SPPD1) (4.04), use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (4.04), improve resources utilisation (materials, water, manpower) on shop floor (SPPD7) (4.03) and minimizing waste during machining process (SPPD5) (4.02).

Table 6.26: Assessment of Sustainable product and process design (SPPD)

		Survey (Overall Mean)	**Company PQR** (Overall Mean)
SPPD1	Design of products for reduced consumption of material and energy.	4.04	1.67
SPPD2	Design of products to reduce the use of hazardous of products and manufacturing process	3.97	2.33
SPPD3	Design for Packaging	3.96	3.00
SPPD4	Design for environment (DFE)	3.84	2.33
SPPD5	Minimizing waste during machining process	4.02	3.67
SPPD6	Energy efficiency during production process	3.98	4.00
SPPD7	Improve resources utilisation (materials, water, manpower) on shop floor	4.03	4.33
SPPD8	Use of efficient and clean technology to reduce carbon dioxide foot print	4.04	4.33

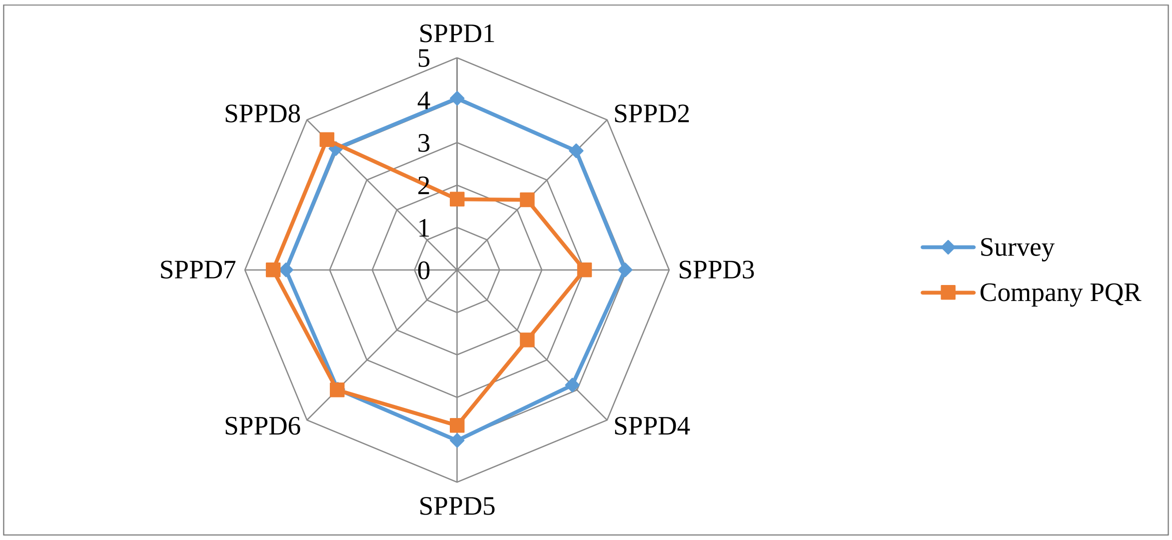


Figure 6.27: Assessment of Sustainable product and process design (SPPD)

In the case of company PQR the top most sustainable product and process designs practices adopted are design of products for reduced consumption of material and energy (SPPD1) (1.67), improve resources utilisation (materials, water, manpower) on shop floor (SPPD7), (4.33), use of efficient and clean technology to reduce carbon dioxide foot print (SPPD8) (4.33) and energy efficiency during production process (SPPD6) (4.00).

The case company results are similar to survey results. The similarities in overall mean for Survey Company and Case Company PQR for Sustainable product and process design can be very clearly seen in the Radar chart in Figure 6.27.

6.6.5.3 Lean Practice (LP)

The assessment of Lean Practice (LP) for sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.27. The data was collected through the plant visit and interviews of vice president and general managers for the six items of Lean Practice (LP) on five point Likert scale (1-Very Low to 5-Very High). Table 6.27 depicts the top most Lean Practice (LP) practices for the survey companies are continuous improvement/Kaizen/ Pokayoke/Mistake proofing (LP2) (3.97), 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (3.88) and total productive maintenance (TPM) (LP4) (3.81).

Table 6.27: Assessment of Lean Practice (LP)

Lean Practice (LP)		**Survey (Overall Mean)**	**Company ABC (Overall Mean)**
LP1	Value Stream Mapping (VSM)	3.56	4.00
LP2	Continuous improvement/Kaizen/ Pokayoke/Mistake proofing	3.97	3.67
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)	3.88	4.00
LP4	Total productive maintenance (TPM)	3.81	4.00
LP5	Just-in-Time (JIT)	3.62	4.00
LP6	Kanban/Pull Production	3.70	4.00

In the case of company PQR the top most Lean Practice practices are 5S (Sort, Shine, Set in order, Standardise, and Sustain) (LP3) (4.00), total productive maintenance (TPM) (LP4) (4.00) and Kanban/Pull Production (LP6) (4.00). The case company results are similar to survey results. The result of survey companies and PQR Company are that validate the survey results. The similarities in overall mean for Survey Company and Case Company PQR for Lean Practice can be very clearly seen in the Radar chart in Figure 6.28.

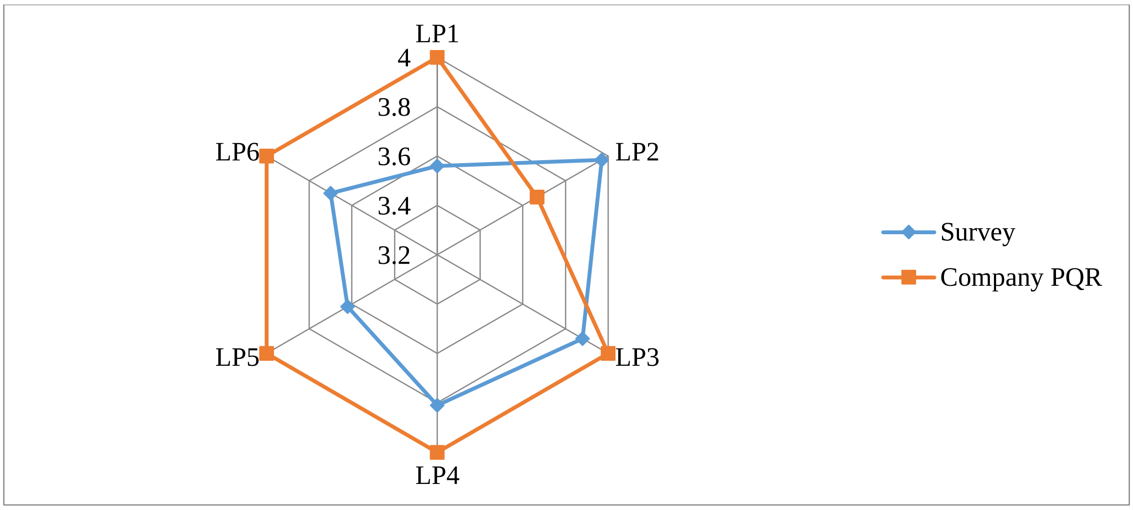


Figure 6.28: Assessment of Lean Practice (LP)

6.6.5.4 Agile Practices and Customization (APC)

The assessment of Agile Practices and Customization (APC) for sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.28. The data was collected through the plant visit and interview of vice president and general managers for the six items of Agile Practices and Customization on five point Likert scale (1-Very Low to 5-Very High). Table 6.28 depicts the top most Agile Practices and Customization (APC) practices for the survey companies are flexibility to change volume as per customer demand (APC5) (4.17), quickly respond to customer (APC4) (4.12) and product variety without increasing cost and sacrificing quality (APC6) (4.08).

Table 6.28: Assessment of Agile Practices and Customization (APC)

Agile Practices and Customization (APC)		**Survey** (Overall Mean)	**Company PQR** (Overall Mean)
APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	3.96	4.33
APC2	Use of Automation System (CNC, DNC & Robotics)	3.99	4.33
APC4	Quickly respond to customer	4.12	4.67
APC5	Flexibility to change volume as per customer demand	4.17	5.00
APC6	Product variety without increasing cost and sacrificing quality	4.08	4.33

In the case of company PQR the top most Agile Practices and Customization adopted are flexibility to change volume as per customer demand (APC5) (5.00), quickly respond to customer (APC4) (4.67) and product variety without increasing cost and sacrificing quality (APC6) (4.33). All practices are similar as adopted by survey companies and case company PQR that validate the results. The similarity in overall mean for Survey Company and Case Company MNO for Agile Practices and Customization is very clearly seen in the Radar chart in Figure 6.29.

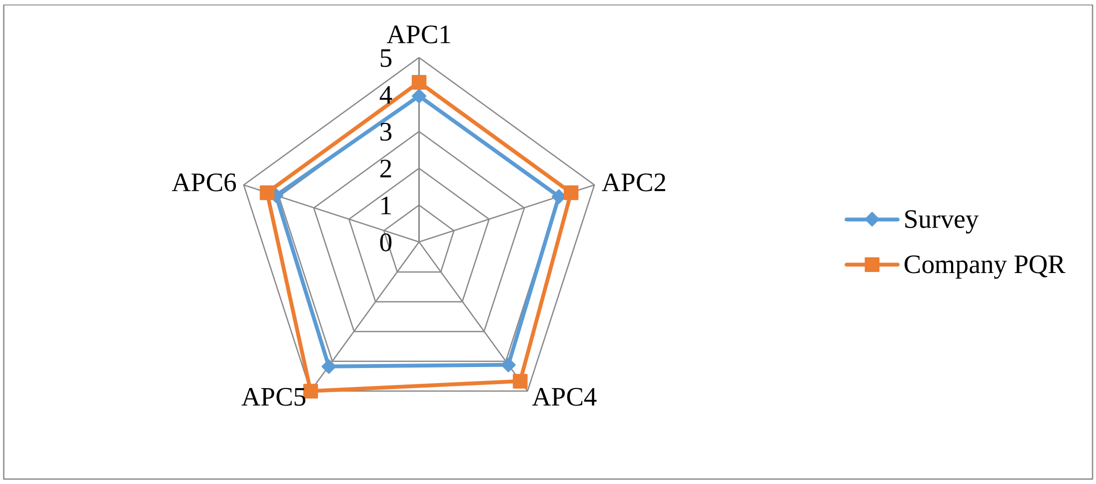


Figure 6.29: Assessments of Agile Practices and Customization (APC)

6.6.5.5 Sustainable supply operations and distribution (SSOD)

The assessment of Sustainable supply operations and distribution (SSOD) for sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.29. The data was collected through the plant visit and interviewed of vice president and general managers for the six items of sustainable supply operations and distribution on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.29 depicts the top most sustainable supply operations and distribution practices for the survey companies are sale of scrap material, used materials and excess capital equipment (SSOD6) (3.94), cooperation with suppliers for environmental objectives (SSOD1) (3.8) and cooperation with customers for green packaging (SSOD3) (3.78).

Table 6.29: Assessments of Sustainable supply operations and distribution (SSOD)

Sustainable supply operations and distribution (SSOD)		Survey (Overall Mean)	Company PQR (Overall Mean)
SSOD1	Cooperation with suppliers for environmental objectives	3.80	4.00
SSOD2	Second-tier supplier environmentally friendly practice evaluation	3.71	4.00
SSOD3	Cooperation with customers for green packaging	3.78	4.00
SSOD4	Supplier's advances in developing environmentally friendly packages	3.72	4.67
SSOD5	Investment recovery (sale) of excess inventories/ materials	3.77	3.67
SSOD6	Sale of scrap material, used materials and excess capital equipment	3.94	4.33

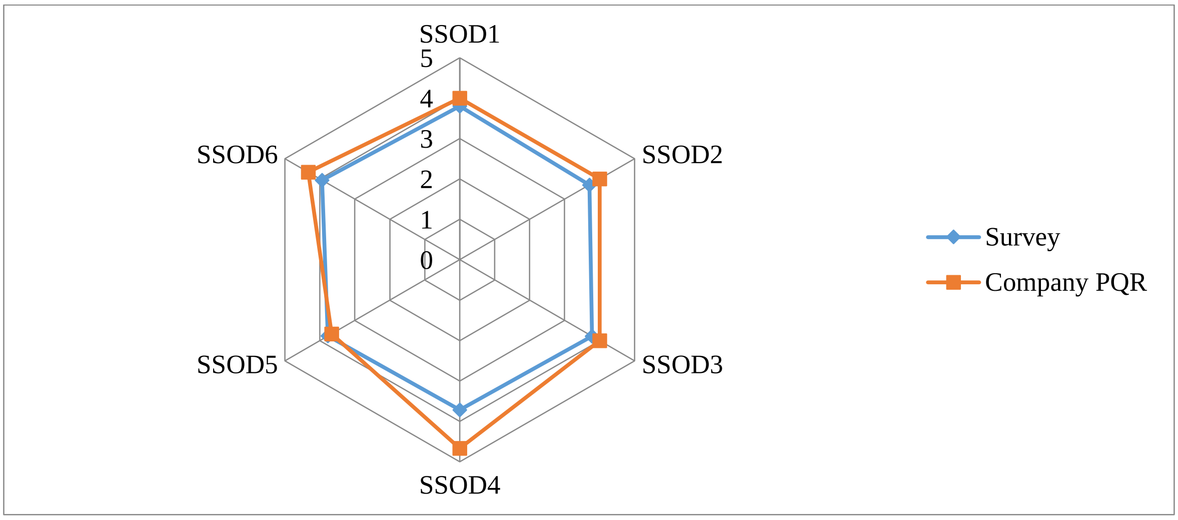


Figure 6.30: Assessments of Sustainable supply operations and distribution (SSOD)

In the case of company PQR the top most sustainable supply operations and distribution adopted are supplier's advances in developing environmentally friendly packages (SSOD4) (4.67), sale of scrap material, used materials and excess capital equipment (SSOD6) (4.33) and cooperation with suppliers for environmental objectives (SSOD1) (4.00). SSOD1 and SSOD6 are similar practices in survey companies and case company PQR, hence that validates the results. The similarity in overall mean for Survey Company and Case Company

PQR for sustainable supply operations and distribution can be very clearly seen in the Radar chart in Figure 6.30.

6.6.5.6 Product recovery and return practices (PRRP)

The assessment of Product recovery and return practices (PRRP) for sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.30. The data was collected through the plant visit and interviewed vice president and general managers for the six items of product recovery and return practices on five point Likert scale (1-Totally disagree to 5-Totally agree). Table 6.30 depicts the top most product recovery and return practices for the survey companies are remanufacturing of returned products as usable product (Recondition and Repair) (PRRP5) (3.79), reduce resource utilisation (Energy and water) (PRRP1) (3.77) and recycle of returned product/material (PRRP2) (3.66).

