A

Dissertation Report

On

Assessment of Barriers & Enablers to Sustainable Product Returns and Recovery Practices in Manufacturing Industry

Submitted in partial fulfillment of the requirements for the award of Degree of

MASTER OF TECHNOLOGY

In

PRODUCTION ENGINEERING

Submitted by

VISHAL GARG

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Under the Guidance of

Prof. G. S. Dangayach

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DEPARTMENT OF MECHANICAL ENGINEERING

Jawahar Lal Nehru Marg, Jaipur-302017(Rajasthan)

CERTIFICATE

This is to certify that the Dissertation entitled **"Assessment of Barriers & Enablers to Sustainable Product Returns and Recovery Practice in Manufacturing Industry"** that is being submitted by Vishal Garg**,** (2014PPE5397) is a bonafide work carried out by him under my supervision to the **Department of Mechanical Engineering, Malaviya National Institute of Technology, Jaipur** for partial fulfillment of of the requirements for the award of the degree of **Master of Technology, Production Engineering**, is found to be satisfactory and is hereby approved for submission.

Dr Govind Sharan Dangayach
Head & Professor
Department of Mechanical Engineering
MNIT Jaipur

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

DEPARTMENT OF MECHANICAL ENGINEERING

Jawahar Lal Nehru Marg, Jaipur-302017(Rajasthan)

CANDIDATE'S DECLARATION

I hereby certify that following work which is being presented in the dissertation entitled **"Assessment of Barriers & Enablers to Sustainable Product Returns and Recovery Practice in Manufacturing Industry"** in the partial fulfillment of requirements for the award of the degree of **Master of technology in Production Engineering** and submitted to the **Department of Mechanical Engineering**, **Malaviya National Institute of Technology, Jaipur** is an authentic record of my own work carried out by me during a period of one year from July 2015 to June 2016 under the supervision of **Prof. G. S. Dangayach,** Head & Professor, Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the result my own work and studies carried out and has not been submitted anywhere else.

Date: **Vishal Garg**

Place: Jaipur **2014PPE5397**

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Vishal Garg

ABSTRACT

The world population is currently growing by approximately 30% or 1.6 billion people between 1990 and 2010. With the trend of growing population, there is a tendency of people to consume more natural resources, such as forests, fossil fuels, water and so on. The increased demand for natural resources are in danger of resources vanishing from planet faster than the rate of regeneration. Sustainable Manufacturing is the creation of manufactured products through economically sound processes that minimize negative environmental impacts while conserving energy and natural resources. A large and growing number of manufacturers are realizing substantial financial and environmental benefits from sustainable business practices. Product returns management plays a significant role in the sustainability of a firm's operations. Although the management of product returns has been traditionally focused on cost reduction, the shrinking global supply of materials and environmental degradation have caused firms to rethink the need to salvage their product returns. Recovery of used products is receiving much attention recently due to growing environmental concern.

This research project aims at identifying the enablers and barriers to sustainable product returns and recovery practices (PRRP) in manufacturing industry. For the identification of enablers and barriers, literature is explored and consulted with industrial experts and academicians, which led to the selection of 28 enablers and 25 barriers. Survey is conducted for the validation of enablers and barriers to find out up to which extent these factors can influence the industries to implement PRRP or hinder to implement PRRP. For doing the analysis 13 Enablers and 12 Barriers are taken according to the literature which is used as a reference.

In this research, enablers and barriers are prioritize for developing a model of identified factors after validation and qualitative analysis of enablers and barriers using interpretive structural modeling (ISM) for studying the interrelationship among identified factors. ISM is used to develop a model which understands the interactions, mutual influence and relationship among the factors. This study seeks to identify which enabler and barrier is acting as the most influential one for the implementation of PRRP in Manufacturing Industry. It also aims at ranking the different types of industries using Technique for Order of Preference by Similarity to Ideal

Solution (TOPSIS) by finding the alternative which is closest to ideal solution and farthest from the negative solution. It is a method of compensatory aggregation that compares a set of alternatives by finding the weights of each criteria, normalizing score for each criteria and then calculating the geometric distance between each alternative and the ideal alternative.

The identification, ranking and validation of the models of enablers and barriers is expected to provide better understanding to decision makers to develop policies and prioritize them to facilitate PRRP adoption and implementation and also rank the different industries which promote and hinder PRRP respectively. The ranking and hierarchy of the industries and enablers and barriers will provide better understanding to the management in industry to develop and prioritize business strategies to facilitate smooth function of organization.

Key words: Product Returns and Recovery Practices, Sustainable, Enablers, Barriers, ISM, TOPSIS

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ABBREVIATION

PRRP	Product Returns & Recovery Practices
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
ISM	Interpretive Structural Modelling
MCDM	Multi Criteria Decision Making
SSCM	Sustainable Supply Chain Management
GM	Green Manufacturing
SMEs	Small and Medium Enterprises
GSCM	Green Supply Chain Management
AHP	Analytic Hierarchy Process
SSIM	Structural Self Interaction Matrix
SEM	Structural Equation Modeling

CHAPTER 1

INTRODUCTION

Sustainable Manufacturing is essential in today's world to plan and decide from a product design and development stage as it had been already concluded that 80% of the product impacts are decided in the design and development stage only. In modern world for the conservation of environment it is necessary to know the complete Life cycle of the product. In addition, with the complete knowledge of Life cycle of product new products can be designed or existing products can be redesigned thus improving material and energy efficiency of product and thus finally improving environmental performances. Thus in order to fulfill the needs of people and to conserve environment the new products should be environment friendly [1].

Due to the emergence of sustainability there is a change in the thinking of entrepreneurs to consider their methodology in business operations. Today's main aim is to boost economic development, for the accomplishment of the objective firms needs to re-think their strategy by implementing the sustainable practices. Nowadays, sustainable issues are challenged to a large extent with the continuous depletion of natural resources, environmental degradation sustainable development has drawn attention. Thus, it is suggested that instead of implementing the old existing practices organization should grab economic opportunities gained after being socially responsible and environmental friendly [2].

Sustainability is the topic of attention since last two decades, with the need stressing on sustainable manufacturing. In the manufacturing phase, attention is on environmental impact assessment and cost analysis. The investigation on sustainable production has revealed three pillars of sustainability: economic, social and environmental impacts. With the increasing concern on environment in last few years, manufacturers have also recognized the need to take the responsibility to reduce industrial energy use and waste. The government has also enacted several environmental laws and policies which had forced the manufacturers to consider environment impact in production [3].

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. It must be noted that sustainability is not a short term process, it is indeed continuously improving, long term process. The Human beings has a fundamental role to play in the cycle of sustainability [4].

With the increasing demand in today's world for the resources there is a need to recapture the value from the unproductive assets resulting from the organization using Product Returns and Recovery Practices (PRRP). It is important as organizations neither ignore nor accumulate the returns of the product. There is a need of continuous improvement in setting appropriate strategies and policies to improve PRRP in Manufacturing Industry in India. Due to the ever increasing pressure from consumers, firms are now engaged in activities that are sensitive to the ecosystem. Thus, the organizations now seek to learn about the waste and the strategies to cope with it to achieve advantage in competitive market and to enhance their performance. Although primary purpose of industries was not concerning environment, it is for economic benefits [5].

In the present scenario, many industries have established product returns and recovery management program to handle the different types of product returns. It is expected as successful product returns and recovery management program has large number of internal and external benefits to organization. In addition due to the large amount of product returns there is a need of effective PRRP. Although the main focus of firms is still cost reduction but the decline in the supply of materials and environmental degradation has led to the need of effective management of product returns [6].

Due to the changing environmental requirements the manufacturing firms are facing a new challenge which is to develop green strategies and implement the recovery processes on the returned product. Normally product recovery occurs in three ways as follows : material recovery, component recovery and product recovery. For the implication of effective product recovery process, supply chains need to be effectively managed which itself is a challenging task due to the fact of expanding product variety, globalization of business and technology advancement. Supply chain is the complete process starting with the flow of goods from suppliers to manufacturers, and going towards wholesalers, retailers, and finally reaching consumers through the distribution channels [7].

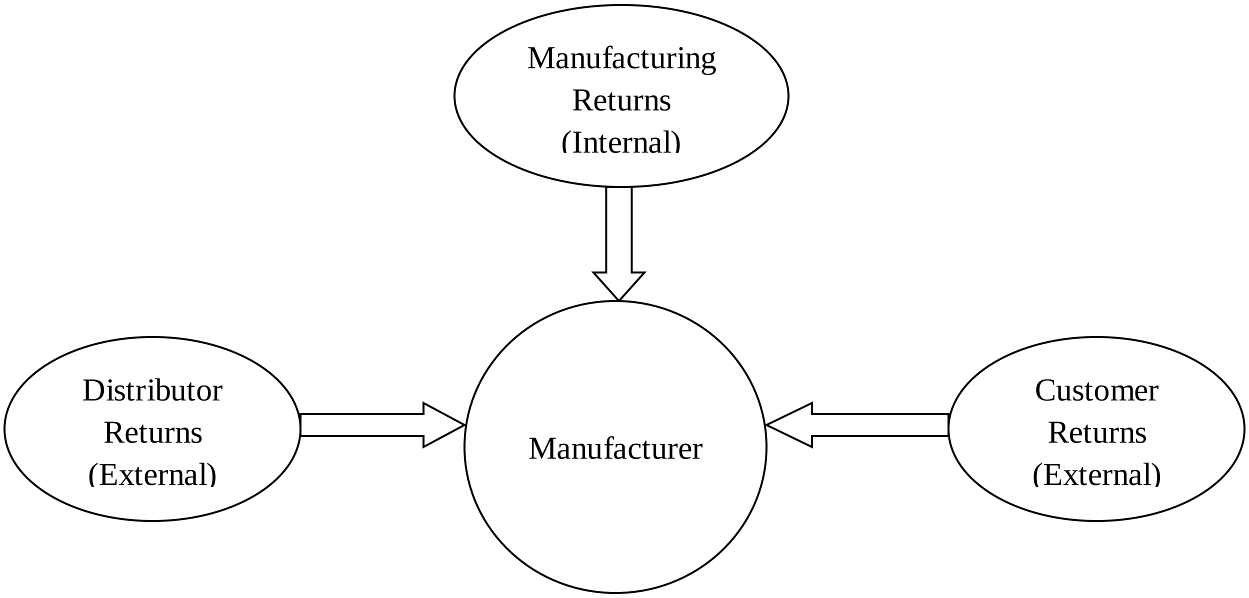

Figure 1.1: Classification of product returns [6]

Figure 1.1 shows that there are three types of returns in manufacturing firms as follows:

- Manufacturing returns : returns for rework, scrap, misspecifications, by-products and partial containers
- Distribution returns : returns because of damage, end-of-shelf life and contamination
- Consumer returns : returns of end-of-use, end-of-life, repair, damage and warranties

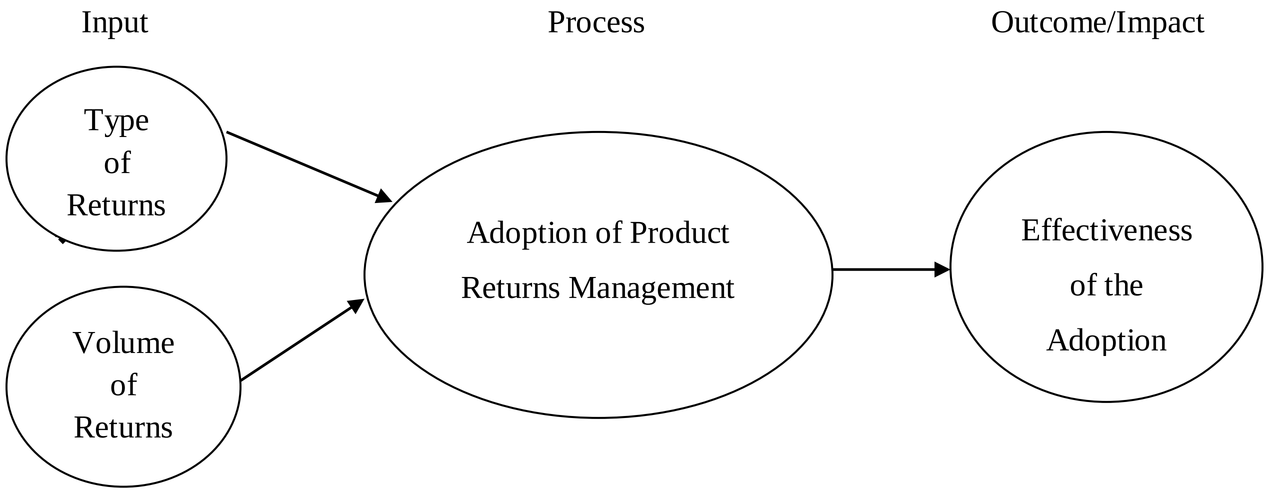

Figure 1.2: Theoretical framework for product returns management [6]

Figure 1.2 shows the theoretical framework for product returns management which is comprised of input, process and output of the adoption. The input is depicted by the type and volume of returns, the process is the adoption of product returns management and the outcome (output) is the effectiveness of the adoption of product returns management.
Figure 1.3 explains the product recovery process. This product recovery process generates recovered products for the purpose of reuse which has to correspond to the requirement of the relevant product design.