Table 6.30: Assessments of Product recovery and return practices (PRRP)

Product recovery and return practices (PRRP)		**Survey** (Overall Mean)	**Company PQR** (Overall Mean)
PRRP1	Reduce resource utilisation (Energy and water)	3.77	4.33
PRRP2	Recycle of returned product/material	3.66	4.33
PRRP3	Reusability of returned product/material	3.54	4.67
PRRP4	Recover of returned product/material for further processing	3.59	4.00
PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	3.79	4.00
PRRP6	Redesign post-use processes and products	3.57	1.33

In case of company PQR the top most sustainable product recovery and return practices adopted are reusability of returned product/material (PRRP3) (4.67), reduce resource utilisation (Energy and water) (PRRP1) (4.33) and recycle of returned product/material (PRRP2) (4.33). PRRP1 and PRRP2 are similar practices adopted by the survey company and the case company. The similarities in overall mean for Survey Company and Case Company PQR for sustainable product recovery and return practices can be very clearly seen in the Radar chart in Figure 6.31.

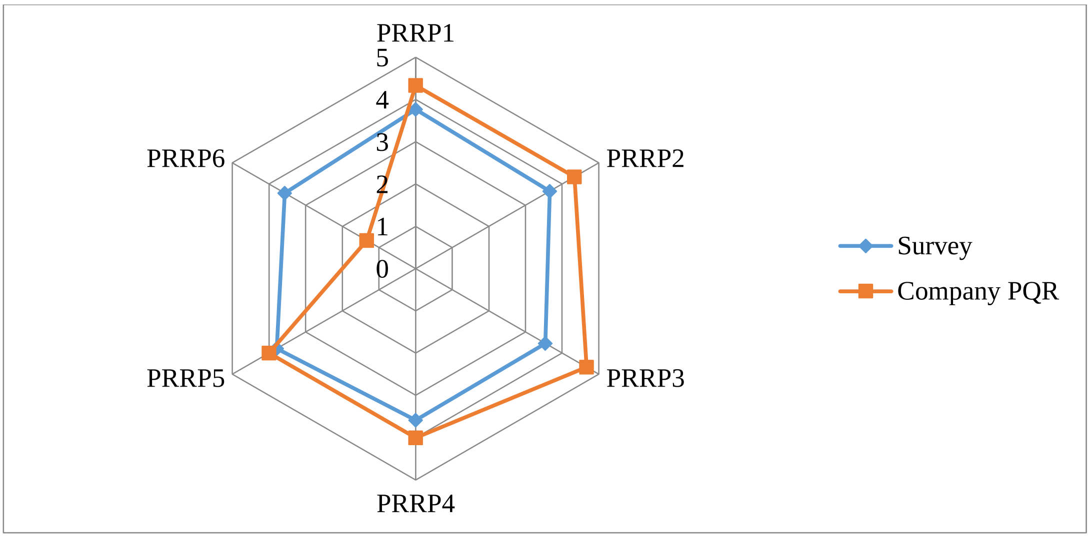


Figure 6.31: Assessments of Product recovery and return practices (PRRP)

6.6.5.7 Sustainable performance measures (SPM)

The assessment of sustainable performance measures (SPM) in the companies of sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.31. The data was collected through the plant visit and interviewed of vice president and general managers for ten items of sustainable performance measures on five point Likert scale (1-Very Low to 5-Very High). Table 6.31 depicts the top most Sustainable performance measures for the survey companies are customer satisfaction (SPM10) (4.19), reduction of air emission, water waste and solid wastes (SPM1) (4.04), decrease of consumption of hazardous/harmful/ toxic materials (SPM2) (4.04), provide Employee training and career development program (SPM9) (4.01) and decrease of frequency for environmental accidents (SPM3) (3.99).

In the case of company PQR the top most Sustainable performance measures (SPM) are reduction of air emission, water waste and solid wastes (SPM1) (4.67), decrease of consumption of hazardous/ harmful/ toxic materials (SPM2) (4.67), customer satisfaction (SPM10) (4.00), provide Employee training and career development program (SPM9) (4.00) and decrease of frequency for environmental accidents (SPM3) (4.00). The similarities in overall mean for Survey Company and Case Company PQM for sustainable performance measures (SPM) can be very clearly seen in the Radar chart in Figure 6.32.

Table 6.31: Assessments of Sustainable performance measures (SPM)

Sustainable performance measures (SPM)		Survey (Overall Mean)	Company PQR (Overall Mean)
SPM1	Reduction of air emission, water waste and solid wastes	4.04	4.67
SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	4.04	4.67
SPM3	Decrease of frequency for environmental accidents	3.99	4.00
SPM4	Decrease in cost of materials purchasing	3.92	2.33
SPM5	Decrease in cost of waste treatment	3.86	4.00
SPM6	Decrease in cost of energy consumption	3.95	4.00
SPM7	Provide good remunerations and wages to employee for stability	3.88	3.67
SPM8	Provide quality health and safety management practices	3.96	4.00
SPM9	Provide Employee training and career development program	4.01	4.00
SPM10	Customer satisfaction	4.19	4.00

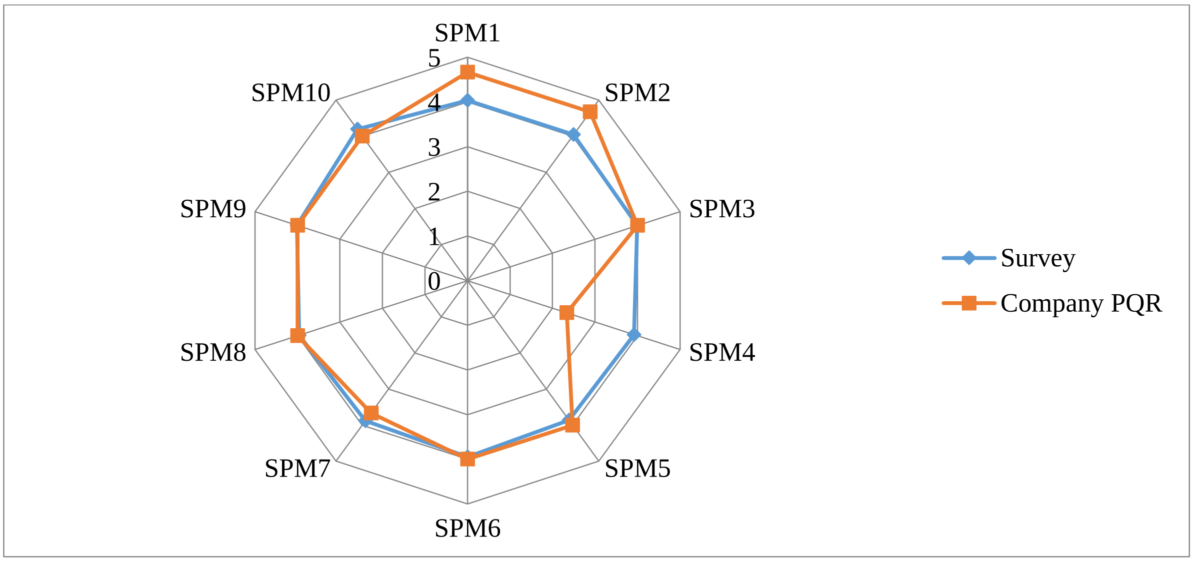


Figure 6.32: Assessments of Sustainable performance measures (SPM)

6.6.5.8 Sustainable manufacturing competitiveness

The assessment of sustainable manufacturing competitiveness (SMC) in the companies of sustainable manufacturing in the survey companies and case company PQR is illustrated in Table 6.32. The data was collected through the plant visit and interviewed of vice president and general managers for the seven items of sustainable manufacturing competitiveness on five point Likert scale (1-Very Low to 5-Very High). Table 6.32 depicts the top most sustainable manufacturing competitiveness achieved by survey companies are improvement in product and process quality (SMC2) (4.18), reduced product manufacturing cost (SMC1) (4.11), on time delivery of customer products (SMC3) (4.11), increase in profitability (SMC6) (4.10) and improve Corporate Social Responsibility and organizational growth (SMC7) (4.07).

Table 6.32: Assessments of Sustainable manufacturing competitiveness (SMC)

Sustainable manufacturing competitiveness (SMC)		Survey (Overall Mean)	Company PQR (Overall Mean)
SMC1	Reduced product manufacturing cost	4.11	4.00
SMC2	Improvement in product and process quality	4.18	5.00
SMC3	On time delivery of customer products	4.11	4.67
SMC4	Innovation in product and process design	4.02	3.33
SMC5	Adoption of advanced technology	4.03	4.67
SMC6	Increase in profitability	4.1	4.33
SMC7	Improve Corporate Social Responsibility and organizational growth	4.07	4.00

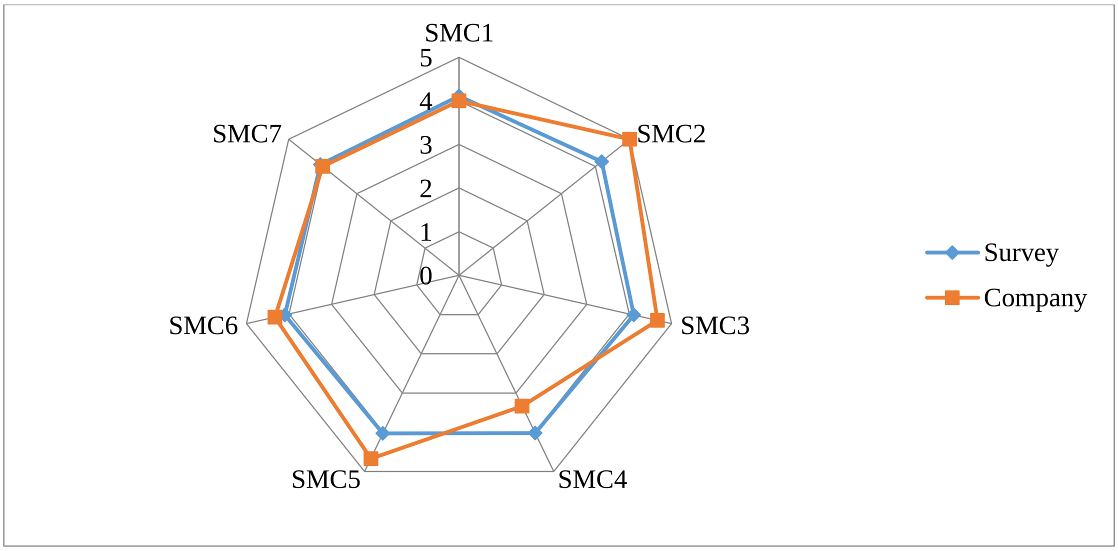


Figure 6.33: Assessments of Sustainable manufacturing competitiveness (SMC)

The company PQR focuses on top most sustainable manufacturing competitiveness i.e. improvement in product and process quality (SMC2) (5.00), reduced product manufacturing cost (SMC1) (4.00), on time delivery of customer products (SMC3) (4.67) and increase in profitability (SMC6) (4.33). The similarity in overall mean for Survey Company and Case Company PQR for sustainable manufacturing competitiveness (SMC) can be very clearly seen in the Radar chart in Figure 6.33.

The company PQR Ltd. is a largest manufacturer of Cold Rolled Steel. The stakeholders of the company are motivated for sustainable development in the organisation. Company implemented various sustainable manufacturing practices, i.e., environmental compliances as per governmental policies are strictly adhered, Use of efficient and clean technology to reduce carbon dioxide foot print, Total productive maintenance (TPM), Flexibility to change volume as per customer demand, Cooperation with suppliers for environmental objectives and Reusability of returned product/material , reduction of air emission, water waste and solid wastes, Improvement in product and process quality for sustainable manufacturing competitiveness.

6.6.5.9 Sustainable manufacturing Index, sustainable performance Index and sustainable manufacturing competitiveness Index

Sustainable manufacturing Index (SMI) (I_{SM}), sustainable performance Index (SPI) (I_{SPM}) and sustainable manufacturing competitiveness Index (SMCI) (I_{SMC}) is computed using equation no. (6), (7) and (8) given in chapter 4. SMI, SPI and SMCI for the company PQR Ltd. are 3.94, 3.34and 3.68 respectively.

6.6.6 Case observations

The company PQR care for the environment and believe that its tomorrow is secure if human beings give back to nature. Be it companies zero discharge policy or fundamental rule of reduce-reuse-recycle; with efficient double checks, air quality control systems and rain water harvesting with optimum use and minimal wastage of the natural resources. Good waste management characterizes of handling, monitoring, treating, reuse and proper disposal of the residual.

The company thoroughly follows appropriate steps to achieve the desired output for solid waste management. The company has installed state-of-art effluent treatment technologies for treatment of effluent generated in different production units.

Quality of treated effluent is maintained as per norms and reused within plant complex in various purposes. No effluent is allowed to go out and thus zero discharge status is maintained. Sewage treatment plants have been established for treatment of sewage generated from colonies and offices.

Legal compliance and satisfying needs & expectations of Customers. Waste management in the company is highly appreciable. Stakeholders of the company manage the different kind of waste as follow:

- Waste gases generated from blast furnace and coke oven are used for power generation to conserve energy
- Plastic waste is sent to ACC for using as fuel
- An incinerator has been established to manage municipal solid waste generated in the township
- From a steel industry variety of solid wastes are generated. In order to handle all these solid waste we have to adopt eco-friendly methodology to ensure statutory compliance and keep environment pollution free. Fly ash is disposed into mine void and fly ash bricks are made. Slag from blast furnace is given to cement plant for cement making. Many other wastes which are generated in various units are sent to sinter plant to use in sinter making.

The company PQM Ltd. follows various steps like Effluent treatment plants, Sewage treatment plants and Water Reservoirs that encourage minimal wastage and pollution of water and also make way for smart use of reprocessed-treated water.

To combat health issues prevalent in the area surrounding the plants, an organized plan has been put into action. Company regularly carries out health, hygiene and AIDS Awareness camps in nearby across plants. A doctor is duly appointed for this task who conducts regular check-ups and provides medicines free-of-cost.

6.7 CROSS CASE ANALYSIS

This study involved multiple case studies to better relate and interpret the findings coming from the empirical analysis. The firms selected for case studies show diverse characteristics on several important dimensions. Table 6.33 shows the cross comparison of company and respondent profile. Company ABC & PQR are the privately owned company whereas the company EFG and MNO are the foreign joint venture company. Companies ABC, EFG, MNO and PQR are using sustainable standard. From the study it is found that company MNO Ltd. is highly focused on sustainable standard as compared to the other companies ABC, EFG and PQR. Table 6.33 shows cross comparison of the issues in sustainable manufacturing.