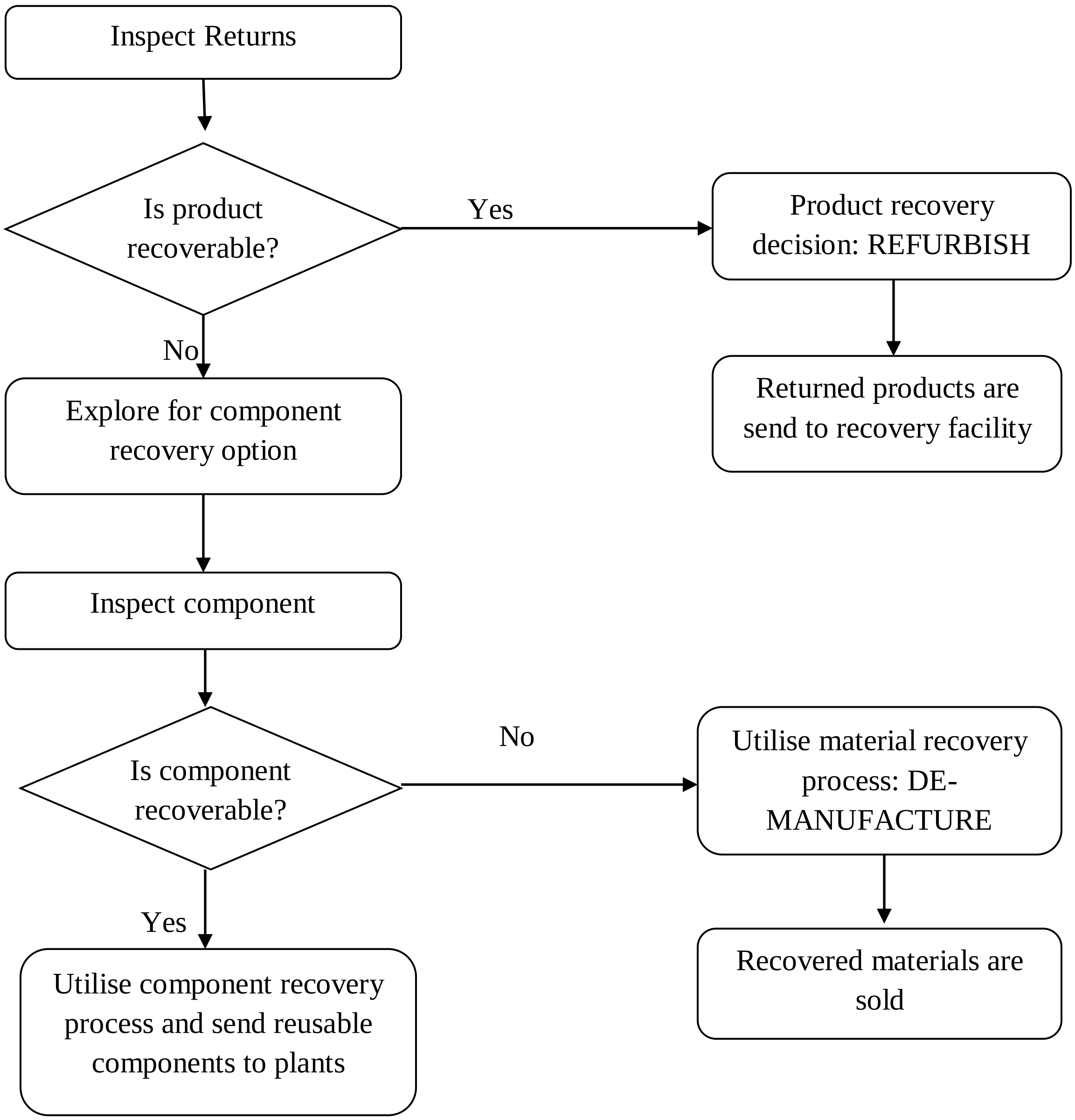

Figure 1.3: Selection process of product recovery options [7]

1.1 Motivation for Research

A large number of literatures are available for the enablers and barriers to Sustainable Product Returns & Recovery Practices for different geographical areas, industries, Countries and economies. In previous literature it is found that enablers and barriers play a crucial role in implementation of Sustainable PRRP. There is a gap to understand how these enablers and barriers influence each other, how they interact with each other or what is the impact of these factors on industries. So research is required to understand the mutual relationship between the factors and how they influence each other and the industries; to develop a relationship model of enablers and barriers separately for manufacturing industry and also to rank the different types of manufacturing industry in India.

1.2 Objectives of Research

- Identification of Enablers to Sustainable Product Returns & Recovery Practices
- Identification of Barriers to Sustainable Product Returns & Recovery Practices
- Identification of direct or indirect relationship among Enablers to PRRP using ISM approach and prepare an ISM model for Enablers
- Identification of direct or indirect relationship among Barriers to PRRP using ISM approach and prepare an ISM model for Barriers
- Ranking of different types of industries considering Enablers using TOPSIS methodology
- Ranking of different types of industries considering Barriers using TOPSIS methodology

1.3 Structure of Dissertation

There are following six chapters in this dissertation report:

Chapter 1 - Introduction: Discusses the overview of the study, its requirement and motivation of the research. Objectives of the research are also included in this chapter and in the end of the chapter the structure of dissertation is described.

Chapter 2 - Literature Review: This chapter covers the literature review on PRRP, Enablers and Barriers to PRRP, ISM and TOPSIS. Enablers and Barriers to PRRP are identified from previous literature and thoroughly explained.

Chapter 3 - Research Methodology: Describes the methodology followed in conducting this project work. Discusses about the questionnaire of survey and the organization of the survey.

This chapter describes the methodology used to analyze the collected data from the survey. The ISM and TOPSIS methodology are also discussed here.

Chapter 4 - Data Analysis and Model Development: Responses from the survey are analyzed in this chapter. After the validation of enablers and barriers ISM model is separately developed to understand the interactions and relationship between the factors. TOPSIS methodology is also applied to the responses from the industries to rank the different types of industries.

Chapter 5 - Result and Discussion: In this chapter after the analysis of data and implication of methodology, the results obtained are described and discussed.

Chapter 6 - Conclusion and Future Scope: In this chapter inferences drawn from results are described and some advices are also mentioned for the successful implementation of PRRP. The future scope on this research is also described.

CHAPTER 2

LITERATURE REVIEW

The literature was searched using the Google Scholar, Science Direct, Emerald Insight, Taylor and Francis, IEEE Online and Springer database. Articles were collected using the keywords

- ❖ Product Returns and Recovery Process
- ❖ Enablers to Product Returns and Recovery Process
- ❖ Barriers to Product Returns and Recovery Process
- ❖ Enablers to Sustainable Manufacturing
- ❖ Barriers to Sustainable Manufacturing
- ❖ TOPSIS Methodology
- ❖ ISM Methodology

The above said database has been used for literature search due to its broader data coverage (e.g. including conference proceedings, working papers and books). The literature search has been conducted by topic and not by journal to include "all" published articles in this field. The extracted articles types included journals, conference proceedings, books, books chapters and working papers. The search using the keywords resulted in thousands of articles. It was not possible to review all these articles within the scope of the present study. Therefore, the search was narrowed down to articles having these keywords in the title of the article. However, these keywords may be as an exact phrase or all the words of the keyword may be randomly present in the title. This is one of the drawbacks of search by topic. The patents and citations were also excluded. This narrowed down the number of articles.

Zainul et al. [8] discussed the enablers and barriers of sustainable housing industry in Malaysia. The enablers were classified into four categories (technological, institutional, internal action and market influence). The findings shows that government's lack of incentive programmes and the slow progress in revising related regulations are major barriers for institutional enablers whereas cost of importing products creates problem for technological enablers, while cost factor and lack of urgency are crucial in internal and low demand affects market influence.

According to Dewangan et al. [9] 11 barriers were obtained through literature review for promotion of innovation to increase the competitiveness in manufacturing sector then Delphi technique is applied for grouping the enablers and ISM and Fuzzy MICMAC is used for analysis and to find out driving and dependence power of each enabler. The outcome is obtained after seven iterations and continuous improvement is at the top most level.

Diabat et al. [10] identified enablers for the implementation of Sustainable Supply chain management (SSCM). In this 13 enablers are find out and then Interpretive Structural Modelling (ISM) is used for analysis. The results show that 5 barriers have impact on industry practices such as Adoption of safety standards, Adoption of green practices, Community economic welfare, Health and safety issues, and Employment stability.

Mittal & Sangwan [11] prioritized the drivers for Green Manufacturing (GM) identified from the literature review and then trank them through Fuzzy TOPSIS method using environmental, social and economic perspectives. It is essential for developing and emerging nations because they lack in financial and other resources. It is expected to help government and industry for the effective implementation of GM. The results revealed that Incentives is most important driver and Supply chain pressure is least effective.

Bhanot et al. [12] enlisted the barriers and enablers of Sustainable Manufacturing with the help of the opinions of researchers and industry professionals around the globe and then analyzing them through the statistical tools to depict the difference in the opinions for strategic implementation of Sustainable Manufacturing. However it is a challenge as the explicitness of enablers and barriers is difficult for firms.

Ghazilla et al. [13] did the analysis on drivers and barriers for GM practices in Malaysian Small and Medium Enterprises (SMEs). In this Delphi technique is used to identify and verify the factors of GM by obtaining opinions from panel of experts. The questionnaire was given to experts and were requested to answer that. 39 drivers and 64 barriers were found and grouped into seven and eight categories respectively. The findings revealed that improved company image is critical driver whereas weak organizational structure is critical barrier.

According to Dubey et al. [14] enablers were identified for the adoption of Green Supply Chain Management (GSCM) practices. Then the questionnaire was asked to fill by experts and then ISM, MICMAC analysis was used and then confirmatory factor analysis was done to test the model. The results shows that Market share and profit share influence the most.

Pandey & Garg [15] identified the key supply chain variables to make supply chain for manufacturing enterprises. An ISM methodology is applied and these variables were classified into five levels based on their driving and dependence power. ISM is used to establish the relationship among enablers and prepare a hierarchy model. The result shows that Customer Satisfaction is the most critical factor in this study.

According to Nishat Faisal [16] an approach to adapt sustainable practices in supply chain by interlinking the enablers was developed. It uses ISM approach for the development of hierarchy model and mutual relationship among enablers. The findings shows that a group of enablers have high driving power and low dependence power thus requiring much attention and are of strategic importance. It is used to differentiate between dependent and independent variables for the effective implementation of sustainability.

Singh & Sushil [17] identified the enablers of Total Quality Management (TQM) and analyzing them with the use of ISM and understand the mutual relationship among enablers. 14 variables were found through the literature review, brainstorming and experts opinion. The findings shows increased load factor is at the top level while top management commitment is at the lowest level of the model. By implementation of model organizations can become more productive, competitive and thus profitable.

Soti et al. [18] studied and enlisted the enablers of six sigma to establish the relationship using ISM. In this 11 enablers were found through literature review and experts opinion and then validated through survey. The findings revealed that effective top management is at the lowest level of ISM model where as reliable data gathering and retrieval system are the most crucial enabler.

According to Mellor & Webster [19] the enablers in implementing the management of employee well being were found. It is a case study in which interviews were conducted in which firm data was analyzed. The health management system for employees was considered. Leadership support, dedicated resources, involvement of stakeholders and intensive communication were obtained as key enablers in this approach.

The aim of the study of Mani et al. [20] is to find enablers and create interrelationship among them to adopt sustainable measures in supply chain. The enablers were measured with the use of MICMAC analysis and classified according to driving and dependence power. In this 14 enablers were found through literature review and expert opinions. Results indicate that competitive pressure has the high driving power where as social sustainability has the least driving power.

Wooi & Zailani [21] worked on the green supply chain program. In this consideration is on the SMEs in Malaysia to identify the barriers to green supply chain initiatives. The barriers were classified into four groups namely: Attitude and perceptional barriers, Information related barriers, Technical barriers and Resource barriers. The findings shows business oriented firm have high tendency to adopt green supply chain program.

According to Luthra et al. [22] barriers to GSCM in automobile industry were found and then analyzed through ISM technique. Classification of barriers is done according to driving and dependence power using MICMAC analysis. 11 barriers were listed through literature and opinion of experts from academics and industry out of which 5 are dependent, 3 driver variables and 3 linkage variables. 4 barriers were top level barriers while one as bottom level barrier.