The critical success factor for the company ABC Ltd. are corporate Social Responsibility/Sustainability, focus on conservation of energy consumption, reduce air emissions and environment, occupational health and safety management. For company EFG the critical success factors are cleaner production, water and material consecration, and waste exchange and Energy conservation. For the company MNO Ltd, the critical success factors are reduction in average consumption of water, reduction in specific generation of waste and corporate social responsibilities. For the company MNO Ltd, the critical success factors are waste gases use for power generation, plastic waste management and solid waste management. Form the cross case analysis it is found that the company MNO has high sustainable performance Index and sustainable manufacturing performance Index and compared to the other companies ABC, EFG and PQR. Therefore, it implies that the machinery company is highly focused on sustainable manufacturing practices and achieving higher level of sustainable manufacturing competitiveness in the market.

Table 6.33: Cross compression of Company and respondent Profile

S. No.	Attributes	Company ABC	Company EFG	Company MNO	Company PQR
1	Type of Industry Sector	Automobile	Electrical & Electronics	Machinery	Process
2	Type of Business	Privately owned	Foreign Joint Venture	Foreign Joint venture	Privately owned
3	Product Range	Gears, Brakes Discs, Brakes Drums, Cylinder block, Pressure plate, Brake plate and Steering Knuckles	switchgear and control gear components, Busbar Trunking Systems Bus Duct and Busbar Riser, MV & LV Switchgear products	Construction, Agriculture, waste handling & demolition on Machinery.	Hot Rolled Coil, Galvanized Coil and sweetgum Coil and Colour Coated Coils, Colour Coated Tiles, High Tensile Steel Strips, Hardened & Tempered Steel Strips, Precision Tubes
4	Annual Turn over	80 million US$	150 million US$	300.62 Million US $	1265 million US$
5	Expenditure on R&D	N/A	2%	5%	3%
6	Main customers	Rotex, Maruti Suzuki, GM motors, Nissan, Toyota, Honda Cars Ltd., Hero Moto corp, Bosch, Sona, LG, Samsung	BPCL,GAIL,IOCL, Ambuja Cement Ltd, Shriram Fertilisers & Chemical, McDowell & Co., J.K. Tyre & Inds. Ltd., Greenply Inds. Ltd.	Defence, Automotive sector, contractions industry and agriculture	Honda Siel Cars, Telco, Hindustan Motors , General Motor, Hyundai Motors, Ford Motors, Mahindra & Mahindra, Lucas TVS,NRB Bearing
7	Number of Employees	550	4000	5500	
8	Working environment	Single Plant	Multi Plant	Multi Plant	Multi Plant
9	Existing Sustainable Standards	ISO 9000, ISO 14000 , QS 9000, TS 16949, Eco management and audit scheme certification	SO 9000, ISO 14000, Green light environment and Sustainable/Green strategy	ISO 9000, ISO 14000, Green Lights, Eco management and audit scheme, environmental initiatives certification programs	ISO 9000 certification, ISO 14001 and Green strategy, environmental initiatives, certification programs
10	Respondents Position	VP production, Managers, Quality head	Senior vice president, general manager and senior managers	of general manager and deputy Manager and sr. engineers	vice president and general managers

Table 6.34: Crass Compression of Issues in sustainable manufacturing

S. No.	Issues	Company ABC	Company EFG	Company MNO	Company PQR
1	**Stakeholder's commitment**	**Environmental** compliances as per governmental policies are strictly adhered **Motivation** towards Sustainability **Emphasis** on improving eco efficiency	**Environmental** compliances as per governmental policies are strictly adhered **Motivation** towards Sustainability **Emphasis** on improving eco efficiency	**Environmental** compliances as per governmental policies are strictly adhered **Cross-functional** cooperation for sustainable manufacturing	**Compliances** as per governmental policies are strictly adhered **Motivation** towards Sustainability **Emphasis** on improving eco-efficiency
2	**Sustainable Product and Process Design**	**Improve** resources utilisation (materials, water, manpower) on shop floor **Design** of products for reduced consumption of material and energy **Design** of products to reduce the use of hazardous of products and manufacturing process	**Design** of products for reduced consumption of material and energy **Minimizing** waste during machining process **Energy** efficiency during production process	**Design** of products for reduced consumption of material and energy **Design** of products to reduce the use of hazardous of products and manufacturing process **Minimizing** waste during machining process **Energy** efficiency during production process	**Design** of products for reduced consumption of material and energy **Improve** resources utilisation (materials, water, manpower) on shop floor **Use of** efficient and clean technology to reduce carbon dioxide foot print **Energy** efficiency during production process
3	**Lean Practices**	**Continuous** improvement/Kaizen/ Pokayoke/Mistake proofing	**Continuous** improvement/Kaizen/ Pokayoke/Mistake proofing **Just-in-**Time	**Continuous** improvement/Kaizen/ Pokayoke/Mistake proofing **Value** Stream Mapping (VSM)	**5S** (Sort, Shine, Set in order, Standardise, and Sustain) **Total productive** maintenance (TPM) Kanban/Pull Production

		5S (Sort, Shine, Set in order, Standardise, and Sustain) **Total productive** maintenance	**Value** Stream Mapping	**5S** (Sort, Shine, Set in order, Standardise, and Sustain)	
4	**Agile Practices and Customization**	**Flexibility** to change volume as per customer demand **Quickly** respond to customer **Use of** Automation System (CNC, DNC & Robotics)	**Use of** flexible Manufacturing system **Product** variety without increasing cost and sacrificing Quality **Quickly** respond to customer	**Quickly** respond to customer **Flexibility** to change volume as per customer demand **Use of** Automation System (CNC, DNC & Robotics)	**Flexibility** to change volume as per customer demand **Quickly** respond to customer **Product** variety without increasing cost and sacrificing quality
5	**Sustainable supply operations and distribution**	**Cooperation** with customers for green packaging **Sale** of scrap material, used materials and excess capital equipment **Supplier's** advances in developing environmentally friendly packages	**Suppliers** for environmental objectives **Investment** recovery (sale) of excess inventories/ materials **Sale of** scrap material, used materials and excess capital equipment	**Cooperation** with customers for green packaging **Supplier's** advances in developing environmentally friendly packages **Cooperation** with suppliers for environmental objectives	**Supplier's** advances in developing environmentally friendly packages **Sale** of scrap material, used materials and excess capital equipment **Cooperation** with suppliers for environmental objectives
6	**Product recovery and return practices**	**Reduce** resource utilisation **Reusability** of returned product/material **Remanufacturing** of returned products as usable product	**Reduce** resource utilisation **Remanufacturing** of returned products as usable product **Reusability** of returned product/material	**Reduce** resource utilisation (Energy and water) **Reycle** of returned product/material and **Reusability** of returned product/material	**Reusability** of returned product/material **Reduce** resource utilisation (Energy and water) **Recycle** of returned product/material

7	**Sustainable performance measures**	**Decrease** in cost of materials purchasing **Decrease** in cost of waste treatment **Decrease** in cost of energy consumption **Decrease** of consumption of hazardous/ harmful/ toxic materials **Provide** Employee training and career development program	**Decrease** of consumption of hazardous/ harmful/ toxic materials **Decrease** in cost of energy consumption **Reduction** of air emission, water waste and solid wastes **Decrease** of frequency for environmental accidents **Decrease** in cost of waste treatment	**Reduction** of air emission, water waste and solid wastes **Decrease** of consumption of hazardous/ harmful/ toxic materials **Decrease** of frequency for environmental accidents Customer satisfaction **Decrease** in cost of energy consumption	**Reduction** of air emission, water waste and solid wastes **Decrease** of consumption of hazardous/ harmful/ toxic materials **Customer** satisfaction **Provide** Employee training and career development program **Decrease** of frequency for environmental accidents
8	**Sustainable manufacturing competitiveness**	**Innovation** in product and process design **Adoption** of advanced technology **Reduced** product manufacturing cost **On time** delivery of customer products	**Improvement** in product and process quality **Reduced** product manufacturing cost **On time** delivery of customer products **Increase** in profitability Adoption of advanced technology	**On time** delivery of customer products **Improvement** in product and process quality **Improve** Corporate Social Responsibility and organizational growth **Innovation** in product and process design **Reduced** product manufacturing cost	**Improvement** in product and process quality **Reduced** product manufacturing cost **On time** delivery of customer products **Increase** in profitability

9	**Critical Success factor**	**Corporate** Social Responsibility/Sustainability **Focus on** conservation of energy consumption, and chemical handling and reduce air emissions. **Excellence** in environment, occupational health and safety management	**Cleaner** production technologies **Water** and material concentration **Waste** exchange **Energy** conservation	**Reduction** in average consumption of water **Reduction** in specific generation of waste **Corporate** social responsibilities **CSR** activities Promote green technologies	**Waste** gases use for power generation **Plastic** waste management **Solid** waste management
10	**Performance Index**	**Sustainable** Manufacturing Index = 3.26 **Sustainable** Performance Index = 3.78 **Sustainable** Manufacturing Competitiveness Index = 3.07	Sustainable Manufacturing Index = 3.86 Sustainable Performance Index = 3.30 Sustainable Manufacturing Competitiveness Index = 3.64	Sustainable Manufacturing Index = 4.23 Sustainable Performance Index = 3.62 Sustainable Manufacturing Competitiveness Index = 3.99	Sustainable Manufacturing Index = 3.94 Sustainable Performance Index = 3.34 Sustainable Manufacturing Competitiveness Index= 3.68

6.8 SUMMARY

In this chapter, four case studies one from each sector i.e. automobile, electrical & electronics, machinery and process sectors were considered. The case studies carried out to get in-depth knowledge of various issues of sustainable manufacturing. All companies included in the study have shown awareness towards sustainable manufacturing. They are gradually changing themselves to face the fierce competition. Stakeholders are committed environmental compliances as per governmental policies in all companies ABC, EFG, MNO and PRQ.

In general, Design of products for reduced consumption of material and energy is the most preferred practice for SPPD in companies EFG, MNO and PQR, whereas for company ABC, Improve resources utilisation (materials, water, manpower) is most preferred practice for SPPD. Continuous improvement/Kaizen/ Pokayoke/Mistake proofing is the most preferred practice for companies ABC, EFG and MNO, whereas company PQR used 5S (Sort, Shine, Set in order, Standardise, and Sustain) for Lean practices. Flexibility to change volume as per customer demand is the most preferred in company ABC & PQR whereas in the company EFG, Use of flexible Manufacturing system and for MNO Company Quickly responds to customer for APC. Cooperation with customers for green packaging is most preferred practice for SSOD in the companies ABC & MNO whereas for company EFG Suppliers for environmental objectives and company PQR preferred Supplier's advances in developing environmentally. Reduce resource utilisation is most preferred practice for PRRP in ABC, EFG and MNO companies whereas in company PQR, reusability of returned product/material is most preferred practice.

The companies are motivated to think in long term implications. Sustainable manufacturing has thus become imperative. This long term orientation is reflected in terms of company's emphasis on internal environmental management, customer cooperation with environmental consideration, green purchasing deployment of continuous improvement strategies, closer supplier relationship etc.

For this four cases an in-depth insight has been gained about the issues of sustainable manufacturing. Based on these knowledge findings a framework is proposed in the next chapter for implementation and assessment of sustainable manufacturing.

CHAPTER 7. A FRAMEWORK FOR SUSTAINABLE MANUFACTURING

7.1 INTRODUCTION

In the present era, there is an urgent need to make all industrial products sustainable to reduce environmental impact in the Production and consumption sector. Sustainable manufacturing is becoming crucial for businesses more than ever before. Due to the emergence of sustainability in manufacturing, there is a change in the thinking of manufacturer to consider the sustainable strategies in business operations. Today's main aim is to boost economic development, for the accomplishment of the objectives of firms via re-thinking their strategy by implementing the sustainable practices.

To create a future sustainable world it is necessary that manufacturing industries in India take interest and help in delivering products that meet sustainability and to develop sustainable processes. To accomplish this, few changes have to be implemented in manufacturing industry with new models and skills. The onus must be on minimizing waste and emissions and low energy consumption. There is a need for continuous improvement in setting appropriate strategies and policies to improve manufacturing sustainability in Indian manufacturing industries.

Due to the increasing pressure from stakeholders, the industries are now engaged in activities that are sensitive to the sustainable system. Thus, the organizations now seek to learn about the strategies to cope with it to achieve advantage in manufacturing competitiveness and to enhance their sustainable performance. It is observed from the survey that Indian manufacturing companies moderately adopted sustainable manufacturing. In this chapter a framework is proposed for implementation and assessment.

7.2 FRAMEWORK

Based on the findings of the survey from chapter 4 & 5 and Chapter 6 from experience gained through case studies, a framework for implementation and assessment of sustainable manufacturing is proposed. Figure 7.1 gives the schematic of proposed framework.

Either president or CEO sets Vision/mission of a company. In line with the mission stakeholders of the company formulate their commitment towards manufacturing sustainability in the company. The stakeholders are the pillars of companies. The different operations and the processes are initiated by the internal or external stakeholders of the company. Nowadays sustainable manufacturing is a major issue for stakeholders to implement in the Indian manufacturing companies.

The framework for sustainable manufacturing is the outcome of survey results and the case study results. The framework is divided in to two phases one is Implantation phase and another assessment phase. Basically this framework is the outcome of proposed theoretical Model in chapter 2 and survey methodology is used for this study as discussed in chapter 3. 345 usable responses were collected and analysed through Structural equation modeling. From the results it is found the stakeholders' commitment for sustainable manufacturing is directly related to the sustainable manufacturing practices. Here Sustainable manufacturing index was calculated. It is also found from the survey results that sustainable manufacturing is directly related to Sustainable performance measures and sustainable manufacturing competitiveness and also sustainable performance measures are directly related to the sustainable manufacturing competitiveness. Here sustainable performance index and sustainable manufacturing competitiveness index was calculated. Survey results were analysed though case studies. Finally, A Framework for sustainable manufacturing was proposed.

In the implementation phase, sustainable manufacturing practice were implemented with the help of internal and extern stakeholders and in assessment phase, assessment of sustainable manufacturing practices was captured through the sustainable manufacturing index, sustainable performance index and sustainable manufacturing competitiveness index. Table 7.1 gives a list of tasks to be performed in the framework.

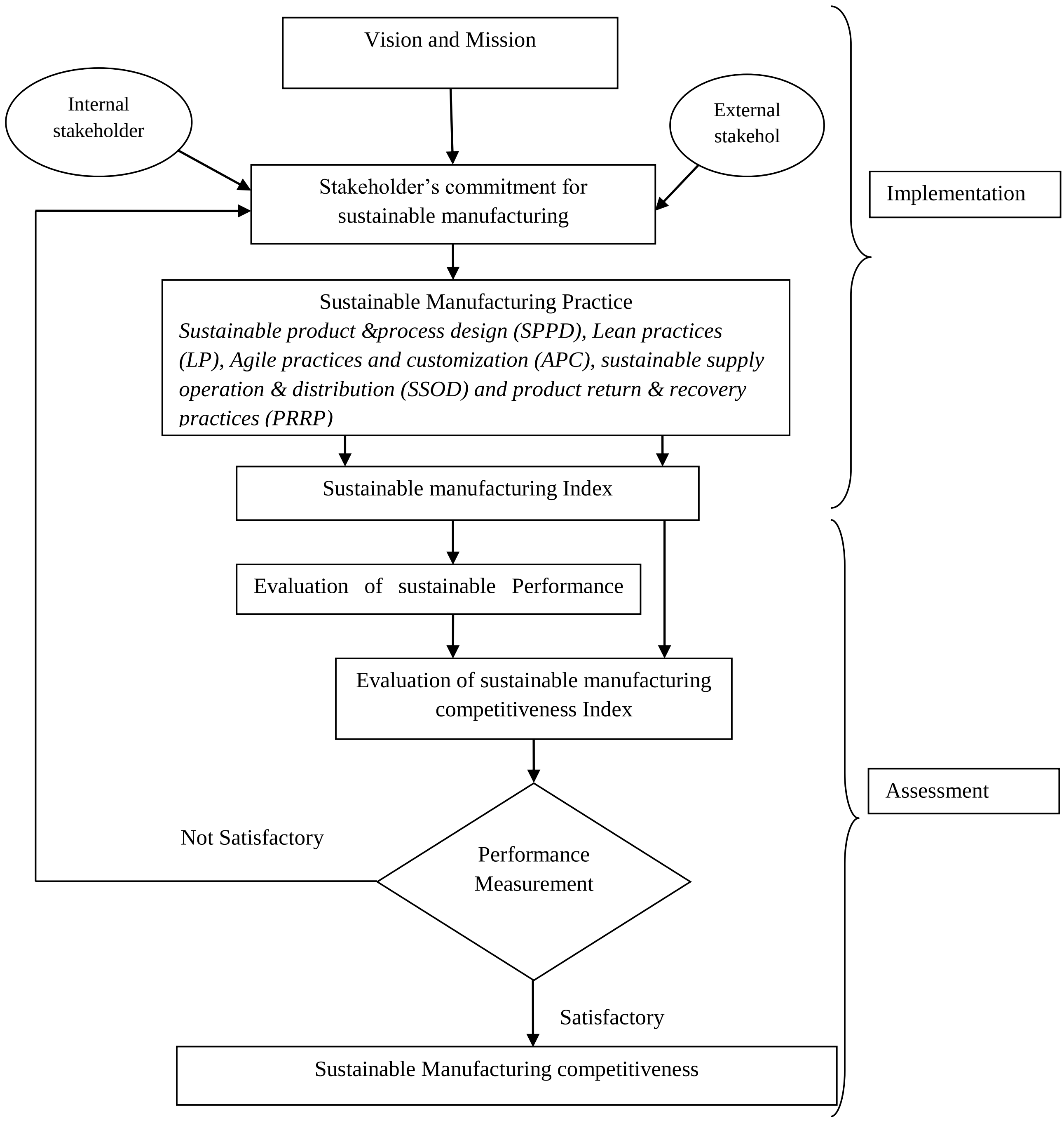


Figure 7.1: Framework for sustainable Manufacturing

Table 7.1: Tasks performed in framework

S. No.	Task	To be performed by
1	Vision/mission	CEO/President
2	Commitments for sustainable manufacturing	Internal and external stakeholders of the company
3	Implementation of sustainable manufacturing	Internal stakeholders and External stakeholders i.e. Top management/Manufacturing/Marketing R&D/Human Resource Managers/ suppliers
4	Sustainable manufacturing index	Manufacturing Function
5	Sustainable performance index	Manufacturing Function
6	Sustainable manufacturing competiveness Index	Manufacturing Function

To know the present and the future requirement of sustainable manufacturing in the company, the involvement of internal and external stakeholders is necessary. The purpose of the stakeholder's involvement is to identify industry practices in sustainability segment. An in-depth study of sustainability segment helps in the identification of the best practices and market trend that ultimately leads to stakeholder's commitment for sustainability.

Both internal and external stakeholders are committed for sustainable manufacturing and formulate the sustainable manufacturing practices in the company. The various sustainable manufacturing practices, i.e., *Sustainable product &process design (SPPD), Lean practices (LP), Agile practices and customization (APC), sustainable supply operation & distribution (SSOD) and product return & recovery practices (PRRP)* need to involve for SM formulation. So that the realistic manufacturing task could be pursued. For this purpose PMUP System model (**P**-*Pre-manufacturing (SPPD),* **M**-*Manufacturing (LP, APC),* ***U****-Use (SSOD)-****P****-Post Use (PRRP))* may be followed

Performance measurement is essential to identify and rectify the present weaknesses. In today's dynamic and global business environment, a company should regularly monitor its performance of manufacturing and other business functions. The sustainable manufacturing Index, sustainable performance index and sustainable manufacturing competitiveness index may be computed by manufacturing function as suggested in Chapter 4.

Sustainable manufacturing Index (SMI) may be calculated by equation no. (1). The scores of the SM practices (on five point scale) may be received from the respondents and then indices for all the practices calculated. The weighted average may be calculated by the help of structural equation model (SEM) results.

Thus the SMI (I_{SM}) may be obtained from the equation given below

$$I_{SM} = W_{SPPD}\, I_{SPPD} + W_{LP}\, I_{LP} + W_{APC} I_{APC} + W_{SSOD} I_{SSOD} + W_{PRRP} I_{PRRP} \quad (1)$$

$W_{SPPD}, W_{LP}, W_{APC}, W_{SSOD}, W_{PRRP}$ = weighted average of each practice and
$I_{SPPD}, I_{LP}, I_{APC}, I_{SSSOD}, I_{PRRP}$ = Indices for all practices

Sustainable performance index (SPI) may be calculated as equation no. (2). The weight may be taken from the SEM model and I_{SM} is obtained from equation no. (1). The SPI obtained from the following equation

$$I_{SPM} = \beta * I_{SM} \quad (2)$$

β = weight to the sustainable manufacturing (SM) as per SEM Model
I_{SM} = Sustainable manufacturing Index (SMI) (I_{SM})

Sustainable manufacturing competitiveness index (SMCI) (I_{SMC}) may be calculated as equation no. (3). The weight may be taken from the SEM model and I_{SM}, I_{SPM} is obtained from equation (1) and (2) respectively.

$$I_{SMC} = W_{SM}\, I_{SM} + W_{SPM}\, I_{SPM} \quad (3)$$

If the sustainable manufacturing competitiveness is satisfactory then company is competitive in sustainable manufacturing, otherwise mission, sustainable manufacturing practices, sustainable performance and manufacturing competiveness may be reviewed by the stakeholders for corrective action. Proper emphasis of each aspect of this framework helps a company to correct its weakness and to make its manufacturing sustainability strong.

7.3 PMUP Model

PMUP System Model (**P**-*Pre-manufacturing (SPPD),* **M**-*Manufacturing (LP, APC),* ***U****-Use (SSOD)-****P****-Post Use (PRRP))* is proposed to implement the sustainable manufacturing. The manufacturing systems has three facets, i.e., products, processes and systems. These three facets are interrelated; manufacturing processes transform materials into products. Processes and products are designed and managed through different manufacturing systems. The products have four life cycle stages pre-manufacturing, manufacturing, use and post use. Sustainable manufacturing is worked upon the product life cycle approach and achieve the triple bottom line (TBL) objectives in terms of environmental, economical and social aspects of sustainability.

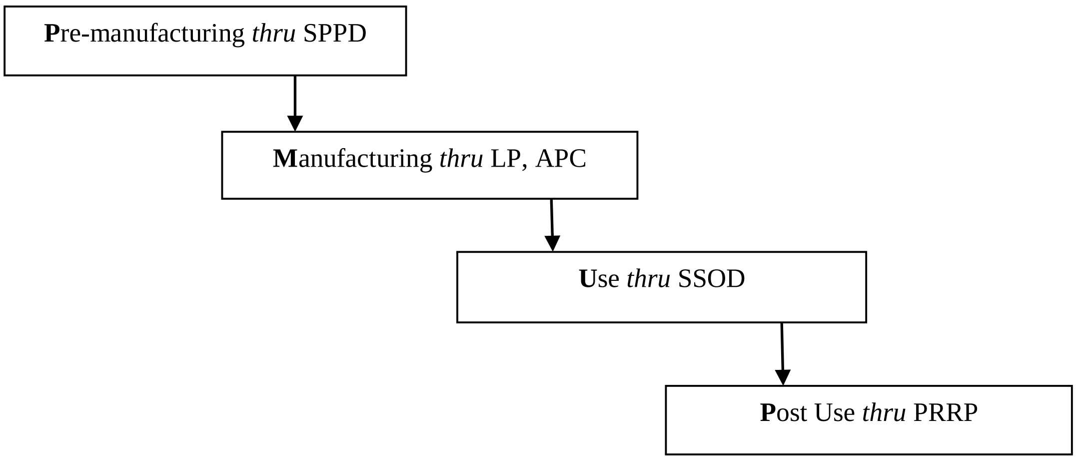


Figure 7.2: PMUP Model

From the review of literature, results of survey and case studies, this research integrate the sustainable manufacturing practices into product life cycle stages. This research is an attempt to incorporate the sustainable manufacturing practices with product life cycle approach. Figure 8.2, it is observed that the **P**re-manufacturing may achieve thru sustainable product and process design (SPPD), **M**anufacturing may achieve thru Lean Practices (LP) and Agile practices and customization (APC), **U**se may achieve thru sustainable supply operations and distribution (SSOD) and **P**ost Use may achieved by product returns and recovery practices (PRRP). PMUP system model is helpful for researchers and mangers to implement and assessment of sustainable manufacturing.

7.4 DISCUSSION

It is seen that formulation and assessment of sustainable manufacturing involve various stakeholders in a company (internal and external), namely management, employees, customers and suppliers. Following observations can be made from the proposed framework:

- Sustainable manufacturing is not a static function. It evolves over the time. There is a need to review SM periodically.
- The effectiveness of the sustainable manufacturing can be captured by sustainable manufacturing competitiveness index (SMCI) (I_{SMC}).
- It is to be noted that every manufacturing firm is involved in implementation of sustainable manufacturing. It cannot be visualised in isolation.
- Based on the survey of Indian manufacturing companies and case studies it can be inferred that sustainable manufacturing is a driving force for continual improvement in terms of environmental, economic and social aspects. It enables a company to satisfy a wide range of requirement through a series of sustainable improvement practices such as *SPPD, LP, APC, SSOD and PRRP*. Sustainable manufacturing enables a company focus on manufacturing competitiveness in terms of cost, quality, delivery, flexibility, innovation and clean technologies. Its implementation and assessment involves a variety of functions of a company such as design, manufacturing, R & D, marketing and human resource etc.

7.5 SUMMARY

Implementation and assessment of sustainable manufacturing practices coherent with the sustainable performance is essential to achieve the manufacturing competitiveness. A detailed guideline for implementation and assessment of sustainable manufacturing is presented in the proposed framework. Few elements of this framework such as SM practices may be customized according to the specific need and manufacturing sector. SM practices and sustainable performance may be reviewed frequently to achieve sustainable manufacturing competiveness of the company.

CHAPTER 8. SUMMARY AND CONCLUSIONS

8.1 INTRODUCTION

Sustainable manufacturing is widely recognized as an integral part of a company's overall corporate sustainability to gain and retain sustainable manufacturing competitiveness. Environmental management, clean technologies and corporate social responsibilities have contributed to an explosive growth for the implementation of sustainable manufacturing within companies. The design for environment, lean practices and clean technologies have harnessed a wide range of benefits for companies, including reduced costs, increased productivity, greater flexibility, and higher quality, enabling companies to improve their competitive position.

Sustainable manufacturing has attracted serious research attention in the current scenario. Numerous articles dealing with the theory and practice of sustainable manufacturing have been published over the years, but the topic is still under considerable development and debate.

This research was aimed at examining the sustainable manufacturing practices in Indian manufacturing companies, through questionnaire survey. The main objective of this research was to gain insights of sustainable manufacturing issues in automobile, electrical & electronics, machinery, and process sector companies. The specific objectives of the research were to:

- Comprehensive literature survey to identify the need of sustainable manufacturing in Indian context
- Develop a theoretical framework for issues of sustainable manufacturing
- Examine the measurement model of sustainable manufacturing practices
- To explore the relationship between sustainable manufacturing and stakeholder's commitment.
- To explore the relationship between sustainable manufacturing and sustainable performance measures
- To explore the relationship between sustainable manufacturing and sustainable manufacturing competitiveness.

- To investigate the relationship between stakeholder's commitment and sustainable performance measures
- To investigate the relationship between stakeholder's commitment and sustainable manufacturing competitiveness.
- To investigate the relationship between sustainable performance measures and sustainable manufacturing competitiveness.
- To study the comparative analysis of sustainable manufacturing practices, stakeholder's commitment, sustainable performance measures and sustainable manufacturing competitiveness
- Develop the case studies in four sectors automobile, electrical & electronics, machinery and process companies to validate the results coming from survey.
- Evolve a framework for evaluation of sustainable manufacturing and examine its possible linkage with sustainable performance and sustainable manufacturing competitiveness.

In this research effort, a survey of Indian manufacturing companies is conducted to study several sustainable manufacturing issues. Survey encompassed companies from four major sectors viz. automobile, electrical & electronics, machinery, and process. Earlier reported studies in Indian context were either restricted to a particular sector or had a small sample. In the present survey of sustainable manufacturing, an attempt was made to examine various issues such as *Sustainable product & process design (SPPD), Lean practices (LP), Agile practices and customization (APC), sustainable supply operation & distribution (SSOD) and product return & recovery practices (PRRP)* etc. in four major industry sectors.