Lin & Ho [23] worked on the adoption of green innovations for logistic service providers. Six factors are obtained through the questionnaire survey including organizational, environmental and technological dimension. Findings reveal that all factors tend to promote the adoption of green innovations. It is also found explicitness of green technology is essential for information sharing within the organization.

Sharma et al. [24] analyzed the barriers for successful implementation of reverse logistics. It uses ISM for analysis and to develop the mutual relationship among barriers. In this study 12 barriers were identified through literature review. Finding of the study were that there are no autonomous barriers, four barriers were dependent, while five linkage and three independent variables.

According to Van Hemel & Cramer [25] an empirical study was done to find the barriers and stimuli for ecodesign in SMEs. Out of 11 barriers listed, three are classified as "no-go" barriers while other eight as "initial" barriers. Findings also revealed that the most crucial external stimuli are customer demands, governmental legislation and industrial sector initiatives whereas internal stimuli were increase of product quality, opportunities for innovation and potential market opportunities.

In the study done by Hillary [26] the concern is for the smaller enterprise for developing the environmental management system. As the environmental impact of SMEs is unknown at national levels so this study emphasize drivers and barriers for environmental management for SMEs. This study identifies the issues which play a crucial role in the successful implementation of Environmental Management System and also suggest the benefits of adopting such practices.

Walsh & Thornley [27] found the barriers to improve the energy efficiency in process industries. In this stress is laid on reducing the energy consumption and greenhouse gas emissions. Through the consultation with industrial and academic experts it is found that return on investment, technology performance and cost were key barriers to process industries, however for low grade heat utilization, location and need for capital support for infrastructure were crucial factors.

Shi et al. [28] did the study in context with Chinese SMEs to find the barriers for the implementation of Cleaner Production through the perspectives of industry, government and expert stakeholders. It uses Analytic Hierarchy Process (AHP) for examining and prioritizing the barriers. On the basis of literature barriers were classified into four groups namely: financial and economic barriers, managerial and organizational barriers, policy and market barriers and lastly technical and informational barriers. Then questionnaire was prepared and distributed to experts to fill. The AHP was used for analysis and findings revealed that top three barriers which impedes the adoption of cleaner production were lack of economic incentive policies, lax environmental enforcement and high initial capital cost.

Murillo-Luna et al. [29] studied the barriers which hinders the adoption of proactive environmental strategies. A group of 25 barriers were listed with the help of literature review and consultation with academia and industrial experts and were grouped into four categories such as external barriers, endemic limitations of the firm, limited environmental motivation and limited preparation of employees and operational inertia. The results indicate that endemic limitations of the firm is termed as most crucial barrier which prevents the firms from adopting proactive environmental strategies.

Sardianou [30] did a case study from Greece which investigates the barriers to industrial energy efficiency investments. Empirical analysis probit models are made from the survey. The results depicted that an energy saving campaign should classify industries into subgroups according to different needs and different managerial aspects. One more thing that is established from this study is the importance of qualified employees.

Thiruchelvam et al. [31] did the study in context with SMEs of Asian countries about their energy consumption and its impact on environment. It studied the barriers to energy efficient and environmentally sound technologies. It suggest the ways to implement environmental and energy conservation laws. It also addresses the issues for the implementation of pollution control and energy conservation programmes.

Liu [32] did the study on awareness, behavior and barriers for carbon management in industrial firms in China. According to do the interviews with the industrial experts it was found that Chinese firms were well informed for the successful carbon management and are willing to enforce the laws for its successful implementation. The barriers were grouped into categories namely: contextual, structural, regulatory and cultural. The findings also indicated that effects of these barriers hinders the translation of awareness into behavior.

2.1 Identification of Enablers to Sustainable Product Returns & Recovery Practices

According to the literature review done, following enablers are identified that help in the adoption of Sustainable PRRP which are as follows:

- ❖ **Innovation:** Innovation plays an important role to enhance manufacturing competitiveness. The new techniques and innovation promotes PRRP.
- ❖ **Technological Opportunities:** The returned product provides lots of technological opportunities as it enhances the knowledge scientifically and creates environment to work efficiently.

- **Competitive Pressure:** The concern of returned product is a crucial factor to survive in global market and due to the innovations, there is an increase in demand of better products thus competitive pressure enables PRRP.
- **Continuous Improvement:** It increases success and reduce failures and improving quality which helps in implementation of PRRP.
- **Top Management Commitment:** It is essential for PRRP as it can provide necessary financial and technical support together with the employee empowerment.
- **Financial Performance:** It creates a lot of opportunities in providing technologies, training hence can be very effective in the implementation of PRRP.
- **Customer Satisfaction:** It is the result of delivering the product or service which meets customer needs.
- **Environmental Cost:** It is related to spending the money minimize the harmful impacts on environment thus showing concern over returned product.
- **Improvement of product characteristics:** It enhances the quality of products and improves the life of product and thus enables firms to concentrate on PRRP.
- **Public Pressure:** It is the pressure from customer to receive better quality of products so to minimize waste it is necessary to work on returned product.
- **Government Regulation:** It is related to law enforcement and judicial regulations regarding the policies of organization which sometimes forces firm to work on PRRP.
- **Low Manufacturing Cost:** It is due to the result of efficient process management with minimum waste outputs so with raw material also available PRRP becomes profitable.
- **Education & Training:** It is periodical deployment of workers training and upgraded technological education thus creating better opportunities for returned product.
- **Attracting foreign direct investment:** Liberalization of Universal Economic Ties and reputation in foreign market also enables PRRP.
- **Improving Quality:** Improving product quality helps in adding value to the used product hence it act as an enabler to PRRP.
- **Customer Demands:** It is clearly focused for the needs and requirements of customers to receive the better feedback for the future of organization.
- **Reduction in Carbon emissions:** It is for reducing the harmful effects of new products and needs thus working on the existing products to achieve sustainability.

- **Green technology adoption:** It is the environmentally-friendly technology to reduce the negative impacts of industrial waste on the planet and working on the concept of recycle.
- **Use of IT tools:** It is related to make use of available advanced tools and technology to work efficiently on the product and maximizing profit.
- **Information sharing:** It is the crucial element which holds the different levels of people together in an organization to achieve common goals and contributing towards PRRP.
- **Employee Involvement:** Employee participation helps to increase the flow of information and knowledge and thus expansion of technology which helps in PRRP.
- **Benchmarking:** It is a continuous systematic approach to measure key business process against the industry best practices so that difficult practices can be adopt.
- **Availability of expertise training:** It makes use of experts for the effective training of employees and work efficiently for the growth of firm.
- **Organizational culture & infrastructure:** It works on social and friendly environment within the organization and also the resources required for implementation of PRRP.
- **Availability of Funds:** It is required to support partners who lack the financial strength to support sustainability endeavors which helps everyone to implement PRRP.
- **Involvement of stakeholders:** It is clearly associated with the effective participation of all the stakeholders to achieve organizational goals.
- **Communication:** Effective and efficient communication can contribute to the growth of any firm hence it enables PRRP.
- **Incentive:** Incentive from policy makers directly or indirectly drives the employees to work efficiently and to achieve effective production.

Table 2.1: List of Enablers to Sustainable PRRP

E_i	Enabler	Sources
E1	Innovation	[9][11][12]
E2	Technological Opportunities	[8][9][11][12]
E3	Competitive Pressure	[9][11][12][13][20]
E4	Continuous Improvement	[9][10][17]
E5	Top Management Commitment	[9][11][13][14][16][17][18]
E6	Financial Performance	[8][9][13][15]
E7	Customer Satisfaction	[10][15][17]
E8	Environmental Cost	[10][11][12]
E9	Improvement of Product Characteristics	[10][13][17]
E10	Public Pressure	[11][20]
E11	Government Regulation	[8][10][12][13][20]
E12	Low Manufacturing Cost	[12][15]
E13	Education & Training	[8][12][13][17]
E14	Attracting Foreign direct Investment	[11][12]
E15	Improving Quality	[12][14][17]
E16	Customer Demands	[8][11][13][20]
E17	Reduction in Carbon emissions	[14][17][20]
E18	Green Technology adoption	[10][14][20]
E19	Use of IT Tools	[11][12][15]
E20	Information Sharing	[8][9][16][20]
E21	Employee Involvement	[17][19]
E22	Benchmarking	[17]
E23	Availability of Expertise Training	[18]
E24	Organizational Culture & Infrastructure	[11][13][18]
E25	Availability of Funds	[16][18][20]
E26	Involvement of Stakeholders	[19][20]
E27	Communication	[11][17][19]
E28	Incentive	[8][11][13][20]

2.2 Identification of Barriers to Sustainable Product Returns & Recovery Practices

According to the literature review done, following barriers are identified that impedes in the adoption of Sustainable PRRP which are as follows:

- **Lack of Top Management Commitment:** Top management is ignorant towards returned product as it is felt that it is having negative impact on the progress of firm. It is an important factor because they control key resources of firm.
- **Lack of government support system:** For any progress government support is essential but due to the lack of interest of government the resources are not fully available to firms.
- **Resistance to Technological Advancement:** It is due to the resistance of firm towards new innovation as they feel it will require a huge amount of investment and might not also give intended results.
- **Lack of IT Implementation:** An efficient technology system is highly desirable to implement PRRP in various stages of product life cycle. IT implementation also reduces use of lots of paper work.
- **Lack of awareness & information:** Sometimes the correct knowledge and information is not reached to correct people such as new policies or technologies due to lack of communication impedes PRRP.
- **Lack of Internal Communication:** It prevents information from being transferred to right place at right time. Informal network linkages are highly essential in order to implement PRRP.
- **Lack of Financial & Human resources:** One of the main barriers to PRRP is the lack of financial & human resources with the correct skills as it is useful for adding value to the waste products.
- **Higher cost associated with returned product:** It is perceived as the return product may require high cost for its recovery but indeed its not so raw material is not required and it also contributes to environment.
- **Lack of Implementing green practices:** Innovative green practices involves energy conservation, disposal of waste and the concept of recycling and reuse.
- **Market competition & uncertainty:** It happens when a firm is doubtful about the results of PRRP and also not sure about their products competing in the market.

- **Fear of Failure:** Risk or fear of failure often hinders PRRP as firm is not sure about their practices or they lack confidence in employees to provide intended results.
- **Difficult to change:** Existing practices are relatively easy and smooth to implement and no extra arrangements required so it creates a lot of problem.
- **Lack of Organization Encouragement:** Management can encourage employees for PRRP by providing rewards for their work and also by proper training but lack of support from organization hurts a lot.
- **Understanding & Perception:** PRRP is not perceived by the organization as a vital responsibility. In addition, the benefits of recovery processes are also misunderstood.
- **Explicitness of Technology:** Complexity in gaining access to external technical support system or misconception about the clarity of technology hinders in PRRP.
- **Company Policies:** It falls under the category of organizational barriers in the adoption of PRRP such as managerial hierarchy which takes longer time to take decisions.
- **Financial Constraints:** Shortage of funds, low revenue falls under the category of financial constraints.
- **Problems with Product Quality:** The product quality is not uniform while implementing new techniques or doing some innovations but due to lack of patience it is not easy to implement such practices.
- **Customer Demands:** Customers' requirements and needs are diversified and vary quickly which makes it difficult in the implementation of PRRP.
- **Unsupportive Behavior among Employees:** Supportive behavior is essential for sharing of information at different levels of organization but sometimes the egoistic nature of employees tends to affect firms in n
- **Supplier Reluctance to Change:** It is due to the traditional mindset of suppliers and their interest. Suppliers involvement is essential for competitive advantage.
- **Improper Training of Employees:** Lack of proper training to employees by organization hinders the process of advancement of firm in every field as the correct human skill is required for growth.
- **Infrastructure Requirement:** Lack of infrastructure to support PRRP such as lack of space creates a lot of problem in product recovery processes.

- **Employee Attitude:** Employees resist changing their attitude towards returned products due to their fear of unknown and lack of interest.
- **Insufficient Equipment:** Lack of reliable and effective equipments hinders a lot in PRRP as competent equipments can contribute to success of practices.