A database of 1425 companies had been created and a structured questionnaire was administered. These companies were pooled in database from industrial directories and included companies from all over India. Selection criterion was based on two parameters, i.e., number of employees (≥10) and annual sales (≥ 0.15 million US $). After reminders, phone calls, e-mails and re-reminders, 345 filled responses have been received, which gives 24.21% response rate. Out of the 345 respondents, 160 (46.4%) were from middle management with 06 - 10 years' experience. Vital statistics of respondents is given in Table 8.1.

Four case studies were developed to validate the results observed in the survey. One case form each sector, viz. automobile, electrical & electronics, machinery, and process is selected for the study. This chapter presents summary of research findings, and major contributions of the research. Furthermore, implications of the study for managers and academics are stated and limitations and scope for further research are also given.

Table 8.1: Vital statistics of survey

S. No.	Industry sector	Questionnaire sent	Responses received (%)
1	Automobile	475	115 (24.20)
2	Electrical & electronics	280	65 (23.21)
3	Machinery	235	75 (31.91)
4	Process	435	90 (20.68)
5	Total	1425	345 (24.21)

8.2 SUMMARY OF THE WORK DONE

In summary, the work done can be highlighted as given below.

- A literature survey was conducted to identify contemporary research issues and their relevance in Indian context. As an outcome of the survey, a comprehensive bibliography is prepared. It is expected that this bibliography will be of use to researchers and students of sustainable manufacturing.
- Based on the Literature survey and discussions with practitioners, a set of research hypotheses were framed.
- A comprehensive questionnaire was prepared to identify response of manufacturing companies on several issues related to sustainable manufacturing.
- A set of general awareness of sustainability issues such as ISO 9000 certification, significant environment policy, Sustainable/Green strategy, Energy efficiency program and Environmental initiatives, certification programs are identified in Indian context. Indian companies follow a progressive path to achieve sustainability.

- The various sustainable manufacturing practices, viz Sustainable product &process design (SPPD), Lean practices (LP), Agile practices and customization (APC), sustainable supply operation & distribution (SSOD) and product return & recovery practices (PRRP) general and specific sector company were identified.
- Various performance measures for sustainability such as environmental, economical and social performance were identified. Similarly, product manufacturing cost, product and process quality, on time delivery of customer products, innovation in product and process design, adoption of advanced technology, increase in profitability, improvement in corporate social responsibility and organizational growth were identified as sustainable manufacturing competitiveness.
- Multifactor congeneric model through structural equation modeling (SEM) to analyze sustainable manufacturing and the relationship of stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness was developed. It was found that *SPPD, LP APC, SSOD and PRRP* practices constitutes sustainable manufacturing and sustainable manufacturing is significantly positive related to sustainable performance and sustainable manufacturing competitiveness. Form the SEM results it is found that stakeholder's commitment insignificantly negative related to sustainable performance and sustainable manufacturing competitiveness and significant positively related to sustainable manufacturing.
- Performance Index is computed on the basis of structural equation modeling (SEM) results. The sustainable manufacturing index is 3.84, sustainable performance index is 3.28 and sustainable manufacturing competitiveness Index is 3.62 computed for Indian manufacturing companies. This implies that the Indian manufacturing companies are moderately adopted/implemented SM practices.
- A sector wise comparative analysis is performed to identify the key sustainable manufacturing practices. Table 8.2 show the best practices adopted by Indian manufacturing companies.

Table 8.2: Best practices adopted

S. No.	SM Practices	Automobile	Electrical & Electronics	Machinery	Process
1	SPPD	Use of efficient and clean technology to reduce carbon di oxide foot print	Improve resources utilisation (materials, water, manpower) on shop floor	Improve resources utilisation (materials, water, manpower) on shop floor	Use of efficient and clean technology to reduce carbon di oxide foot print
2	LP	Continuous improvement/Kaizen/ /Pokayoke/Mistake proofing	Continuous improvement /Kaizen/ Pokayoke/ Mistake proofing	Continuous improvement/ Kaizen/ Pokayoke/Mistake proofing	Total productive maintenance (TPM)
3	APC	Flexibility to change volume as per customer demand	Flexibility to change volume as per customer demand	Product variety without increasing cost and sacrificing quality	Flexibility to change volume as per customer demand
4	SOOD	Sale of scrap material, used materials and excess capital equipment	Second-tier supplier environmentally friendly practice evaluation	Sale of scrap material, used materials and excess capital equipment	Cooperation with suppliers for environmental objectives
5	PRRP	Remanufacturing of returned products as usable product (Recondition and Repair)	Reduce resource utilisation (Energy and water)	Remanufacturing of returned products as usable product (Recondition and Repair)	Reduce resource utilisation (Energy and water)

- To gain the in-depth knowledge of sustainable manufacturing in Indian manufacturing companies, four cases are developed. A methodology is proposed for case study. A critical comparison of case companies on various issues is also made. From the case study; it is found that machinery sector is in top position having implemented/adopted sustainable manufacturing practices. Sustainable performance index and sustainable manufacturing competitiveness index for machinery sector is far better than automobile, electrical & electronics and process sector.

- Based on learning through survey and cases, a framework for implementation and assessment of sustainable manufacturing is proposed.

8.3 RESEARCH FINDINGS

Twelve hypotheses were framed (given in Chapter 2) based on the literature and research questions of this study.

8.3.1 Sustainable Manufacturing and Practices (Dimensions)

In the literature on sustainable manufacturing, there is a plethora of studies available in the developed countries (Law & Gunasekaran, 2012; Yuan et al., 2012; Lee & Lee, 2014; Govindan et al., 2015a), however, the majority of them focus on the supply chain and logistics. This study aim to exploring the inclusion of sustainable manufacturing practices in term of sustainable product and process design (SPPD), Lean Practices (LP), Agile practices and customization (APC), sustainable supply operations and distribution (SSOD) and product recovery and return practices (PRRP). The SM practices (SPPD, LP, APC, SSOD and PRRP) can be used by the managers focusing on improving the manufacturing sustainability within the organisation. SEM results shown in Table 4.37 suggest that sustainable product and process design (SPPD), Lean Practices (LP), Agile practices and customization (APC), sustainable supply operations and distribution (SSOD) and product recovery and return practices (PRRP) constitute the sustainable manufacturing. The SPPD and SSOD contribute more compared to other practices, LP and APC are the second level contributors for sustainable manufacturing and PRRP is lagging behind as compared to other practices in Indian manufacturing industries. The result supports hypotheses H1,2, H3, H4, H5, H6 and reaffirm the assertion of sustainable manufacturing with five practices, i.e., sustainable product and process design (SPPD), Lean Practices (LP), Agile practices and customization (APC), sustainable supply operations and distribution (SSOD) and product recovery and return practices (PRRP).

8.3.2 Stakeholder's Commitment Sustainable Manufacturing

Findings of the research indicate a significant relationship between stakeholder's commitments and sustainable manufacturing. This implies that stakeholders of the company can have an impact on sustainable manufacturing. The stakeholder (internal or external) leads to manufacturing sustainability in terms of use of efficient and clean technology, minimizing waste during machining process, use of flexible manufacturing systems, Cooperation with suppliers for environmental objectives and customer satisfaction. Few earlier studies by Theyel & Hofmann, (2012) and Nejati et al., (2014) have identified the relationship of sustainability practices and stakeholders involvement. In this research, it is also found that stakeholder's commitment plays an important role for the adoption of sustainable manufacturing in Indian industries. These findings support the hypothesis H7.

8.3.3 Stakeholder's Commitment and Sustainable Performance Measures

This research investigates the relationship between Stakeholder's commitment and sustainable performance measures through hypothesis H8, i.e., there exists a relationship between stakeholder's commitment and sustainable performance measures. Sarkis et al. (2010) and Blome et al. (2014) investigate the stakeholder orientation towards the financial and environmental performance. The found the positive relationship between stakeholder orientation and performance. In this research, the relationship between stakeholder's commitment and sustainable performance is negatively associated. These findings are not supported H8. Although Yu & Ramanathan, 2014 also found the negative relationship between stakeholder involvement for sustainability and environment performance.

8.3.4 Stakeholder's Commitment and Sustainable Manufacturing Competitiveness

This research also investigated the relationship between stakeholder's commitment and sustainable manufacturing competitiveness through H9. The SEM results indicate that a negative and insignificant relationship between stakeholder's commitment and sustainable manufacturing competitiveness. These finding are not supported H9. This implies that stakeholder's commitment does not lead to firm's manufacturing competitiveness directly. Stakeholder's commitment helps a manufacturing firm for manufacturing competitiveness through sustainable manufacturing practices. Although Jin et al. (2013) also found that the external stakeholder, i.e., supplier's involvement has insignificant relationship with manufacturing firm's competitive advantage.

8.3.5 Sustainable Manufacturing and Sustainable Performance Measures

In this research, statistical analysis and results demonstrate a significant relationship between sustainable manufacturing and sustainable performance measures. This implies that sustainable manufacturing practices help in improving sustainable performance of the companies in terms of environmental, economical and social performance.

The hypothesis H10 is supported by the SEM results and is in accord with earlier by Severo et al. (2015) and Chuang & Yang (2014), they affirm a positive relationship between sustainable manufacturing practices and sustainable performance. Thus, the findings of this research are in line with the earlier research.

8.3.6 Sustainable Manufacturing and Sustainable Manufacturing Competitiveness

Adoption of sustainable manufacturing in Indian industries significantly affects the manufacturing competitiveness of the company. The statistical result indicates a significant and positive relationship between sustainable manufacturing and sustainable manufacturing competitiveness. These results confirm the hypothesis H11. The outcome supports the earlier research Markley et al. (2007), Gallardo-Vázquez et al. (2014) and Vanpoucke et al. (2014). They demonstrate importance of adoption of sustainable manufacturing practices leads to the manufacturing competitiveness. The recent study by Mitra & Datta (2014) also investigates the significant and positive relationship of environmentally sustainable product design & logistics and competiveness. Thus, the hypothesis H11 is supported.

8.3.7 Sustainable Performance Measures and Sustainable Manufacturing Competitiveness

The findings of this research indicate a significant and positive relationship between sustainable performance and sustainable manufacturing competitiveness. This implies that the sustainable performance of the company leads to the manufacturing competitiveness of the company. The previous research by Tan et al. (2011), Mitra & Datta (2014) and Despotovic et al. (2015) also proved that the sustainable performance improved sustainable manufacturing competitiveness. The research findings support the view of a positive and significant impact of sustainable performance measures on the sustainable manufacturing competitiveness. Thus, findings support the hypothesis H12.

8.4 KEY INSIGHTS MAJOR CONTRIBUTIONS OF THE RESEARCH

This thesis has attempted to fill some of the gaps in the contemporary research on sustainable manufacturing, especially in the Indian context. An extensive multi-sector survey of Indian manufacturing companies on sustainable manufacturing is conducted.

8.4.1 Key Insights

Based on the learning from survey and case studies, sustainable manufacturing practices, sustainable performance measures and manufacturing competitiveness are identified for Indian manufacturing companies and also the relationship of stakeholder's commitment is identified. The study depicted that sustainable manufacturing of most companies focused on agile practices and customization (APC) and lean practices in the organisations. Indian manufacturing companies need to work upon the other practices like SPPD, SSOD and PRRP to achieving sustainability in the manufacturing. The key insights from the study are given as:

- The Indian manufacturing companies give greater emphasis on the agile practice & customization and Lean practices for sustainable manufacturing issues.
- Sustainable manufacturing contributes to the competitive success.
- Sustainable manufacturing is not limited to a few decisions about environmental management and clean technology, but it is defined by the total pattern of decisions across the full of product life cycle (PLC) in manufacturing system.
- The typical PMUP model followed by the Indian companies is Pre-manufacturing (SPPD) - Manufacturing (LP, APC) - Use (SSOD) - Post Use (PRRP). Hence it may be mentioned that pre-manufacturing achieved by SPPD, manufacturing is achieved by LP and APC, use is achieved by SSOD and post use is achieved by PRRP.
- It seems that Indian manufacturing companies are still in infantile stage as per the sustainable product and process design & development. Product returns and recovery practice required a huge investment. Hence the Indian companies should focus on these issues.

8.4.2 Contributions of the Research

The contribution to knowledge recorded in the thesis is fourfold. Firstly a comprehensive bibliography on sustainable manufacturing issues is prepared and literature is classified. A review of the literature on sustainable manufacturing shows that there has been little work reported on study of SM in Indian manufacturing companies. Secondly, an extensive multi-sector survey of Indian manufacturing companies' is conducted to investigate various issues in SM. The companies belonging to automobile, electronics, machinery, and process sectors have participated in the study. The third contribution to knowledge is made through the development of four cases to obtain further insight on sectoral sustainable manufacturing issues. Forth contribution to knowledge is based on the survey and case studies learning, a framework for implementation and assessment of sustainable manufacturing is proposed. Major contributions of the research can be highlighted as:

A comprehensive bibliography is prepared and literature is classified.

- Sector wise sustainable awareness practices identified.
- Sustainable manufacturing practices are identified specific to the Indian context.
- Structural equation model is developed to identify the relationship between stakeholder's commitment, sustainable manufacturing, sustainable performance measures and sustainable manufacturing competitiveness
- A quantitative index is suggested to measure sustainable manufacturing, sustainable performance and sustainable manufacturing competitiveness.
- A methodology is suggested for case studies.
- Four cases are developed and analyzed (one from each manufacturing sector i.e. automobile, electronics, machinery, and process) for the better understanding of the survey results.
- A framework is proposed, which captures the influence of internal and external stakeholder's commitment for the adoption of sustainable manufacturing strategies to address the triple-bottom line. This framework may guide to the industry professionals to implementation SM practices. The framework also depicts the Implementation and

assessment of sustainable manufacturing practice achieving the TBL in terms sustainable performance measures and sustainable manufacturing competitiveness.

- PMUP system model for Indian companies is suggested.
- Sustainability in manufacturing is balance by PMUP model to address the triple bottom line (TBL): environmental stewardship, economic growth, and social well-being.

8.5 IMPLICATION OF THE RESEARCH

Present research may be very helpful for Indian manufacturing industry towards a better understanding and management of manufacturing sustainability. The results of this study provided a framework by identifying sustainable manufacturing practices (SPPD, LP, APC, SSOD and PRRP) and their relationships with sustainable performance to achieve manufacturing competitiveness. This study suggests that the sustainable manufacturing practices have significant impacts on sustainable manufacturing initiatives, performance and competitiveness.

8.5.1 Managerial Implications

- The present research may help the stakeholders to develop strong regulatory norms/policies to promote the sustainable manufacturing practices in Indian manufacturing industries. This research may help production/manufacturing managers/practitioners to understand various issues related to sustainable manufacturing and how they can be used gainfully to improve their practices and performances towards sustainable development.
- This study has revealed that adoption of SM practices in Indian manufacturing companies such as reduction of energy consumption, resource utilisation, emissions and solid waste can see significant improvements in their sustainable performance.
- The equations for performance indices given as equation no. 7.1, 7.2 and 7.3 respectively can act as templates for assessing the sustainable manufacturing, sustainable performance and manufacturing competitiveness. Using these equations (templates), effectiveness of sustainable manufacturing implementation can be evaluated.

- By building on the work of previous studies conducted in the industrialized countries, this study helps to provide a better understanding on sustainable manufacturing competitiveness in a dynamic and changing business environment, and points out what sustainable manufacturing means for Indian manufacturers.

8.5.2 Implications for Academia

The study also provides several implications for academics:

- The questionnaire developed can be improved further to examine linkages with other sustainability functions and evolving paradigms such as reverse logistics, cleaner production etc.
- A set of sustainable performance measures can be developed further.
- The findings of the study can act as a foundation for developing a resource based view of a particular sector.
- The case studies developed in this research can be used as a pedagogic tool performs.
- The bibliography on sustainable manufacturing may be used for further research on the topic and as an aid to class room teaching.
- This research provides the basis to stakeholder's commitment to enhance the sustainable manufacturing practices and sustainable performance measures to achieve the sustainable manufacturing competitiveness.

8.6 LIMITATIONS AND SCOPE FOR FUTURE WORK

The four major manufacturing sector companies (automobile, electrical & electronics, machinery, and process) have been included in our study. Companies from all parts of the country (East: 13 (3.8%), West: 46 (13.3%), North: 270 (78.3%), and South: 16 (4.6)) responded to our questionnaire. The response rate is 24.21 %, which comes under the range as suggested by Flynn et al. (1990) (between 10 to 30 %) for such type of studies. However, this study has some limitations, which future researchers could consider.

- The sample size may increase; as suggested by Hair et al. (2013).
- The large industries of Indian manufacturing across four sectors have been considered, the study can be further taken up to the micro, small and medium enterprises (MSME) of the Indian manufacturing scenario.
- The similar study may be done in the different countries on the Globe by using the similar methodology and the framework suggested in this study. The questionnaire can be further developed as that it can be used for a global survey across various sectors and then comparison can be made between the Indian companies and their global counterpart.
- LISREL, R and Mplus software may also be used for the analysis of structural equation modelling.
- Future search may also adopt multivariate regression analysis for the data analysis purpose
- In future longitudinal studies can be conducted by considering the other sustainable manufacturing practices like mass customization, smart manufacturing practices etc.
- This study considered the sustainable performance combine with environmental, economical and social; the further research may include the dimensions of TBL separately.
- Finally, a comprehensive software system could be developed to assess the sustainable manufacturing index, sustainable performance index and manufacturing competitiveness index to explore the issues of sustainable manufacturing.

8.7 CONCLUDING REMARKS

The study evolved Indian specific practices, which are explored through the review of literature and the discussion with industry professionals. The variables on sustainable manufacturing practices and sustainable performance measures may be useful for academicians and practitioners for their process. The study has developed sustainable manufacturing model which comprises five practices viz. *Sustainable product &process design (SPPD), Lean practices (LP), Agile practices and customization (APC), sustainable supply operation & distribution (SSOD) and product return & recovery practices (PRRP).*

It is further observed that the stakeholder's commitment play an important role to improve the sustainable performance and sustainable manufacturing competitiveness of the company, for this one should focus on the contextual parameters in terms of sustainable manufacturing practices. In the regard, a Multifactor congeneric model to analyse the relationship of stakeholder's commitment, sustainable manufacturing, sustainable performance and sustainable manufacturing competitiveness is developed. A sector wise comparative analysis is performed. The result of the study reveals that the Indian companies are more focused on agile practices and customization (APC) practices and lean practices. The four case studies one from each sector is developed to assess the in-depth knowledge.

The basis of sustainable manufacturing is the notion of making dynamic changes in the manufacturing structure, so as to create manufacturing competitiveness. Sustainable manufacturing concept is addressed directly toward providing a strategic framework in manufacturing into which the individual decisions about various practices such as SPPD, LP, APC, SSOD and PRRP can be properly addressed. The study reveals that the Indian manufacturing companies need to focus on economical performance to achieve the best sustainable manufacturing competitiveness. They need to work on reduction of raw materials and energy consumption, and expresses on waste treatment and waste discharge to improve the overall economy of the courntry. Other than this, the performance of Indian companies is observed to be relatively significant in terms of environmental and social performance.

Finally, Indian manufacturing companies have realized the benefits of sustainable manufacturing and have started taking proactive approach towards sustainability responsiveness. The validated model and findings suggest that this study can help to improve the understanding of sustainable manufacturing issues among Indian manufacturing companies, lead to better decision making and strategies for implementing SM practices.

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Appendix-1

Survey questionnaire

Part A

1. Name of Company:

2. Address:

3. Region of the company: (a) East (b) West (c) North (d) South

4. Nature of Ownership: (a) Private Limited [ ] (b) Public Limited [ ] (c) Public Sector [ ]

5. Type of Company: (a) Automobile [ ] (b) Electrical & Electronics [ ] (c) Machinery [ ] (d) Process [ ] (e) other.......................

6. Number of Employees: (a) 100 [ ] (b) 101- 500 [ ] (c) 501 – 1000 [ ] (d) 1001 – 5000 [ ] (e) 5001 and above [ ]

7. Name of respondent (optional):

8. Age:

9. Gender

10. Email Address:

11. Experience in Years:

12. Position in the Company:

    (a) Junior Management [ ] (b) Middle Management [ ]
    (c) Senior Management [ ] (c) Owner/Promoter/CEO [ ]

13. How long you been with your current Company:

    (a) Less than 3 Years [ ] (b) 3-6 Years [ ] (c) 6-12 Years [ ]
    (d) more than 12 Years [ ]

14. Your Area of work in the Company (Please Tick)

    (a) R & D/Product Design and Development Cell [ ]
    (b) Production/ Manufacturing [ ]
    (c) Purchasing/Supply chain [ ]
    (d) Marketing and Sales [ ]
    (e) Information Technology/ Information System [ ]

(f) Finance [ ]
(g) Human Resource [ ]
(h) Any other (Please Specify) ....

15. Please indicate the region of parent company

(a) An Indian parent company [ ] (b) An European parent company [ ]
(c) A Japanese parent company[ ] (d) A US parent company [ ]
(e) Other foreign parent company (Please Specify)..

16. Does your company have ISO 9000 certification?

(a) YES [ ] (b) NO [ ]

17. Does your company have the significant environment policy?

(a) YES [ ] (b) NO [ ]
If yes, for how long it existed...

18. Does your company follow Sustainable/Green strategy?

(a) YES [ ] (b) NO [ ]

19. Do you practice any energy efficiency program in your organization?

(a) YES [ ] (b) NO [ ]

20. Do you participate in environmental initiatives, certification programs?

(a) YES [ ] (b) NO [ ]

If yes, Please indicate

(1) ISO 14000 [ ] (b) Eco-Management and Audit Scheme [ ]
(c) EPA [ ] (c) Green Lights [ ]

21. Please indicate your company's annual sales turnover (in million US $ of Rupees):

(a) 0.15 – 0.75[ ] (b) 0.75 – 1.5 [ ] (c) 1.5 –7. 5 [ ]
(d) 7.5-15 [ ] (e) 15-75 [ ] (f) Above 75 [ ]

22. Please indicate the growth of the organization during the last three years:

(a) Increase up to 10% per year [ ] (b) Increase more than 10% per year [ ]
(c) Constant [ ] (d) Decrease up to 10% per year [ ]

23. Please indicate the market share of the organization during the last three years:

(a) Increase up to 10% per year [ ] (b) Increase more than 10% per year [ ]
(c) Constant [ ] (d) Decrease up to 10% per year [ ]

24. Does your Company adopted/implemented Sustainable manufacturing?

(a) YES [ ] (b) NO [ ]

If yes, Please Indicate the level of agreement

(a) Voluntarily[ ]
(b) To comply with regulations [ ]
(c) Under pressure from customers [ ]
(d) Under pressure from competition [ ]

25. Stakeholder's Commitments (SHC) for Sustainable Manufacturing

How do you rate the level of stakeholders Commitment with respect to the following in Your Company?
(1-very Low………to…………….5-very High)

SHC1	Environmental compliances as per governmental policies are strictly adhered	1	2	3	4	5
SHC2	Cross-functional cooperation for sustainable manufacturing	1	2	3	4	5
SHC3	Motivation towards Sustainability	1	2	3	4	5
SHC4	Emphasis on improving eco-efficiency	1	2	3	4	5
SHC5	Stakeholders Expertise	1	2	3	4	5
SHC6	Total quality environmental management	1	2	3	4	5

PART B

1. SUSTAINABLE MANUFACTURING PRACTICES (SMPs)

Sustainable Product Design (SPD)

How do you rate the level of importance of each practice of Sustainable Product Design with respect to the following in Your Company?

(1-Very Low..........to...........5-Very High)

SPD1	Design of products for reduced consumption of material and energy.	1	2	3	4	5
SPD2	Design of products to reduce the use of hazardous of products and manufacturing process	1	2	3	4	5
SPD3	Design for Packaging	1	2	3	4	5
SPD4	Design for environment (DFE)	1	2	3	4	5
SPD5	Use of Life cycle assessment (LCA)	1	2	3	4	5

Sustainable Manufacturing Process Design (SMPD)

How do you rate the level of agreement of following Sustainable Manufacturing Process Design aspects in Your Company?
(1-Totally disagree.........to............5-Totally agree)

SMPD1	Minimizing waste during machining process	1	2	3	4	5
SMPD2	Energy efficiency during production process	1	2	3	4	5
SMPD3	Improve resources utilisation (materials, water, manpower) on shop floor	1	2	3	4	5
SMPD4	Use of efficient and clean technology to reduce carbon dioxide foot print	1	2	3	4	5
SMPD5	Improving the utilisation of vegetable oil based metalworking fluids/cryogenic machining	1	2	3	4	5
SMPD6	Use of additive Manufacturing					

Lean Practices (LP)

How do you rate the level of Implementation of following Lean Practices in Your Company?
(1-Very Low.........to............5-Very High)

LP1	Value Stream Mapping (VSM)	1	2	3	4	5
LP2	Continuous improvement/Kaizen//Pokayoke/Mistake proofing	1	2	3	4	5
LP3	5S (Sort, Shine, Set in order, Standardise, and Sustain)	1	2	3	4	5
LP4	Total productive maintenance (TPM)	1	2	3	4	5
LP5	Just-in-Time (JIT)	1	2	3	4	5
LP6	Kanban/Pull Production	1	2	3	4	5

Agile Practices and Customization (APC)

How do you rate the level of Implementation of following Agile Practices and Customization in Your Company?
(1-Very Low.............to.............5-Very High)

APC1	Use of Flexible Manufacturing system (CAD/CAM/CAE,CAPP and CIM)	1	2	3	4	5
APC2	Use of Automation System (CNC, DNC & Robotics)	1	2	3	4	5
APC3	Use of Information Technology (ERP, MRP, SAP)	1	2	3	4	5
APC4	Quickly respond to customer	1	2	3	4	5
APC5	Flexibility to change volume as per customer demand	1	2	3	4	5
APC6	Product variety without increasing cost and sacrificing quality	1	2	3	4	5

Sustainable Supply Operations and Distribution (SSOD)

How do you rate the level of agreement of following Sustainable operations & distribution in Your Company?
(1-Totally disagree.............to....................5-Totally agree)

SSOD1	Cooperation with suppliers for environmental objectives	1	2	3	4	5
SSOD2	Second-tier supplier environmentally friendly practice evaluation	1	2	3	4	5
SSOD3	Cooperation with customers for green packaging	1	2	3	4	5
SSOD4	Supplier's advances in developing environmentally friendly packages	1	2	3	4	5
SSOD5	Investment recovery (sale) of excess inventories/ materials	1	2	3	4	5
SSOD6	Sale of scrap material, used materials and excess capital equipment	1	2	3	4	5

Product Returns and Recovery Practices (PRRP)

How do you rate the level of agreement of following activities of Product Returns and Recovery Practices in Your Company?
(1-Totally disagree.................to...................5-Totally agree)

PRRP1	Reduce resource utilisation (Energy and water)	1	2	3	4	5
PRRP2	Recycle of returned product/material	1	2	3	4	5
PRRP3	Reusability of returned product/material	1	2	3	4	5
PRRP4	Recover of returned product/material for further processing	1	2	3	4	5
PRRP5	Remanufacturing of returned products as usable product (Recondition and Repair)	1	2	3	4	5
PRRP6	Redesign post-use processes and products	1	2	3	4	5

2. SUSTAINABLE MANUFACTURING COMPETITIVENESS (SMC)

How do you rate the level of Achievement of following Sustainable Manufacturing Competitiveness by implementing/adopting the Sustainable Manufacturing Practices Your Company?
(1-Very Low....................to................5-Very High)

SMC1	Reduced product manufacturing cost	1	2	3	4	5
SMC2	Improvement in product and process quality	1	2	3	4	5
SMC3	On time delivery of customer products	1	2	3	4	5
SMC4	Innovation in product and process design	1	2	3	4	5
SMC5	Adoption of advanced technology	1	2	3	4	5
SMC6	Increase in profitability	1	2	3	4	5
SMC7	Improve Corporate Social Responsibility and organizational growth	1	2	3	4	5

3. SUSTAINABLE PERFORMANCE MEASURES (SPM)

How do you rate the level of Improvement of following Sustainable Performance in Your Company?
(1-Very Low...................to................5-Very High)

SPM1	Reduction of air emission, water waste and solid wastes	1	2	3	4	5
SPM2	Decrease of consumption of hazardous/ harmful/ toxic materials	1	2	3	4	5
SPM3	Decrease of frequency for environmental accidents	1	2	3	4	5
SPM4	Decrease in cost of materials purchasing	1	2	3	4	5
SPM5	Decrease in cost of waste treatment	1	2	3	4	5
SPM6	Decrease in cost of energy consumption	1	2	3	4	5
SPM7	Provide good remunerations and wages to employee for stability	1	2	3	4	5
SPM8	Provide quality health and safety management practices	1	2	3	4	5
SPM9	Provide Employee training and career development program	1	2	3	4	5
SPM10	Customer satisfaction	1	2	3	4	5

Your cooperation and valuable time spent in answering the questionnaire is highly appreciated.