Table 2.2: List of Barriers to Sustainable PRRP

B_i	Barrier	Sources
B1	Lack of Top Management Commitment	[22][26][27][28][29]
B2	Lack of government support system	[22][23][28]
B3	Resistance to Technological Advancement	[21][22][24][26][27][28]
B4	Lack of IT Implementation	[22][26]
B5	Lack of Awareness & Information	[21][22][24][26][27][28][30][31]
B6	Lack of Internal Communication	[21][27][31]
B7	Lack of Financial & Human Resource	[21][23][26][27][29][30][31]
B8	Higher Cost associated with returned product	[22][25][26][27][29][30]
B9	Lack of Implementing green practices	[21][22][23][26]
B10	Market Competition & Uncertainty	[22][26][28][29]
B11	Fear of Failure	[21][22]
B12	Difficult to Change	[21][22]
B13	Lack of Organization Encouragement	[22][23][29][32]
B14	Understanding & Perception	[26][29]
B15	Explicitness of Technology	[23][26][28]
B16	Company Policies	[24][27][32]
B17	Financial Constraints	[24][26][27][28][29][30]
B18	Problems With Product Quality	[24][25]
B19	Customer Demands	[25][28]
B20	Unsupportive Behavior among employees	[26][30][31]
B21	Supplier Reluctance to Change	[21][22]
B22	Improper Training of employees	[26][28][30]
B23	Infrastructure Requirement	[26][27][28][30][31]
B24	Employee Attitude	[26][30]
B25	Insufficient Equipment	[26][29]

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Questionnaire Design

A questionnaire was developed based on the enablers and barriers in the previous section. The questionnaire is divided into two parts:

In the first part of questionnaire survey participants have to tell how much enabler and barrier can influence your decision in adoption or implementation of Product Returns & Recovery Practices in Manufacturing Industry. The participants have to rate the elements which drive the industry to implement the Product Returns & Recovery Practices on a likert scale from 1 to 5: 1 - Not at all Influential, 2 - Slightly Influential, 3 - Somewhat Influential, 4 - Very Influential, 5 - Extremely Influential

This type of scale is often used in research and due to equal spacing between the single scoring numbers, an interval scale is simulated to allow further statistical analysis.

The second part enquires basic information concerning the respondent such as his/her Name, Organization and Designation.

3.2 Pilot Study

Survey Instrument was developed in two stages. In the first stage, a draft of the questionnaire was provided to academicians and they were requested to critically evaluate the items from the standpoint of item specificity and clarity of construction. Based on the critique received, some items were revised to improve their specificity and clarity.

The second stage involved administering the questionnaire to experts and industrial professionals. The professionals were asked to complete the revised questionnaire and indicate any ambiguity or other difficulty they experienced in responding to the items, as well as to offer any suggestions they deemed appropriate.

3.3 Data Collection

The primary objective of the study was to develop an instrument to measure the participant's perception of Enablers and Barriers to Product Returns & Recovery Practices in Manufacturing Industry. The General Managers, Deputy General Managers, Senior Managers, Assistant

Engineers, Engineers are likely to be “thought” leaders with respect to activities in organization, therefore, they were asked to fill the survey in this study.

The questionnaire was used for an online survey via Google forms website. An E-mail was sent to about 250 senior executives working in the manufacturing/production departments all over India. The E-mail contained the web link of the survey, explained the background and the objective of the study. The low response rate was the major concern during the initial stage of the survey. In order to increase the response rate, email reminders were sent repeatedly and in some cases telephonic calls were made.

3.4 ISM Methodology [33][34][35]

ISM stands for Interpretive Structural Modelling which helps to impose order and direction on the complexity of relationships among elements of a system. It is interpretive as the judgment of the group decides whether and how the variables are related. It is structural as on the basis of relationship, an overall structure is extracted from the complex set of variables. It is a modeling technique as the specific relationships and overall structure are portrayed in a graphical model.

The various steps involved in the ISM methodology are given below:

Step 1: Variables considered for the system under consideration are listed.

Step 2: From variables identified in step1, a contextual relationship is established among variables to identify which pairs of variables should be examined.

Step 3: A structural self-interaction matrix (SSIM) is developed for variables, indicating pair-wise relationships among the variables of the system under consideration.

Step 4: Reachability matrix is developed from SSIM and the matrix is checked for transitivity. Transitivity of contextual relation is a basic assumption in ISM. It states that if variable A is related to B and B to C, then A is necessarily related to C.

Step 5: The reachability matrix obtained in step 4 is partitioned into different levels.

Step 6: Based on relationships stated in the reachability matrix, a directed graph is drawn and transitive links removed

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: The ISM model developed in step7 is checked for conceptual inconsistency and necessary modifications are made. The above steps are shown in Figure. 3.1.

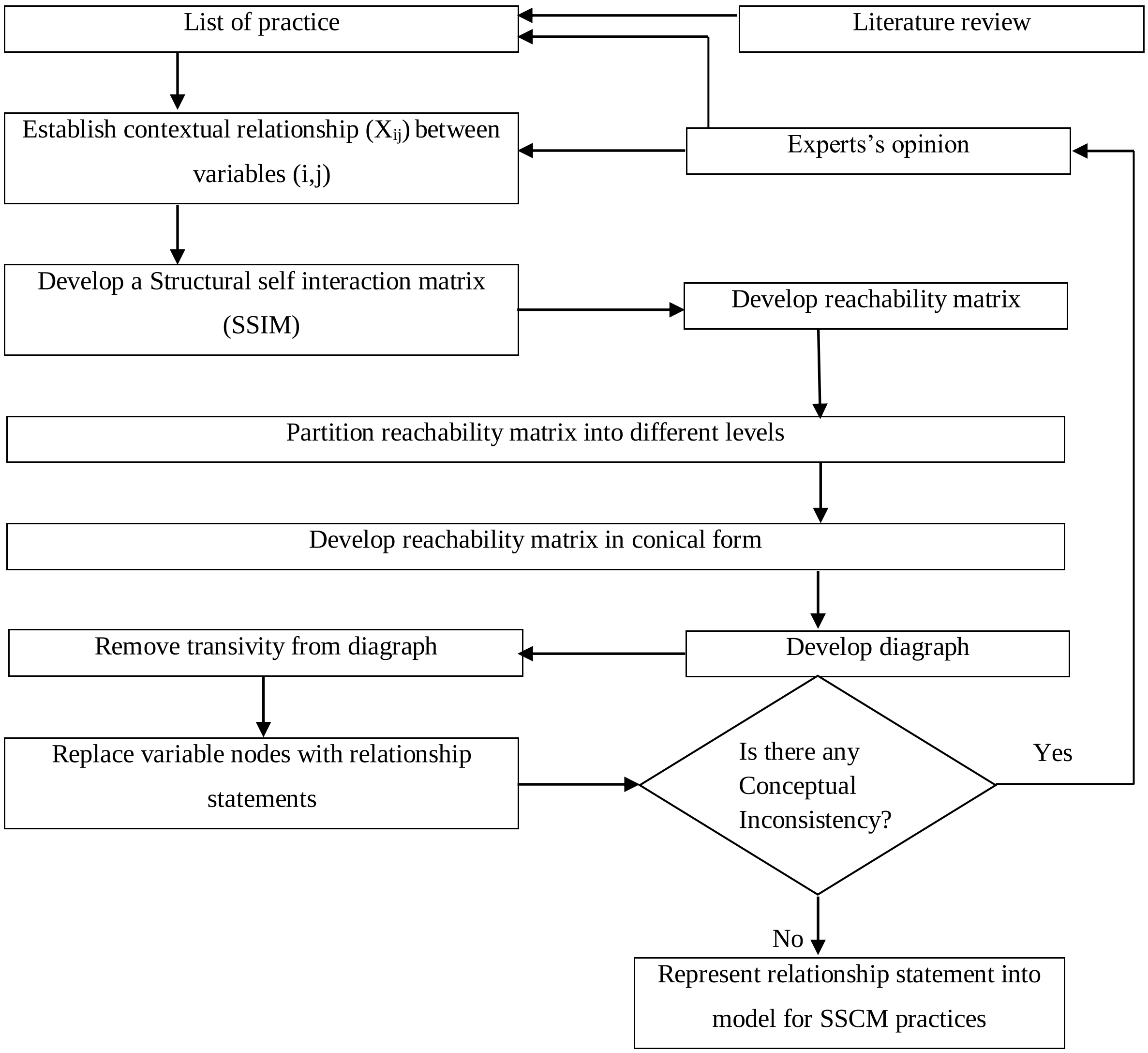

Figure 3.1: Flow Chart to prepare ISM model [36][37]

3.4.1 Structural Self Interaction Matrix (SSIM)

Keeping in mind contextual relationship for each practice, the existence of a relation between any two practices (i and j) and associated direction of the relation is questioned. Four symbols denote the direction of the relationship between practices (i and j)

- Type V : Practice i will help achieve practice j
- Type A : Practice j will helps achieve practice i
- Type X : Practice i and j help achieve each other
- Type O : Practices i and j are unrelated

3.4.2 Initial Reachability Matrix

In this step, a reachability matrix is developed from SSIM. The SSIM format is converted into an initial reachability matrix format by transforming information from each SSIM cell into binary digits. This transformation is done with the following rules :

- ❖ If an entry in the cell (i, j) in SSIM is V, then cell (i, j) entry becomes 1 and cell (j, i) entry becomes 0 in the initial reach- ability matrix
- ❖ If an entry in the cell (i, j) in SSIM is A, then cell (i, j) entry becomes 0 and cell (j, i) entry becomes 1 in the initial reach- ability matrix
- ❖ If an entry in the cell (i, j) in SSIM is X, then entries in both kills (i, j) and (j, i) become 1 in the initial reachability matrix.
- ❖ If an entry in the cell (i, j) in SSIM is O, then entries in both the cells (i, j) and (j, i) become 0 in the initial reachability matrix

3.4.3 Final Reachability Matrix

The final reachability matrix for the factors is obtained by incorporating the transivities as explained in step IV of the ISM methodology. The final reachability matrix for the factors is obtained by incorporating the transivity. It is a basic assumption made in ISM. It states that

- ❖ "If factor 1 is related to 2, and factor 2 is related to 3,
  then factor 1 is necessarily related to 3".

3.4.4 Level Partitions

From the final reachability matrix, the reachability and antecedent set for each element is found. The reachability set consists of the element itself and the other elements which it may help achieve, whereas the antecedent set consists of the element itself and the other elements which may help in achieving it. Thereafter, the intersection of these sets is derived for all the elements. The factors for which the reachability and the intersection sets are same occupy the top level in ISM hierarchy. The top level element in the hierarchy would not help achieve any other element above its own level. Once the top level element is identified, it is separated out from the other elements. Then, the same process is repeated to find out the elements in the next level. This process is continued until the level of each element is found.

3.4.5 Conical Matrix

Conical matrix is developed by clustering factors in the same level across the rows and columns of the final reachability matrix. The drive power of a factor is derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in columns. Next, drive power and dependence power ranks are calculated by giving highest ranks to the factors that have the maximum number of ones in the rows and columns, respectively. The conical matrix helps in the generation of diagraph and later on structural model.

3.5 TOPSIS Methodology [38][39]

The full name of TOPSIS is Technique for Order of Preference by Similarity to Ideal Solution is a Multi Criteria Decision Making (MCDM) method. MCDM is a sub-discipline of operations research that explicitly considers multiple criteria in decision making environments.

TOPSIS method considers three types of attributes or criteria:

- ❖ Qualitative benefit attributes/criteria
- ❖ Quantitative benefit attributes
- ❖ Cost attributes or criteria

The basic thought is to define the ideal solution and negative ideal solution for decision making problem firstly, then find a feasible solution and rank the alternatives according to the closeness between the feasible solution and the ideal solution, which is made the nearest from the ideal solution and farthest from the negative ideal solution.

- ❖ TOPSIS assumes that we have m alternatives (options) and n attributes/criteria and we have the score of each option with respect to each criterion.
- ❖ Let x_{ij} score of option i with respect to criterion j
  We have a decision matrix $X = (x_{ij})$ $m \times n$ matrix.
- ❖ Let J be the set of benefit attributes or criteria (more is better)
- ❖ Let J' be the set of negative attributes or criteria (less is better)

The solution steps are as follows:

Step 1: Construct normalized decision matrix

This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria.

Normalize scores or data as follows:

$r_{ij} = x_{ij} / (\Sigma x^2_{ij})$ for $i = 1, \ldots, m; j = 1, \ldots, n$

Step 2: Construct the weighted normalized decision matrix.

Assume we have a set of weights for each criteria w_j for $j = 1, \ldots n$.

Multiply each column of the normalized decision matrix by its associated weight.

An element of the new matrix is:

$v_{ij} = w_j r_{ij}$

Step 3: Determine the ideal and negative ideal solutions

Ideal solution.

$A^* = \{ v_1^*, \ldots, v_n^* \}$, where

$v_j^* = \{ \max_i (v_{ij}) \text{ if } j \in J ; \min_i (v_{ij}) \text{ if } j \in J' \}$

Negative ideal solution.

$A' = \{ v_1', \ldots, v_n' \}$, where

$v' = \{ \min_i (v_{ij}) \text{ if } j \in J ; \max_i (v_{ij}) \text{ if } j \in J' \}$

Step 4: Calculate the separation measures for each alternative

The separation from the ideal alternative is:

$S_i^* = [\Sigma_j (v_j^* - v_{ij})^2]^{½}$ $i = 1, \ldots, m$

Similarly, the separation from the negative ideal alternative is:

$S'_i = [\Sigma_j (v_j' - v_{ij})^2]^{½}$ $i = 1, \ldots, m$

Step 5: Calculate the relative closeness to the ideal solution C_i^*

$C_i^* = S'_i / (S_i^* + S'_i)$, $0 < C_i^* < 1$

Rank the alternatives according to the value of C_i^*. 1st rank is given to the alternative having the highest value of C_i^* where as last rank to the alternative having lowest value of C_i^*.

CHAPTER – 4

DATA ANALYSIS AND MODEL DEVELOPMENT

Reliability is concerned with the consistency of our measurement, that's the degree to which the questions used in a survey elicit the same type of information each time they are used under the same conditions. Lack of reliability may arise from divergences between observers or instruments of measurement or instability of the attribute being measured.

4.1 Cronbach's alpha

The internal stability of a set of computation items is meant to the degree to which items in the set are analogous. It can be approximated using reliability coefficient such as Cronbach's alpha. **Minitab 17** is used to determine the reliability of each factor in terms of the Cronbach's alpha. An alpha value of 0.7 is often contemplated for confirming internal consistency on a scale of 0 to 1, where '0' define that the data is not reliable and '1' define that the data is fully reliable. In this study, lowest value of the Cronbach's alpha value of 0.7788 for the enablers and 0.8584 for the barriers is achieved, which is considered good, and hence it can be accomplished that the data is highly reliable[12].

Table 4.1: Mean and Cronbach's alpha for Enablers

E_i	ENABLER	MEAN	Cronbach's alpha
E1	Innovation	4.0698	0.7956
E2	Technological Opportunities	4.4349	0.7808
E3	Competitive Pressure	3.8148	0.7971
E4	Continuous Improvement	3.9306	0.7872
E5	Top Management Commitment	3.7973	0.7940
E6	Financial Performance	4.4021	0.7935
E7	Customer Satisfaction	4.4100	0.7854
E8	Environmental Cost	3.9439	0.7922
E9	Improvement of Product Characteristics	4.4037	0.7842
E10	Public Pressure	3.6381	0.7820
E11	Government Regulation	3.8301	0.7977
E12	Low Manufacturing Cost	3.9968	0.7889
E13	Education & Training	3.7931	0.7829
E14	Attracting Foreign direct Investment	3.7333	0.7926
E15	Improving Quality	4.3148	0.7829
E16	Customer Demands	4.0624	0.7788
E17	Reduction in Carbon emissions	3.8132	0.7914

E18	Green Technology adoption	3.7576	0.7954
E19	Use of IT Tools	3.7920	0.7869
E20	Information Sharing	3.3439	0.7903
E21	Employee Involvement	3.6137	0.7915
E22	Benchmarking	3.3317	0.7927
E23	Availability of Expertise Training	3.6862	0.7971
E24	Organizational Culture & Infrastructure	3.5333	0.7997
E25	Availability of Funds	3.9915	0.7949
E26	Involvement of Stakeholders	3.3703	0.8043
E27	Communication	3.1920	0.7970
E28	Incentive	3.4830	0.8063

4.2 Ranking of Enablers

In Table 4.1 the enablers are listed with their means and Cronbach's alpha value. The ranking of enablers is on the basis of their mean value. In Table 4.2 ranking of enablers is done, from the mean value it is seen that Technological Opportunities is having the highest value of 4.4349 on a scale of 5 where as communication has the lowest value of 3.1920. In this study 28 enablers are listed and for doing the analysis only top 13 enablers are taken[11].

Table 4.2: Ranking of Enablers according to mean value

E_i	ENABLER	MEAN	RANK
E2	Technological Opportunities	4.4349	1.
E7	Customer Satisfaction	4.4100	2.
E9	Improvement of Product Characteristics	4.4037	3.
E6	Financial Performance	4.4021	4.
E15	Improving Quality	4.3148	5.
E1	Innovation	4.0698	6.
E16	Customer Demands	4.0624	7.
E12	Low Manufacturing Cost	3.9968	8.
E25	Availability of Funds	3.9915	9.
E8	Environmental Cost	3.9439	10.
E4	Continuous Improvement	3.9306	11.
E11	Government Regulation	3.8301	12.
E3	Competitive Pressure	3.8148	13.
E17	Reduction in Carbon emissions	3.8132	14.
E5	Top Management Commitment	3.7973	15.
E13	Education & Training	3.7931	16.
E19	Use of IT Tools	3.7920	17.
E18	Green Technology adoption	3.7576	18.
E14	Attracting Foreign direct Investment	3.7333	19.
E23	Availability of Expertise Training	3.6862	20.
E10	Public Pressure	3.6381	21.

E21	Employee Involvement	3.6137	22.
E24	Organizational Culture & Infrastructure	3.5333	23.
E28	Incentive	3.4830	24.
E26	Involvement of Stakeholders	3.3703	25.
E20	Information Sharing	3.3439	26.
E22	Benchmarking	3.3317	27.
E27	Communication	3.1920	28.

4.3 Ranking of Barriers

In Table 4.3 the barriers are listed with their means and Cronbach's alpha value. The ranking of barriers is done on the basis of their mean value. In Table 4.4 ranking of barriers is done, from the mean value it is seen that Lack of Financial & Human Resource is having the highest value of 4.4508 on a scale of 5 where as Supplier Reluctance to Change has the lowest value of 2.5185. In this study 25 barriers are listed and for doing the analysis only top 12 barriers are taken[40].

Table 4.3: Mean and Cronbach's alpha for Barriers

B_i	BARRIER	MEAN	Cronbach's alpha
B1	Lack of Top Management Commitment	3.9788	0.8661
B2	Lack of government support system	3.3486	0.8659
B3	Resistance to Technological Advancement	4.2915	0.8676
B4	Lack of IT Implementation	3.6788	0.8660
B5	Lack of Awareness & Information	4.0333	0.8685
B6	Lack of Internal Communication	3.2179	0.8606
B7	Lack of Financial & Human Resource	4.4508	0.8617
B8	Higher Cost associated with returned product	3.6206	0.8708
B9	Lack of Implementing green practices	2.9788	0.8647
B10	Market Competition & Uncertainty	3.1444	0.8658
B11	Fear of Failure	2.7238	0.8656
B12	Difficult to Change	2.5444	0.8601
B13	Lack of Organization Encouragement	3.4264	0.8601
B14	Understanding & Perception	2.9555	0.8617
B15	Explicitness of Technology	4.1476	0.8641
B16	Company Policies	3.1846	0.8584
B17	Financial Constraints	4.2275	0.8664
B18	Problems With Product Quality	3.0804	0.8625
B19	Customer Demands	3.3963	0.8695
B20	Unsupportive Behavior among employees	3.4095	0.8617
B21	Supplier Reluctance to Change	2.5185	0.8664
B22	Improper Training of employees	3.8619	0.8627
B23	Infrastructure Requirement	3.1719	0.8673
B24	Employee Attitude	3.5555	0.8702
B25	Insufficient Equipment	3.9084	0.8661

Table 4.4: Ranking of Barriers according to mean value

B_i	BARRIER	MEAN	RANK
B7	Lack of Financial & Human Resource	4.4508	1.
B3	Resistance to Technological Advancement	4.2915	2.
B17	Financial Constraints	4.2275	3.
B15	Explicitness of Technology	4.1476	4.
B5	Lack of Awareness & Information	4.0333	5.
B1	Lack of Top Management Commitment	3.9788	6.
B25	Insufficient Equipment	3.9084	7.
B22	Improper Training of employees	3.8619	8.
B4	Lack of IT Implementation	3.6788	9.
B8	Higher Cost associated with returned product	3.6206	10.
B24	Employee Attitude	3.5555	11.
B13	Lack of Organization Encouragement	3.4264	12.
B20	Unsupportive Behavior among employees	3.4095	13.
B19	Customer Demands	3.3963	14.
B2	Lack of government support system	3.3486	15.
B6	Lack of Internal Communication	3.2179	16.
B16	Company Policies	3.1846	17.
B23	Infrastructure Requirement	3.1719	18.
B10	Market Competition & Uncertainty	3.1444	19.
B18	Problems With Product Quality	3.0804	20.
B9	Lack of Implementing green practices	2.9788	21.
B14	Understanding & Perception	2.9555	22.
B11	Fear of Failure	2.7238	23.
B12	Difficult to Change	2.5444	24.
B21	Supplier Reluctance to Change	2.5185	25.

4.4 Implementation of ISM on Enablers to PRRP

Based on the contextual relationship between enablers, the Structural Self Interaction Matrix has been framed. Based on the thinking of academician experts, the SSIM has been concluded and is presented in Table 4.5.

Table 4.5: Structural Self Interaction Matrix for Enablers

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	E2	X	O	V	O	V	X	A	V	A	O	X	O	X
2	E7		X	A	O	A	A	O	A	O	O	A	O	O
3	E9			X	X	X	A	O	O	O	O	X	O	X
4	E6				X	V	V	O	A	X	O	V	V	O
5	E15					X	A	A	O	A	V	X	A	A
6	E1						X	X	V	A	V	V	O	X
7	E16							X	V	O	O	V	O	V

8	**E12**								X	A	V	A	A	A
9	**E25**									X	V	V	O	O
10	**E8**										X	A	A	A
11	**E4**											X	A	A
12	**E1**												X	A
13	**E3**													X

The SSIM is converted into a binary matrix, called the initial reachability matrix. Table 4.6 represent the initial reachability matrix for enablers. It is acquired from the SSIM by replacing the concerned binary values.

Table 4.6: Initial reachability matrix for Enablers

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	**E2**	1	0	1	0	1	1	0	1	0	0	1	0	1
2	**E7**	0	1	0	0	0	0	0	0	0	0	0	0	0
3	**E9**	0	1	1	1	1	0	0	0	0	0	1	0	1
4	**E6**	0	0	1	1	1	1	0	0	1	0	1	0	0
5	**E15**	0	1	1	0	1	0	0	0	0	1	1	0	0
6	**E1**	1	1	1	0	1	1	1	1	0	1	1	0	1
7	**E16**	1	0	0	0	1	1	1	1	0	0	1	0	1
8	**E12**	1	0	0	1	1	1	0	1	1	1	1	0	0
9	**E25**	1	0	0	1	1	1	0	1	1	1	1	0	0
10	**E8**	0	0	0	0	0	0	0	0	0	1	0	0	0
11	**E4**	1	1	1	0	1	0	0	1	0	1	1	0	0
12	**E11**	0	0	0	0	1	0	0	1	0	1	1	1	0
13	**E3**	1	0	1	0	1	1	0	1	0	1	1	1	1

The final reachability matrix for the enablers is obtained by consolidating the transivities as explained in Step IV of ISM methodology which is shown in Table 4.7.

Table 4.7: Final Reachability Matrix with Driving and Dependence Power for Enablers

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Driving Power**
1	**E2**	1	1	1	1	1	1	1	1	0	1	1	1	1	12
2	**E7**	0	1	0	0	0	0	0	0	0	0	0	0	0	1
3	**E9**	1	1	1	1	1	1	0	1	1	1	1	1	1	12
4	**E6**	1	1	1	1	1	1	1	1	1	1	1	0	1	12
5	**E15**	1	1	1	1	1	0	0	1	0	1	1	1	1	10
6	**E1**	1	1	1	1	1	1	1	1	0	1	1	1	1	12
7	**E16**	1	1	1	1	1	1	1	1	0	1	1	1	1	12
8	**E12**	1	1	1	1	1	1	0	1	1	1	1	0	0	10
9	**E25**	1	1	1	1	1	1	1	1	1	1	1	1	1	13
10	**E8**	0	0	0	0	0	0	0	0	0	1	0	0	0	1

11	**E4**	1	1	1	1	1	1	0	1	0	1	1	0	1	10
12	**E11**	1	1	1	1	1	1	1	1	1	1	1	1	0	11
13	**E3**	1	1	1	1	1	0	1	1	0	1	1	1	1	12
Dependence Power		**11**	**12**	**11**	**11**	**11**	**9**	**7**	**11**	**5**	**12**	**11**	**8**	**9**	**128/128**

From the final reachability matrix, the reachability and antecedent set for each enabler is established. Thereafter the intersection of these sets is obtained for all enablers. The enablers for which reachability and intersection sets are same occupy the same level in ISM hierarchy. Once any level is found, it is eliminated from other elements. Then same process is iterated to find out elements in next level. This process is continued until level of each enabler is obtained.