Thanking You! Name and Signature

APPENDIX-2

Industry Database

S. No.	Company Code	Industry Sector	Location of Company	Region of	Product Range
1	A1	Automobile	Ghaziabad	North	Automobile Component
2	A2	Automobile	G.B.Nagar	North	Automobile Component
3	A3	Automobile	Faridabad	North	Two Wheeler Spare Parts
4	A4	Automobile	Manesar (Gurgaon)	North	Automobile Electrical Spare Parts
5	A5	Automobile	Gurgaon	North	Automotive Filters
6	A6	Automobile	Gurgaon	North	Automotive Filters
7	A7	Automobile	Kundali	North	Brakes, Clutch
8	A8	Automobile	Ballabhgarh	North	Shock Absorber
9	A9	Automobile	Faridabad	North	Exhaust Gas Catalyst
10	A10	Automobile	Greater Noida	North	Gear Transmission System
11	A11	Automobile	Greater Noida	North	Two Wheeler
12	A12	Automobile	Sahibabad	North	Sheet Metal Component
13	A13	Automobile	Faridabad	North	Precision Turned Components
14	A14	Automobile	Greater Noida	North	Automotive Plastic Components
15	A15	Automobile	Ghaziabad	North	Sheet Metal Component
16	A16	Automobile	Haridwar	North	Two Wheeler
17	A17	Automobile	Faridabad	North	Automobile Component
18	A18	Automobile	Manesar (Gurgaon)	North	Automobile Component
19	A19	Automobile	G.B.Nagar	North	Pressure Vessels
20	A20	Automobile	Bangalore	South	Automobile Component
21	A21	Automobile	Bangalore	South	Vehicles
22	A22	Automobile	Ballabhgarh	North	Steering Systems
23	A23	Automobile	Manesar (Gurgaon)	North	Automobile Component

24	A24	Automobile	Khatola Gurgaon	North	Automobile Component
25	A25	Automobile	Faridabad	North	Automobile Component
26	A26	Automobile	Greater Noida	North	Four Wheelers
27	A27	Automobile	Khushkhera, Alwar	North	Automobile Component
28	A28	Automobile	Manesar (Gurgaon)	North	Automotive Electrical System
29	A29	Automobile	Greater Noida	North	Two Wheeler
30	A30	Automobile	Manesar (Gurgaon)	North	Automobile Component
31	A31	Automobile	Manesar (Gurgaon)	North	Automobile Component
32	A32	Automobile	Noida	North	Automotive Breaking System
33	A33	Automobile	Pantnagar	North	Four Wheelers
34	A34	Automobile	Manesar (Gurgaon)	North	Two Wheeler
35	A35	Automobile	Faridabad	North	Automobile Component
36	A36	Automobile	Jaipur	North	Spark Plugs, Engines
37	A37	Automobile	Faridabad	North	Automobile Clutch And Assemblies
38	A38	Automobile	Bhiwadi	North	Automotive Radiator
39	A39	Automobile	Gurgaon	North	Vehicle Tracking Systems
40	A40	Automobile	Gurgaon	North	Auto Component Industry
41	A41	Automobile	Ghaziabad	North	Automotive Radiator
42	A42	Automobile	Gurgaon	North	Suspension System
43	A43	Automobile	Noida	North	Automotive Control Switch Gear
44	A44	Automobile	Faridabad	North	Automotive Clutch And Breaks
45	A45	Automobile	Jaipur	North	Bearings
46	A46	Automobile	Gurgaon	North	Automobile Lamps
47	A47	Automobile	Bhiwadi, Rajasthan	North	Bearings
48	A48	Automobile	Gurgaon	North	Automobile Component
49	A49	Automobile	Dharuhera, Rewari	North	Plastic Injection Moulding Part
50	A50	Automobile	Faridabad	North	Automotive Filters

51	A51	Automobile	Faridabad	North	Automobile Component
52	A52	Automobile	Gurgaon	North	Auto Component
53	A53	Automobile	Faridabad	North	Vehicle Tracking Systems
54	A54	Automobile	Faridabad	North	Automotive Clutch And Breaks
55	A55	Automobile	Faridabad	North	Automotive Filters
56	A56	Automobile	Faridabad	North	Suspension System
57	A57	Automobile	Greater Noida	North	Air Conditioner System
58	A58	Automobile	Haridwar	North	Four Wheelers
59	A59	Automobile	Noida	North	Fuel Tanks And Allied Acessories
60	A60	Automobile	Gurgaon	North	Automotive Radiator
61	A61	Automobile	Dharuhera	North	Two Wheeler
62	A62	Automobile	Manesar (Gurgaon)	North	Automobile Electrical Spare Parts
63	A63	Automobile	Manesar (Gurgaon)	North	Suspension System
64	A64	Automobile	Manesar (Gurgaon)	North	Automobile Component
65	A65	Automobile	Manesar (Gurgaon)	North	Two Wheelers
66	A66	Automobile	Gurgaon	North	Two Wheelers
67	A67	Automobile	Bangalore	South	Bearings
68	A68	Automobile	Jaipur	North	Automobile Component
69	A69	Automobile	Faridabad	North	Auto Parts
70	A70	Automobile	Manesar (Gurgaon)	North	Automotive Electrical System
71	A71	Automobile	New Delhi	North	Automobile Component
72	A72	Automobile	Haridwar	North	Vehicle Tracking Systems
73	A73	Automobile	Manesar (Gurgaon)	North	Automobile Component
74	A74	Automobile	Waghodia, Vadodara	West	Automobile Component
75	A75	Automobile	Ludhiana, Punjab	North	Automotive Cluch And Breakes
76	A76	Automobile	New Delhi	North	Suspension System
77	A77	Automobile	Bawal Haryana	North	Automobile Component

78	A78	Automobile	Pune,Maharashtra	West	Engines
79	A79	Automobile	Jaipur	North	Bearings
80	A80	Automobile	Noida	North	Auto Parts
81	A81	Automobile	Greater Noida	North	Two Wheeler
82	A82	Automobile	Greater Noida	North	Automotive Plastic Component
83	A83	Automobile	Manesar (Gurgaon)	North	Two Wheeler
84	A84	Automobile	Gurgaon	North	Two Wheeler
85	A85	Automobile	Ahmedabad	North	Four Wheelers
86	A86	Automobile	Manesar (Gurgaon)	North	Automotive Plastic Component
87	A87	Automobile	Ghaziabad	North	Two Wheeler
88	A88	Automobile	Bawal	North	Automobile Component
89	A89	Automobile	Gurgaon	North	Sheet Metal Component
90	A90	Automobile	Gurgaon	North	Automobile Component
91	A91	Automobile	Gurgaon	North	Automobile Component
92	A92	Automobile	Haridwar,	North	Automotive Radiator
93	A93	Automobile	Gurgaon	North	Shock Absorber
94	A94	Automobile	Greater Noida	North	Two Wheeler
95	A95	Automobile	Ghaziabad	North	Piston & Rings
96	A96	Automobile	Gurgaon	North	Smart Mood Lighting System
97	A97	Automobile	Gurgaon	North	Automobile Component
98	A98	Automobile	Ghaziabad	North	Piston & Rings
99	A99	Automobile	Faridabad Haryana	North	Automobile Component
100	A100	Automobile	Balewadi Pune	West	Engines
101	A101	Automobile	Agra, Uttar Pradesh	North	Piston & Rings
102	A102	Automobile	Faridabad, Haryana	North	Automotive Filters
103	A103	Automobile	Faridabad, Haryana	North	Automobile Component
104	A104	Automobile	Gurgaon	North	Auto Component

105	A105	Automobile	New Delhi	North	Vehicle Tracking Systems
106	A106	Automobile	Sitapura,Jaipur	North	Automotive Cluch And Breakes
107	A107	Automobile	Sitapura,Jaipur	North	Automotive Filters
108	A108	Automobile	Sitapura,Jaipur	North	Suspension System
109	A109	Automobile	Sitapura,Jaipur	North	Air Conditioner System
110	A110	Automobile	Manesar (Gurgaon)	North	Four Wheelers
111	A111	Automobile	Sarita Vihar, New Delhi	North	Fuel Tanks And Allied Acessories
112	A112	Automobile	Greater Noida, Uttar Pradesh	North	Automotive Radiator
113	A113	Automobile	Noida, Uttar Pradesh	North	Automobile Component
114	A114	Automobile	Gurgaon	North	Automobile Component
115	A115	Automobile	Faridabad, Haryana	North	Automotive Radiator
116	E1	Electrical & Electronics	Bankura West Bengal	East	Power Control Products
117	E2	Electrical & Electronics	Gurgaon	North	Medical Equipment
118	E3	Electrical & Electronics	Noida, Uttar Pradesh	North	Panel Manufacture
119	E4	Electrical & Electronics	Noida, Uttar Pradesh	North	Gas Generator Sets
120	E5	Electrical & Electronics	New Delhi	North	Power Generation Products
121	E6	Electrical & Electronics	Faridabad	North	Electrical Power
122	E7	Electrical & Electronics	New Delhi	North	Cad, Cam, Business Intelligence
123	E8	Electrical & Electronics	Noida	North	Electro-Plating And Special Facilities Of Panel Manufacture
124	E9	Electrical & Electronics	Greater Noida	North	Heavy Duty Exhaust Fan
125	E10	Electrical & Electronics	Vadodara, Gujarat	West	Multimedia Services And Business
126	E11	Electrical & Electronics	Jaipur	North	Vsn300 Wifi Logger Card. Abb. Vsn300 Wifi Logger Card
127	E12	Electrical & Electronics	Ghaziabad	North	Medium Voltage Switchgear Products
128	E13	Electrical & Electronics	Faridabad, Haryana	North	Electronic Products, Air Circuit Breakers
129	E14	Electrical & Electronics	Gurgaon	North	Electrical & Electronics Products
130	E15	Electrical & Electronics	Noida, Uttar Pradesh	North	Electrical And Electronic Products
131	E16	Electrical & Electronics	Noida, Uttar Pradesh	North	Home Lightings, Home Furnishing Articles

132	E17	Electrical & Electronics	Greater Noida, Uttar Pradesh	North	Power Control Centers,
133	E18	Electrical & Electronics	Greater Noida, Uttar Pradesh	North	Switch Gear, Contactors, Mechanical Switching Devices
134	E19	Electrical & Electronics	Noida, Uttar Pradesh	North	Microcontrollers, Converters, Amplifiers
135	E20	Electrical & Electronics	Ballabgarh Faridabad	North	Air Fuel Ratio Controller, Linear Actuators
136	E21	Electrical & Electronics	Delhi	North	Industrial & Domestic Circuit Protection Switchgear
137	E22	Electrical & Electronics	Noida, Uttar Pradesh	North	Power Control Centers, Capacitor Control Panels
138	E23	Electrical & Electronics	Gurgaon	North	Measurement & Control Instruments
139	E24	Electrical & Electronics	New Delhi	North	Power Transformers, Distribution Transformers
140	E25	Electrical & Electronics	Greater Noida	North	Microcontrollers, Converters, Amplifiers
141	E26	Electrical & Electronics	Greater Noida	North	Manufacturer Of Modem, Router & Networking Devices
142	E27	Electrical & Electronics	Noida	North	Electric Control Panels
143	E28	Electrical & Electronics	Faridabad	North	Tv, Fridge, Washing Machine
144	E29	Electrical & Electronics	Gurgaon, Haryana	North	Hv & Lv Switchboards. Hv & Lv Switchboards
145	E30	Electrical & Electronics	New Delhi	North	Digital Switching Equipment
146	E31	Electrical & Electronics	Jaipur	North	Electronic Products, Air Circuit Breakers
147	E32	Electrical & Electronics	Faridabad	North	Smartphones, Feature Phones, Tablets, Laptops
148	E33	Electrical & Electronics	Greater Noida	North	Electrical Items · Transformer Parts
149	E34	Electrical & Electronics	Greater Noida	North	Energy Meters
150	E35	Electrical & Electronics	Gurgaon	North	Electrical Control Panel
151	E36	Electrical & Electronics	Noida	North	Electrical Panels, Mcc Panels
152	E37	Electrical & Electronics	Greater Noida	North	Automation Systems
153	E38	Electrical & Electronics	Noida, Uttar Pradesh	North	Rectifier
154	E39	Electrical & Electronics	Ajmer Rajasthan	North	Electric Panels
155	E40	Electrical & Electronics	Delhi	North	Electric Lamp Bulb
156	E41	Electrical & Electronics	Rudrapur, Uttarakhand	North	Grandjets, Xljets, Idanit, Turbojets
157	E42	Electrical & Electronics	Noida	North	Electronics Products,
158	E43	Electrical & Electronics	New Delhi	North	Automobile Component

159	E44	Electrical & Electronics	Jaipur	North	Electronic Relays, Digital Panel
160	E45	Electrical & Electronics	Gurgaon	North	Power Plant Equipment- Mills, Cement
161	E46	Electrical & Electronics	Delhi	North	Modular Switches
162	E47	Electrical & Electronics	Faridabad	North	Switch Gear, Mechanical Switching Devices
163	E48	Electrical & Electronics	Jaipur	North	Electric Control Panel
164	E49	Electrical & Electronics	Jaipur	North	Optical Fibre Cables
165	E50	Electrical & Electronics	Bangaluru	South	Rubber Moulded Parts:-Slider Chain
166	E51	Electrical & Electronics	Jaipur	North	Flour Mill & Rice Mill Manufacturer
167	E52	Electrical & Electronics	Malviya Nagar Jaipur	North	Electric Control Panel
168	E53	Electrical & Electronics	Jaipur	North	Solar Epc & Components
169	E54	Electrical & Electronics	Mundka, Delhi	North	Automation System and Control Panels
170	E55	Electrical & Electronics	Jaipur``	North	Plc Control Panels Electrical Control Panels Boards
171	E56	Electrical & Electronics	Gurgaon	North	Ups Systems And Batteries
172	E57	Electrical & Electronics	Noida, Uttar Pradesh	North	Low Voltage Power Control Centre, Motor Control Centre
173	E58	Electrical & Electronics	Haridwar	North	Electrical Control Panel
174	E59	Electrical & Electronics	Noida, Uttar Pradesh	North	Electrical Switch Boards
175	E60	Electrical & Electronics	Jaipur	North	Led Lights & Medium Voltage Ct/Pt & Vacuum Circuit.
176	E61	Electrical & Electronics	Sahibabad	North	Power Transformers, Distribution Transformers
177	E62	Electrical & Electronics	Bhiwadi, Rajasthan	North	Low Voltage Power Control Centre
178	E63	Electrical & Electronics	Gurgaon, Haryana	North	Switch Gear, Contactors, Mechanical Switching Devices
179	E64	Electrical & Electronics	Gurgaon, Haryana	North	Power Plant Equipment- Mills, Cement
180	E65	Electrical & Electronics	Noida	North	Electric Control Panel and Synchronization Panel
181	M1	Machinery	Rajkot,Gujarat	West	Refrigeration & Equipment Of Refrigeration
182	M2	Machinery	Gurgaon, Haryana	North	Rotary Piston Blowers, Process Gas Blowers
183	M3	Machinery	Noida	North	Allied Products, Evaporator
184	M4	Machinery	Powai	West	Submersible Pump, Jet Pump, Mood Pump
185	M5	Machinery	Pune	West	Ice Machine Filters, Combination Filter System