Table 4.8: Level I Iteration for Enablers

Enablers	Reachability Set	Antecedent Set	Intersection	Levels
E2	1,2,3,4,5,6,7,8,10,11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,7,8,11,12,13	
E7	2	1,2,3,4,5,6,7,8,9,11,12,13	2	**I**
E9	1,2,3,4,5,6,8,9,10,11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,9,11,12,13	
E6	1,2,3,4,5,6,7,8,9,10,11	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,7,8,9,11	
E15	1,2,3,4,5,8,10,11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,8,11,12,13	
E1	1,2,3,4,5,6,7,8,10,11,12,13	1,3,4,6,7,8,9,11,12,13	1,3,4,6,7,8,11,12,13	
E16	1,2,3,4,5,6,7,8,10,11,12,13	1,4,6,7,9,12,13	1,4,6,7,12,13	
E12	1,2,3,4,5,6,8,9,10,11,12	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,9,11,12	
E25	1,2,3,4,5,6,7,8,9,10,11,12,13	3,4,8,9,12	3,4,8,9,12	
E8	10	1,3,4,5,6,7,8,9,10,11,12,13	10	**I**
E4	1,2,3,4,5,6,8,10,11	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,11	
E11	1,2,3,4,5,6,7,8,9,10,11,12	1,3,5,6,7,8,9,12,13	1,3,5,6,7,8,9,12	
E3	1,2,3,4,5,6,7,8,10,11,12,13	1,3,5,6,7,9,13	1,3,5,6,7,13	

Table 4.9: Level II Iteration for Enablers

Enablers	Reachability Set	Antecedent Set	Intersection Set	Levels
E2	1,3,4,5,6,7,8,11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,7,8,11,12,13	**II**
E9	1,3,4,5,6,8,9,11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,9,11,12,13	**II**
E6	1, 3,4,5,6,7,8,9, 11	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,7,8,9,11	**II**
E15	1, 3,4,5,8, 11,12,13	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,8,11,12,13	**II**
E1	1, 3,4,5,6,7,8, 11,12,13	1,3,4,6,7,8,9,11,12,13	1,3,4,6,7,8,11,12,13	
E16	1, 3,4,5,6,7,8, 11,12,13	1,4,6,7,9,12,13	1,4,6,7,12,13	
E12	1, 3,4,5,6,8,9, 11,12	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,9,11,12	**II**
E25	1, 3,4,5,6,7,8,9, 11,12,13	3,4,8,9,12	3,4,8,9,12	
E4	1, 3,4,5,6,8, 11	1,3,4,5,6,7,8,9,11,12,13	1,3,4,5,6,8,11	**II**
E11	1,3,4,5,6,7,8,9, 11,12	1,3,5,6,7,8,9,12,13	1,3,5,6,7,8,9,12	
E3	1, 3,4,5,6,7,8, 11,12,13	1,3,5,6,7,9,13	1,3,5,6,7,13	

Table 4.10: Level III Iteration for Enablers

Enablers	Reachability Set	Antecedent Set	Intersection Set	Levels
E1	6,7,12,13	6,7,9,12,13	6,7, 12,13	**III**
E16	6,7,12,13	6,7,9,12,13	6,7,12,13	**III**
E25	6,7,9,12,13	9,12	9,12	
E11	6,7,9,12	6,7,9,12,13	6,7,9,12	**III**
E3	6,7,12,13	6,7,9,13	6,7,13	

Table 4.11: Level IV Iteration for Enablers

Enablers	Reachability Set	Antecedent Set	Intersection Set	Levels
E25	9,13	9	9	
E3	13	9,13	13	**IV**

Table 4.12: Level V Iteration for Enablers

Enablers	Reachability Set	Antecedent Set	Intersection Set	Levels
E25	9	9	9	**V**

Conical matrix is developed by grouping enablers in the same level across the rows and columns of the final reachability matrix. Table 4.13 shows the conical matrix.

Table 4.13: Conical matrix for Enablers

	E7	E8	E4	E15	E12	E6	E9	E2	E1	E11	E16	E3	E25	Driving Power
E7	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
E8	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
E4	1	1	1	1	1	1	1	1	1	0	0	0	0	**9**
E15	1	1	1	1	1	1	1	1	0	1	0	1	0	**10**
E12	1	1	1	1	1	1	1	1	1	1	0	0	1	**11**
E6	1	1	1	1	1	1	1	1	1	0	1	0	1	**11**
E9	1	1	1	1	1	1	1	1	1	1	0	1	1	**12**
E2	1	1	1	1	1	1	1	1	1	1	1	1	0	**12**
E1	1	1	1	1	1	1	1	1	1	1	1	1	0	**12**
E11	1	1	1	1	1	1	1	1	1	1	1	0	1	**12**
E16	1	1	1	1	1	1	1	1	1	1	1	1	0	**12**
E3	1	1	1	1	1	1	1	1	1	1	1	1	0	**12**
E25	1	1	1	1	1	1	1	1	1	1	1	1	1	**13**
Dependence Power	**12**	**12**	**11**	**11**	**11**	**11**	**11**	**11**	**10**	**9**	**7**	**7**	**5**	**128**

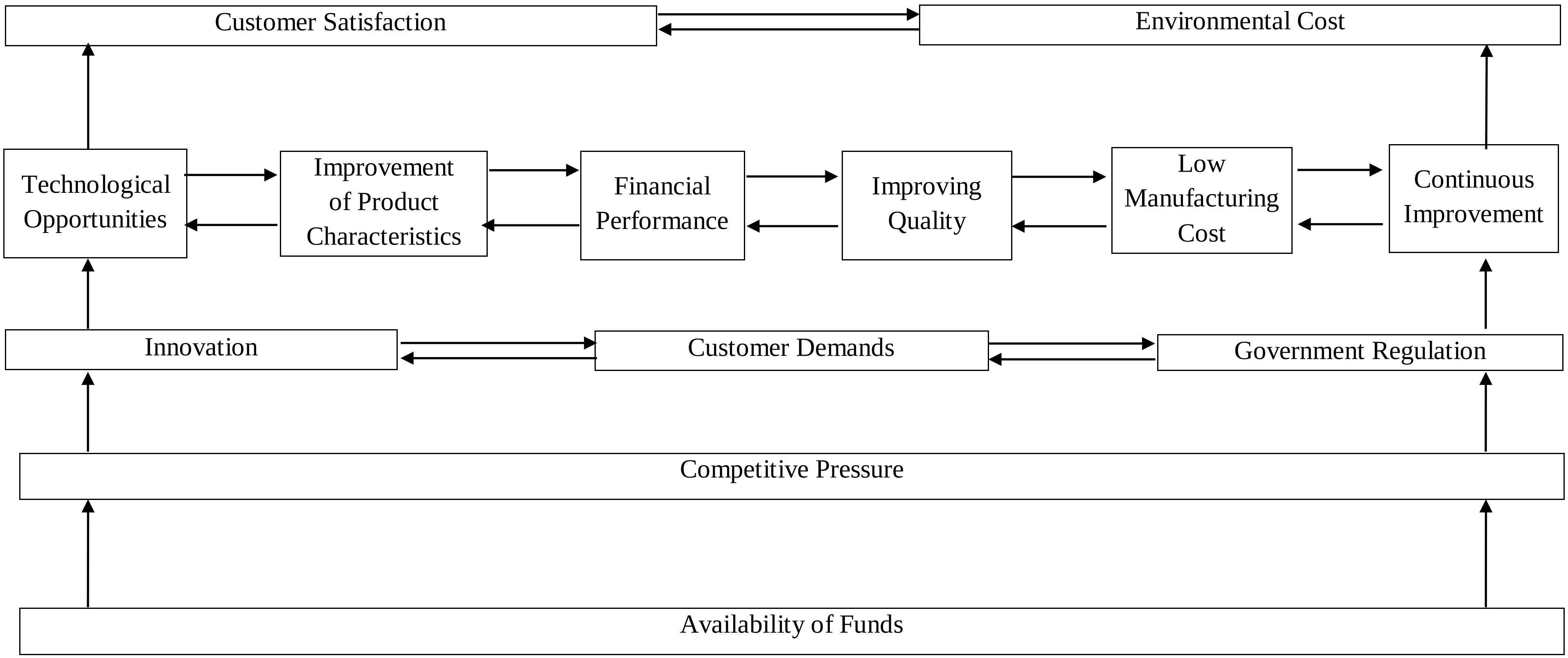

Figure 4.1: ISM Model for Enablers to PRRP

Figure 4.1 shows the categorization of Enablers to PRRP in Various levels of ISM as: Level I: Customer Satisfaction [E7] and Environmental Cost [E8], Level II: Technological Opportunities [E2], Improvement of Product Characteristics [E9], Financial Performance [E6], Improving Quality [E15], Low Manufacturing Cost [E12], Continuous Improvement [E4], Level III: Innovation [E1], Customer Demands [E16], Government Regulation [E11], Level IV: Competitive Pressure [E3], Level V: Availability of Funds [E25]

4.5 Ranking of Industries using TOPSIS considering Enablers to PRRP

The data is collected from four different manufacturing sectors of India namely Automobile, Machinery, Process and Electrical which is shown in Table 4.14.

Table 4.14: Decision Matrix for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
Automobile	4.43	4.64	4.63	4.37	4.44	4.06	4.13	4.68	3.86	3.87	4.21	3.7	4.42
Machinery	4.3	4.2	4.2	4.3	4.3	4.1	4.2	3.5	4.2	4.1	3.9	4.1	3.3
Process	4.73	4.41	4.33	4.55	4.36	3.98	4.08	3.83	4.28	3.61	4.06	3.55	3.81
Electrical	4.27	4.26	4.33	4.39	4.08	4.13	3.79	3.62	3.67	4.21	4.09	4.03	3.41

In Table 4.15 weightage of top 13 enablers is listed to perform the analysis. The weight of each enabler is calculated by simple method of dividing its value by sum of total value.

Table 4.15: Weightage and mean value for Enablers

S.No	E_i	ENABLER	MEAN	WEIGHT
1.	E2	Technological Opportunities	4.4349	0.08273
2.	E7	Customer Satisfaction	4.4100	0.08226
3.	E9	Improvement of Product Characteristics	4.4037	0.08215
4.	E6	Financial Performance	4.4021	0.08212
5.	E15	Improving Quality	4.3148	0.08049
6.	E1	Innovation	4.0698	0.07592
7.	E16	Customer Demands	4.0624	0.07578
8.	E12	Low Manufacturing Cost	3.9968	0.07455
9.	E25	Availability of Funds	3.9915	0.07446
10.	E8	Environmental Cost	3.9439	0.07357
11.	E4	Continuous Improvement	3.9306	0.07332
12.	E11	Government Regulation	3.8301	0.07145
13.	E3	Competitive Pressure	3.8148	0.07116

To apply TOPSIS on Enablers, consider Table 4.14 which is termed as decision matrix. In this study

m = 4 alternatives or Industries (A1, A2, A3, A4)

n = 13 criteria (Enablers)

A1 denotes Automobile, A2 denotes Machinery, A3 denotes Process, A4 denotes Electrical.

Step 1 (a) : Evaluate $(\Sigma x^2_{ij})^{1/2}$ for each column

Table 4.16: Topsis Step 1(A) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
A1	19.625	21.529	21.437	19.097	19.713	16.483	17.057	21.902	14.899	14.977	17.721	13.690	19.536
A2	18.490	17.640	17.640	18.490	18.490	16.810	17.640	12.250	17.640	16.810	15.210	16.810	10.890
A3	22.373	19.448	18.749	20.702	19.009	15.840	16.646	14.669	18.318	13.032	16.483	12.602	14.516
A4	18.233	18.147	18.749	19.272	16.646	17.057	14.364	13.104	13.469	17.724	16.728	16.241	11.628
Σx_{ij}^2	**78.721**	**76.764**	**76.575**	**77.561**	**73.858**	**66.19**	**65.707**	**61.925**	**64.326**	**62.543**	**66.142**	**59.343**	**56.57**
$(\Sigma x_{ij}^{2})^{1/2}$	**8.872**	**8.761**	**8.751**	**8.807**	**8.594**	**8.136**	**8.106**	**7.869**	**8.02**	**7.908**	**8.133**	**7.703**	**7.521**

Step 1 (b) : Divide each column by $(\Sigma x^2_{ij})^{1/2}$ to get r_{ij}

Table 4.17: Topsis Step 1(B) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
A1	0.499	0.529	0.529	0.496	0.516	0.499	0.509	0.594	0.481	0.489	0.517	0.48	0.587
A2	0.484	0.479	0.479	0.488	0.500	0.504	0.518	0.444	0.523	0.518	0.479	0.532	0.438
A3	0.533	0.503	0.495	0.516	0.507	0.489	0.503	0.486	0.533	0.456	0.499	0.461	0.506
A4	0.481	0.486	0.495	0.498	0.474	0.507	0.467	0.46	0.457	0.532	0.503	0.523	0.453

Step 2 : Multiply each column by w_j to get v_{ij}

Table 4.18: Topsis Step 2 for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
A1	0.0413	0.0435	0.0434	0.0407	0.0415	0.0378	0.0385	0.0443	0.0358	0.0359	0.0379	0.0343	0.0417
A2	0.0400	0.0394	0.0393	0.0400	0.0402	0.0382	0.0392	0.0331	0.0389	0.0381	0.0351	0.0380	0.0311
A3	0.0441	0.0413	0.0406	0.0423	0.0408	0.0371	0.0381	0.0362	0.0397	0.0335	0.0366	0.0329	0.0360
A4	0.0397	0.0399	0.0406	0.0408	0.0381	0.0385	0.0354	0.0343	0.0340	0.0391	0.0368	0.0373	0.0322

Step 3 (a) : Find ideal solution A*.

A* = {0.0441, 0.0435, 0.0434, 0.0423, 0.0415, 0.0385, 0.0392, 0.0443, 0.0397, 0.0391, 0.0379, 0.0380, 0.0417}

Table 4.19: Topsis Step 3(A) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
A1	0.0413	**0.0435**	**0.0434**	0.0407	**0.0415**	0.0378	0.0385	**0.0443**	0.0358	0.0359	**0.0379**	0.0343	**0.0417**
A2	0.0400	0.0394	0.0393	0.0400	0.0402	0.0382	**0.0392**	0.0331	0.0389	0.0381	0.0351	**0.0380**	0.0311
A3	**0.0441**	0.0413	0.0406	**0.0423**	0.0408	0.0371	0.0381	0.0362	**0.0397**	0.0335	0.0366	0.0329	0.0360
A4	0.0397	0.0399	0.0406	0.0408	0.0381	**0.0385**	0.0354	0.0343	0.034	**0.0391**	0.0368	0.0373	0.0322

Step 3 (b) : Find negative ideal solution A'.

A' = {0.0397, 0.0394, 0.0393, 0.0400, 0.0381, 0.0371, 0.0354, 0.0331, 0.0340, 0.0335, 0.0351, 0.0329, 0.0311}

Table 4.20: Topsis Step 3(B) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3
A1	0.0413	0.0435	0.0434	0.0407	0.0415	0.0378	0.0385	0.0443	0.0358	0.0359	0.0379	0.0343	0.0417
A2	0.0400	**0.0394**	**0.0393**	**0.0400**	0.0402	0.0382	0.0392	**0.0331**	0.0389	0.0381	**0.0351**	0.0380	**0.0311**
A3	0.0441	0.0413	0.0406	0.0423	0.0408	**0.0371**	0.0381	0.0362	0.0397	**0.0335**	0.0366	**0.0329**	0.0360
A4	**0.0397**	0.0399	0.0406	0.0408	**0.0381**	0.0385	**0.0354**	0.0343	**0.0340**	0.0391	0.0368	0.0373	0.0322

Step 4 (a) : Evaluate separation from ideal solution $S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½}$ for each row

Table 4.21: Topsis Step 4(A) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3	$\Sigma(v_j^*-v_{ij})^2$	$[\Sigma(v_j^*-v_{ij})^2]_{1/2}$
A1	0.0028	0	0	0.0016	0	0.0007	0.0007	0	0.0039	0.0032	0	0.0037	0	0.00005052	0.0071
A2	0.0041	0.0041	0.0041	0.0023	0.0013	0.0003	0	0.0112	0.0008	0.001	0.0028	0	0.0106	0.00030478	0.0174
A3	0	0.0022	0.0028	0	0.0007	0.0014	0.0011	0.0081	0	0.0056	0.0013	0.0051	0.0057	0.00017350	0.0132
A4	0.0044	0.0036	0.0028	0.0015	0.0034	0	0.0038	0.01	0.0057	0	0.0011	0.0007	0.0095	0.00029285	0.0171

Step 4 (b) : Evaluate separation from negative ideal solution $S_i' = [\Sigma (v_j^* - v_{ij})^2]^{½}$ for each row

Table 4.22: Topsis Step 4(B) for Enablers

	E2	E7	E9	E6	E15	E1	E16	E12	E25	E8	E4	E11	E3	$\Sigma(v_j^*-v_{ij})^2$	$[\Sigma(v_j^*-v_{ij})^2]_{1/2}$
A1	0.0016	0.0041	0.0041	0.0007	0.0034	0.0007	0.0031	0.0112	0.0018	0.0024	0.0028	0.0014	0.0106	0.00031493	0.0177
A2	0.0003	0	0	0	0.0021	0.0011	0.0038	0	0.0049	0.0046	0	0.0051	0	0.00009133	0.0095
A3	0.0044	0.0019	0.0013	0.0023	0.0027	0	0.0027	0.0031	0.0057	0	0.0015	0	0.0049	0.00011289	0.0106
A4	0	0.0005	0.0013	0.0008	0	0.0014	0	0.0012	0	0.0056	0.0017	0.0044	0.0011	0.0000608	0.0077

Step 5: Evaluate the relative closeness to the ideal solution $C_i^* = S'_i / (S_i^* + S'_i)$

Table 4.23: Topsis Step 5 for Enablers

	$S_i' / (S_i^* + S_i')$	C_i^*	Ranking
Automobile	0.0177/0.0248	**0.7137**	**1**
Machinery	0.0095/0.0269	0.3531	3
Process	0.0106/0.0238	0.4454	2
Electrical	0.0077/0.0248	0.3105	4

Table 4.23 shows that Automobile industries shows high tendency towards the adoption of PRRP and are ranked I[st] in analysis, followed by Process industries, Machinery industries and then Electrical industries.

4.6 Implementation of ISM on Barriers to PRRP

Based on the contextual relationship between barriers, the Structural Self Interaction Matrix has been framed. Based on the thinking of academician experts, the SSIM has been concluded and is presented in Table 4.24.

Table 4.24: Structural Self Interaction Matrix for Barriers

		1	2	3	4	5	6	7	8	9	10	11	12
1	**B7**	X	V	X	V	O	A	V	V	V	X	V	A
2	**B3**		X	A	X	A	A	X	O	X	O	O	A
3	**B17**			X	O	O	A	V	V	V	X	A	A
4	**B15**				X	X	A	O	A	X	V	A	A
5	**B5**					X	A	A	X	V	O	A	A
6	**B1**						X	V	V	V	O	V	X
7	**B25**							X	V	V	V	O	A
8	**B22**								X	O	V	V	A
9	**B7**									X	V	A	A
10	**B8**										X	A	O
11	**B24**											X	A
12	**B13**												X

The SSIM is converted into a binary matrix, called the initial reachability matrix. Table 4.25 represent the initial reachability matrix for barriers. It is acquired from the SSIM by replacing the concerned binary values.

Table 4.25: Initial reachability matrix for Barriers

		1	2	3	4	5	6	7	8	9	10	11	12
1	**B7**	1	1	1	1	0	0	1	1	1	1	1	0
2	**B3**	0	1	0	1	0	0	1	0	1	0	0	0
3	**B17**	1	1	1	0	0	0	1	1	1	1	0	0
4	**B15**	0	1	0	1	1	0	0	0	1	1	0	0
5	**B5**	0	1	0	1	1	0	0	1	1	0	0	0
6	**B1**	1	1	1	1	1	1	1	1	1	0	1	1
7	**B25**	0	1	0	0	1	0	1	1	1	1	0	0
8	**B22**	0	1	0	0	1	0	1	1	1	1	0	0
9	**B4**	0	1	0	1	0	0	0	0	0	1	0	0
10	**B8**	1	0	1	0	0	0	0	0	0	1	0	0
11	**B24**	0	0	0	1	1	0	0	0	1	1	1	0
12	**B13**	1	1	1	1	1	1	1	1	1	0	1	1

The final reachability matrix for the barriers is obtained by consolidating the transivities as explained in Step IV of ISM methodology. Table 4.26 shows the final reachability matrix with driving power and dependence for barriers.

Table 4.26: Final Reachability Matrix with Driving and Dependence Power for Barriers

		1	2	3	4	5	6	7	8	9	10	11	12	Driving Power
1	**B7**	1	1	1	1	1	0	1	1	1	1	1	0	**10**
2	**B3**	0	1	0	1	1	0	1	1	1	1	0	0	**7**
3	**B17**	1	1	1	1	1	0	1	1	1	1	1	0	**10**
4	**B15**	1	1	1	1	1	0	1	1	1	1	0	0	**9**
5	**B5**	0	1	1	1	1	0	1	1	1	1	1	0	**9**
6	**B1**	1	1	1	1	1	1	1	1	1	1	1	1	**12**
7	**B25**	1	1	1	1	1	0	1	1	1	1	1	0	**10**
8	**B22**	1	1	1	1	1	0	0	1	1	1	1	0	**9**
9	**B4**	1	1	1	1	1	0	1	0	1	1	1	0	**9**
10	**B8**	1	1	1	1	0	0	1	1	1	1	1	0	**9**
11	**B24**	1	1	1	1	1	0	0	1	1	1	1	0	**9**
12	**B13**	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Dependence Power		**10**	**12**	**11**	**12**	**11**	**2**	**10**	**11**	**12**	**12**	**10**	**2**	**115/115**

From the final reachability matrix, the reachability and antecedent set for each barrier is established. Thereafter the intersection of these sets is obtained for all enablers. The barriers for which reachability and intersection sets are same occupy the same level in ISM hierarchy. Once any level is found, it is eliminated from other elements. Then same process is iterated to find out elements in next level. This process is continued until level of each enabler is obtained.

Table 4.27: Level I Iteration for Barriers

Barriers	Reachability Set	Antecedent Set	Intersection Set	Levels
B7	1,2,3,4,5,7,8,9,10,11	1,3,4,6,7,8,9,10,11,12	1,3,4,5,7,8,9,10,11	
B3	2,4,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10,11,12	2,4,5,7,8,9,10	**I**
B17	1,2,3,4,5,7,8,9,10,11	1,3,4,5,6,7,8,9,10,11,12	1,3,4,5,7,8,9,10,11	
B15	1,2,3,4,5,7,8,9,10	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,8,9,10	**I**
B5	2,3,4,5,7,8,9,10,11	1,2,3,4,5,6,7,8,9,11,12	2,3,4,5,7,8,9,11	
B1	1,2,3,4,5,6,7,8,9,10,11,12	6,12	6,12	
B25	1,2,3,4,5,7,8,9,10,11	1,2,3,4,5,6,7,9,10,12	1,2,3,4,5,7,9,10	
B22	1,2,3,4,5,8,9,10,11	1,2,3,4,5,6,7,8,10,11,12	1,2,3,4,5,8,10,11	
B4	1,2,3,4,5,7,9,10,11	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,9,10	**I**
B8	1,2,3,4,7,8,9,10,11	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,7,8,9,10,11	**I**
B24	1,2,3,4,5,8,9,10,11	1,3,5,6,7,8,9,10,11,12	1,3,5,8,9,10,11	
B13	1,2,3,4,5,6,7,8,9,10,11,12	6,12	6,12	

Table 4.28: Level II Iteration for Barriers

Barriers	Reachability Set	Antecedent Set	Intersection Set	Levels
B7	1,3,5,7,8,11	1,3,6,7,8,11,12	1,3,7,8,11	
B17	1,3,5,7,8,11	1,3,5,6,7,8,11,12	1,3,5,7,8,11	**II**
B5	3,5,7,8,11	1,3,5,6,7,8,11,12	3,5,7,8,11	**II**
B1	1,3,5,6,7,8,11,12	6,12	6,12	
B25	1,3,5,7,8,11	1,3,4,5,6,7,12	1,3,5,7	
B22	1,3,5,8,11	1,3,5,6,7,8,11,12	1,3,5,8,11	**II**
B24	1,3,5,8,11	1,3,5,6,7,8,11,12	1,3,5,8,11	**II**
B13	1,3,5,6,7,8,11,12	6,12	6,12	

Table 4.29: Level III Iteration for Barriers

Barriers	Reachability Set	Antecedent Set	Intersection Set	Levels
B7	1,7,	1,6,7,12	1,7,	**III**
B1	1,6,7,12	6,12	6,12	
B25	1,7	1,6,7,12	1,7	**III**
B13	1,6,7,12	6,12	6,12	

Table 4.30: Level IV Iteration for Barriers

Barriers	Reachability Set	Antecedent Set	Intersection Set	Levels
B1	6,12	6,12	6,12	**IV**
B13	6,12	6,12	6,12	**IV**