186	M6	Machinery	Bangalore	South	Seed Paddy Cleaner , Grader Machinery
187	M7	Machinery	Hyderabad	South	Hand Tools, Grease Gunn, Bucket
188	M8	Machinery	Gurgaon, Haryana	North	Hand Tools, Grease Gunn, Bucket
189	M9	Machinery	Noida, Uttar Pradesh	North	Water Purifiers
190	M10	Machinery	Abu Road, Rajasthan	North	Coil Filter, Coil Car, Coil Handling System
191	M11	Machinery	Delhi	North	Oil, Gas, Water Treatment & Solar Energy Machines
192	M12	Machinery	Mumbai	West	Slip House Machine & Shaping Machine
193	M13	Machinery	Delhi	North	Fine Ceramic Plant And Machinery
194	M14	Machinery	Kolkata	East	Agricultural Machinery Manufacturers
195	M15	Machinery	Faridabad	North	Valves , Check Valves, Globe Valves
196	M16	Machinery	Jaipur	North	Air Compressor Supplier
197	M17	Machinery	Larlu	North	Turbines
198	M18	Machinery	Gurgaon	North	Manufacturer Of Heavy Machinery
199	M19	Machinery	Pune	West	Construction & Mining Machinery
200	M20	Machinery	Ballabgharh Haryana	North	Sheets, Flats, Rods
201	M21	Machinery	Kolkata	East	Balancing Valves, Butterfly Valves
202	M22	Machinery	Delhi	North	Soda Machinery
203	M23	Machinery	Kanpur	East	Furnace, Kilns, Burners, Oven
204	M24	Machinery	Jaipur	North	Glass & Iron & Steel
205	M25	Machinery	Jaipur	North	Rockwool Panel, Pre-coated Sheet Insulation Products
206	M26	Machinery	Jaipur	North	Textile Accessories, Cooling System
207	M27	Machinery	Faridabad, Haryana	North	Porcelain Insulators
208	M28	Machinery	Surat	West	Air Purifiers, Ducted Ac, And Split Air Conditioners
209	M29	Machinery	Mumbai	North	Material Handling Equipment
210	M30	Machinery	Delhi	North	Construction Equipment
211	M31	Machinery	Navi Mumbai	West	Military Motor Vehicle Manufacturing
212	M32	Machinery	Navi Mumbai	West	Hydraulic Press Supplied to Carbon Products

213	M33	Machinery	Mumbai	West	Godrej Appliances
214	M34	Machinery	Mumbai	North	Lead Alloys and Lead Acid Batteries
215	M35	Machinery	New Delhi	West	Domestic Dishwashers, Industrial Dishwashers
216	M36	Machinery	Noida	North	Pump Gears, Synchro Hubs & Gears
217	M37	Machinery	Chennai	South	Vibrating Screens, Screw Conveyor
218	M38	Machinery	Alwar	North	Structural Metal Products, Tanks, Reservoirs And Steam
219	M39	Machinery	Coimbatore	South	Textile Accessories, Cooling System
220	M40	Machinery	New Delhi	North	Ac Products
221	M41	Machinery	Faridabad Haryana	North	Hydraulic Cylinder
222	M42	Machinery	Pune	North	Products Two Grades Pipe/Tube
223	M43	Machinery	Jaipur	North	Agri Machinery
224	M44	Machinery	Jaipur	North	Truck And Bus Manufacturer
225	M45	Machinery	Mumbai	West	Food Processing Machines
226	M46	Machinery	Hoogly, West Bangal	East	Food Processing Machines
227	M47	Machinery	Mumbai	West	Textile Accessories, Cooling System
228	M48	Machinery	Hosur	East	Injection Moulds & Precision Moulds.
229	M49	Machinery	Rajkot, Gujarat	West	Timing Gears - Product Leaflet
230	M50	Machinery	Jaipur	North	Boiler House Products & Monitoring Equipment
231	M51	Machinery	New Delhi	North	Metal Forming Machines In India
232	M52	Machinery	Noida	North	Milk Powder Packing Machines
233	M53	Machinery	Bhiwadi, Rajasthan	North	Cold Rolling Mill, Galvanising, Pre-Coated Facility
234	M54	Machinery	Pune	West	Circular Knitting Machines
235	M55	Machinery	New Delhi	North	Power Production
236	M56	Machinery	Kolkata	East	Screening Equipment, Grinding Equipment
237	M57	Machinery	Jaipur	North	Machinery For Tea, Ctc Tea, Black Tea, Green Tea
238	M58	Machinery	Noida, Uttar Pradesh	North	Textile Accessories, Cooling System
239	M59	Machinery	Akurdi Pune	West	Two Wheeler Parts, Three Wheel

240	M60	Machinery	Ambala	North	Domestic Dishwashers, Kitchen Hoods
241	M61	Machinery	Noida, Uttar Pradesh	North	Transmission Gears and Shafts
242	M62	Machinery	Jabalpur	West	Structural Metal Products, Steam Generators
243	M63	Machinery	Ghaziabad, Uttar Pradesh	North	Sheets, Flats, Rods
244	M64	Machinery	Faridabad	North	Balancing Valves, Butterfly Valves
245	M65	Machinery	Noida, Uttar Pradesh	North	Soda Machinery
246	M66	Machinery	Surat, Gujrat	West	Furnace, Kilns, Burners, Oven
247	M67	Machinery	Baroda	West	Glass & Iron & Steel
248	M68	Machinery	Chennai	South	Single Pump Water Booster Pumps
249	M69	Machinery	Haridwar, Uttakhand P	North	Grader Machinery
250	M70	Machinery	Gurgaon	North	Equipment of Refrigeration
251	M71	Machinery	Jaipur	North	Rotary Piston Blowers, Process Gas Blowers
252	M72	Machinery	Jaipur	North	Allied Products, Evaporator
253	M73	Machinery	Jaipur	North	Submersible Pump, Mood Pump
254	M74	Machinery	Noida	North	Washing Machines, Industrial Dishwashers
255	M75	Machinery	Noida	North	Transmission Gears and Shafts Differential
256	P1	Process	Mumbai	West	Cement
257	P2	Process	Raigad	West	Steel Tubes
258	P3	Process	Bhiwadi	North	Non Ferrous Tubes
259	P4	Process	Nuh, Mewat	North	Chemicals
260	P5	Process	Bangalore	South	Tyres
261	P6	Process	Mumbai	West	Paints
262	P7	Process	Manesar (Gurgaon)	North	Cement
263	P8	Process	Dolvi	West	Cement
264	P9	Process	Burnpur	East	Paper
265	P10	Process	Mathura	North	Chemicals
266	P11	Process	Alwar	North	Beverages

267	P12	Process	Jamnagar	West	Cloth
268	P13	Process	Vki Area, Jaipur	North	Oil
269	P14	Process	Dolvi, Mumbai	West	Food Products
270	P15	Process	Hoobly, West Bengal	East	Woven Sacks
271	P16	Process	Rohtak, Haryana	North	Chemicals
272	P17	Process	Dolvi Maharashtra	West	Petroleum products
273	P18	Process	Mumbai	West	Chemicals
274	P19	Process	Mumbai	South	Grinding Wheels
275	P20	Process	Sitapur, Uttar Pradesh	North	Lubricants
276	P21	Process	Jodhpur	North	Tyres
277	P22	Process	Beawar	North	Cotton Yarn
278	P23	Process	Goa	West	Oil
279	P24	Process	Barsingsar Bikaner	North	Oil & LPG
280	P25	Process	Bccl Dhanbad	East	Medicine
281	P26	Process	Ghaziabad	North	Sealants
282	P27	Process	West Bengal India	East	Plastic Products
283	P28	Process	Rajsamand	North	Weld Consumables
284	P29	Process	Rajsamand	North	Food items
285	P30	Process	Gurgaon, Haryana	North	TOR Steel
286	P31	Process	Chennai	South	Tea
287	P32	Process	Faridabad, Haryana	North	Cement
288	P33	Process	Bhilwara	North	Plastic Wood
289	P34	Process	Vki Jaipur	North	Medicine
290	P35	Process	Udaipur	North	Weld Consumables
291	P36	Process	Bhilwara	North	Steel
292	P37	Process	Bhilwara	North	Plastic Products
293	P38	Process	Dolvi	West	Paint

294	P39	Process	Mumbai	West	Jams & Juice
295	P40	Process	Vishakhapatanam	South	Tyres
296	P41	Process	Pune, Maharashtra	West	Fabrics
297	P42	Process	Kolkata	East	Grinding Wheels
298	P43	Process	Mumbai	West	Cement
299	P44	Process	Noida, Uttar Pradesh	North	Chemicals
300	P45	Process	Gurgaon	North	Aluminium
301	P46	Process	Gurgaon	North	Medicine
302	P47	Process	Noida, Uttar Pradesh	North	Cold Rolled Steel
303	P48	Process	Bahadurgarh	North	Detergent
304	P49	Process	Dolvi	West	Oil
305	P50	Process	Jaipur	North	Aluminium
306	P51	Process	Pune, Maharashtra	West	Petroleum products
307	P52	Process	Udaipur	North	Explosives
308	P53	Process	Udaipur	North	Urea
309	P54	Process	Mumbai	West	Cotton Yarn
310	P55	Process	Mumbai	West	Petroleum products
311	P56	Process	Mumbai	West	Ferro Alloys
312	P57	Process	Kaiga, Karnataka	South	Steel
313	P58	Process	Udaipur	North	Tobacco
314	P59	Process	Gulabpura	North	Packaging
315	P60	Process	New Delhi	North	Tyres
316	P61	Process	Beawer	North	Fibres
317	P62	Process	Pune, Chinchwid	West	Steel
318	P63	Process	Gurgaon	North	Steel pipes
319	P64	Process	Sriperumbudur, Tamil Nadu	South	Steel strips
320	P65	Process	Panipat	North	Sugar

321	P66	Process	Jaipur	North	Steel bars
322	P67	Process	Greater Kailash-Ii, New Delhi	North	Chemicals
323	P68	Process	Gurgaon	North	Tubes
324	P69	Process	Raniganj, West Bengal	East	Cement
325	P70	Process	Lakeri, Bundi	North	Rolled Products
326	P71	Process	Alwar	North	Beverages
327	P72	Process	Gurgaon	North	Fabrics
328	P73	Process	Bhilwara	North	Seed
329	P74	Process	Jaipur	North	Food Products
330	P75	Process	Vadinagar	West	Cement
331	P76	Process	Mumbai	West	Consumer products
332	P77	Process	Rajsamand	North	Fabrics
333	P78	Process	Hisar Haryana	North	Fabrics
334	P79	Process	Dolvi, Maharashtra	West	Plastic Products
335	P80	Process	Dolvi, Maharashtra	West	Steel
336	P81	Process	Pune	West	Urea
337	P82	Process	Jodhpur	North	Alumina Hydrate
338	P83	Process	Delhi	North	Chemicals
339	P84	Process	Gurgaon, Haryana	North	Food Products
340	P85	Process	Udaipur	North	Steel
341	P86	Process	Jaipur	North	Cotton yarn
342	P87	Process	Udaipur	North	Abrasives
343	P88	Process	Udaipur	North	Packaging
344	P89	Process	Bhilwara	North	Fabrics
345	P90	Process	Visakhapatnam	South	Polyester

LIST OF PUBLICATIONS

Peer Reviewed International Journal Publications:

Gupta, S., Dangayach, G. S., & Singh, A. K. (2015). Key Determinants of Sustainable Product Design and Manufacturing. Procedia CIRP, 26, 99-102. Elsevier Publication.

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N. (2015). Analytic Hierarchy Process (AHP) Model for Evaluating Sustainable Manufacturing Practices in Indian Electrical Panel Industries. Procedia-Social and Behavioral Sciences, 189, 208-216. Elsevier Publication.

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N. (2016). A Pilot Study of Sustainable Machining Process Design in Indian Process Industry. Lecture Notes in Mechanical Engineering (pp. 379-385). Springer India.

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N. (2016). Sustainable Product returns and Recovery: A Pilot Study of Indian Automobile Industry. Materials Today Proceedings. Elsevier Publication.

International/National Conferences

Gupta, S., Dangayach, G. S., & Singh, A. K., "Implementation of Shainin Doe Variable Search Tool for Sustainable Manufacturing in an Automotive Industry" Proceedings of International Conference on Smart Technologies for Mechanical Engineering during 25-26 Oct 2013 at Delhi Technological University.

Gupta, S., Dangayach, G. S., & Singh, A. K., " Evaluation of Sustainable Manufacturing Practices using AHP in Electrical Panel Industries" Proceedings of International Conference on Operations Management in Digital Economy during "December 12-14, 2014 at Department of Management Studies, IIT Roorkee

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N " Some Issues in Sustainable Supply Chain Management: A Literature Review" Proceedings of International Conference on Energy and Environment during 17-18 January 2015 at Department of Electrical and Mechanical Engineering Kautilya Campus, Jaipur.

Gupta, S., Dangayach, G. S., Singh, A. K., & Rao, P. N " Achieving Sustainability in manufacturing through lean an experience from Indian automobile industry" accepted for the presentation in 17th ISME Conference on Advances in Mechanical Engineering organised by Indian Society of Mechanical Engineers (ISME) in Indian Institute of Technology Delhi, New Delhi during October 3-4, 2015.

Gupta, S., Dangayach, G. S., & Singh, A. K. "Continuous Process Improvement for Achieving Sustainability in Manufacturing" Proceedings of All India Seminar on Sustainable Manufacturing during 18-19 January 2014 at The Institution of Engineers (India) Production Engineering Division Board, Jaipur.

Gupta, S., Dangayach, G. S., & Singh, A. K., "Strategies for Sustaining Product Design and Development" Proceedings of National Conference on Sustainable Manufacturing for Brighter Future during 2-3 January 2015 at Department of Management Studies, Malaviya National Institute of Technology Jaipur, Rajasthan, India.

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Experience

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