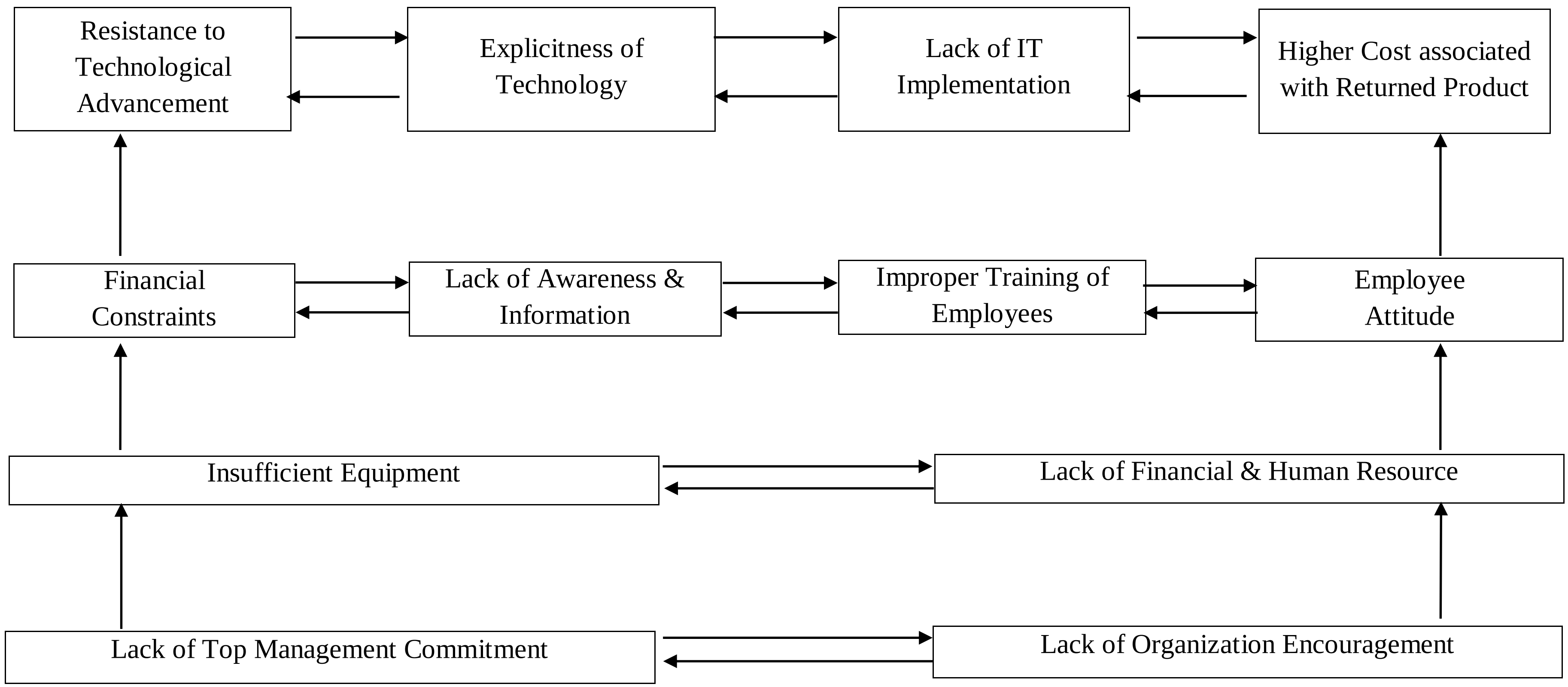

Figure 4.2: ISM Model for Barriers

Figure 4.2 shows the ISM model for Barriers to PRRP which categorized the Barriers into levels such as: Level I: Resistance to Technological Advancement [B3], Explicitness of Technology [B15], Lack of IT Implementation [B4], Higher Cost associated with returned Product [B8], Level II: Financial Constraints [B17], Lack of Awareness & Information [B5], Improper Training of Employees [B22], Employee Attitude [B24], Level III: Lack of Financial & Human Resource [B7], Insufficient Equipment [B25], Level IV : Lack of Top Management Commitment [B1], Lack of Organization Encouragement [B13].

Conical matrix is developed by grouping barriers in the same level across the rows and columns of the final reachability matrix. Table 4.31 shows the conical matrix.

Table 4.31: Conical matrix for Barriers

	B3	B4	B8	B15	B5	B22	B17	B24	B25	B7	B13	B1	Driving Power
B3	1	1	1	1	1	1	0	0	1	0	0	0	**7**
B4	1	1	1	1	1	0	1	1	1	1	0	0	**9**
B8	1	1	1	1	0	1	1	1	1	1	0	0	**9**
B15	1	1	1	1	1	1	1	0	1	1	0	0	**9**
B5	1	1	1	1	1	1	1	1	1	0	0	0	**9**
B22	1	1	1	1	1	1	1	1	0	1	0	0	**9**
B24	1	1	1	1	1	1	1	1	0	1	0	0	**9**
B17	1	1	1	1	1	1	1	1	1	1	0	0	**10**
B25	1	1	1	1	1	1	1	1	1	1	0	0	**10**
B7	1	1	1	1	1	1	1	1	1	1	0	0	**10**
B13	1	1	1	1	1	1	1	1	1	1	1	1	**12**
B1	1	1	1	1	1	1	1	1	1	1	1	1	**12**
Dependence Power	**12**	**12**	**12**	**12**	**11**	**11**	**11**	**10**	**10**	**10**	**2**	**2**	**115**

4.7 Ranking of Industries using TOPSIS considering Barriers to PRRP

For the barriers also response from same industries and respondents were taken. The response for the barriers from industries is listed in Table 4.32. In Table 4.33 weightage of top 12 barriers is listed to perform the analysis. The weight of each barrier is calculated by simple method of dividing its value by sum of total value.

Table 4.32: Decision Matrix for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
Automobile	4.366	4.4	4.055	4	4.133	3.955	3.577	4.066	3.667	4.266	3.622	3
Machinery	4.8	4	4.2	4	4.4	4.3	4.4	4.2	3.3	2.7	4.2	3.7
Process	4	4.116	4.216	4.2	3.8	3.766	3.583	3.483	3.6	3.883	3.283	3.766
Electrical	4.678	4.595	4.524	4.464	3.75	3.904	4.238	3.595	4.154	3.309	3.083	3.452

Table 4.33: Weightage and mean value for Barriers

S.No	B_i	BARRIER	MEAN	WEIGHT
1.	B7	Lack of Financial & Human Resource	4.4508	0.0943
2.	B3	Resistance to Technological Advancement	4.2915	0.0909
3.	B17	Financial Constraints	4.2275	0.0896
4.	B15	Explicitness of Technology	4.1476	0.0879
5.	B5	Lack of Awareness & Information	4.0333	0.0855
6.	B1	Lack of Top Management Commitment	3.9788	0.0843
7.	B25	Insufficient Equipment	3.9084	0.0828
8.	B22	Improper Training of employees	3.8619	0.0818
9.	B4	Lack of IT Implementation	3.6788	0.0779
10.	B8	Higher Cost associated with returned product	3.6206	0.0767
11.	B24	Employee Attitude	3.5555	0.0753
12.	B13	Lack of Organization Encouragement	3.4264	0.0726

To apply TOPSIS on Barriers, consider Table 4.32 which is termed as decision matrix. In the study

m = 4 alternatives or Industries (A1, A2, A3, A4)

n = 12 criteria (Barriers)

A1 denotes Automobile, A2 denotes Machinery, A3 denotes Process, A4 denotes Electrical.

Step 1 (a) : Evaluate $(\Sigma x^2_{ij})^{1/2}$ for each column

Table 4.34: Topsis Step 1(A) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
A1	19.062	19.36	16.443	16.000	17.081	15.642	12.795	16.532	13.446	18.198	13.118	9.000
A2	23.040	16.000	17.640	16.000	19.360	18.490	19.360	17.640	10.890	7.290	17.640	13.690
A3	16.000	16.941	17.774	17.640	14.440	14.183	12.837	12.131	12.96	14.692	10.778	14.183
A4	21.883	21.114	20.446	19.927	14.062	15.241	17.96	12.924	17.255	10.949	9.505	11.916
Σx_{ij}^2	**79.985**	**73.415**	**72.323**	**69.567**	**64.943**	**63.556**	**62.952**	**59.227**	**54.551**	**51.129**	**51.041**	**48.789**
$(\Sigma x_{ij}^{2)1/2}$	**8.943**	**8.568**	**8.504**	**8.34**	**8.058**	**7.972**	**7.934**	**7.696**	**7.385**	**7.15**	**7.144**	**6.985**

Step 1 (b) : Divide each column by $(\Sigma x^2_{ij})^{1/2}$ to get r_{ij}

Table 4.35: Topsis Step 1(B) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
A1	0.488	0.513	0.476	0.479	0.513	0.496	0.45	0.528	0.496	0.596	0.507	0.429
A2	0.536	0.466	0.494	0.479	0.546	0.539	0.554	0.545	0.446	0.377	0.588	0.529
A3	0.447	0.48	0.495	0.503	0.471	0.472	0.451	0.452	0.487	0.543	0.459	0.539
A4	0.523	0.536	0.532	0.535	0.465	0.489	0.534	0.467	0.562	0.463	0.431	0.494

Step 2 : Multiply each column by w_j to get v_{ij}

Table 4.36: Topsis Step 2 for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
A1	0.0460	0.0466	0.0426	0.0421	0.0438	0.0418	0.0372	0.0432	0.0386	0.0457	0.0382	0.0311
A2	0.0505	0.0423	0.0442	0.0421	0.0466	0.0454	0.0458	0.0446	0.0347	0.0289	0.0442	0.0384
A3	0.0421	0.0436	0.0443	0.0442	0.0402	0.0397	0.0373	0.0369	0.0379	0.0416	0.0345	0.0391
A4	0.0493	0.0487	0.0476	0.0470	0.0397	0.0412	0.0442	0.0382	0.0437	0.0355	0.0324	0.0358

Step 3 (a) : Find ideal solution A*.

A* = {0.0421, 0.0423, 0.0426, 0.0421, 0.0397, 0.0397, 0.0372, 0.0369, 0.0347, 0.0289, 0.0324, 0.0311}

Table 4.37: Topsis Step 3(A) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
A1	0.0460	0.0466	**0.0426**	**0.0421**	0.0438	0.0418	**0.0372**	0.0432	0.0386	0.0457	0.0382	**0.0311**
A2	0.0505	**0.0423**	0.0442	**0.0421**	0.0466	0.0454	0.0458	0.0446	**0.0347**	**0.0289**	0.0442	0.0384
A3	**0.0421**	0.0436	0.0443	0.0442	0.0402	**0.0397**	0.0373	**0.0369**	0.0379	0.0416	0.0345	0.0391
A4	0.0493	0.0487	0.0476	0.0470	**0.0397**	0.0412	0.0442	0.0382	0.0437	0.0355	**0.0324**	0.0358

Step 3 (b) : Find negative ideal solution A'.

A' = {0.0505, 0.0487, 0.0476, 0.0470, 0.0466, 0.0454, 0.0458, 0.0446, 0.0437, 0.0457, 0.0442, 0.0391}

Table 4.38: Topsis Step 3(B) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13
A1	0.0460	0.0466	0.0426	0.0421	0.0438	0.0418	0.0372	0.0432	0.0386	**0.0457**	0.0382	0.0311
A2	**0.0505**	0.0423	0.0442	0.0421	**0.0466**	**0.0454**	**0.0458**	**0.0446**	0.0347	0.0289	**0.0442**	0.0384
A3	0.0421	0.0436	0.0443	0.0442	0.0402	0.0397	0.0373	0.0369	0.0379	0.0416	0.0345	**0.0391**
A4	0.0493	**0.0487**	**0.0476**	**0.0470**	0.0397	0.0412	0.0442	0.0382	**0.0437**	0.0355	0.0324	0.0358

Step 4 (a) : Evaluate separation from ideal solution $S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½}$ for each row

Table 4.39: Topsis Step 4(A) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13	$\Sigma(v_j^*-v_{ij})^2$	$[\Sigma(v_j^*-v_{ij})^2]_{1/2}$
A1	0.0039	0.0043	0	0	0.0041	0.0021	0	0.0063	0.0039	0.0168	0.0058	0	0.0004257	0.0206
A2	0.0084	0	0.0016	0	0.0069	0.0057	0.0086	0.0077	0	0	0.0118	0.0073	0.000479	0.0218
A3	0	0.0013	0.0017	0.0021	0.0005	0	0.0001	0	0.0032	0.0127	0.0021	0.008	0.0002492	0.0157
A4	0.0072	0.0064	0.005	0.0049	0	0.0015	0.007	0.0013	0.009	0.0066	0	0.0047	0.0003414	0.0184

Step 4 (b) : Evaluate separation from negative ideal solution $S_i' = [\Sigma (v_j^* - v_{ij})^2]^{½}$ for each row

Table 4.40: Topsis Step 4(B) for Barriers

	B7	B3	B17	B15	B5	B1	B25	B22	B4	B8	B24	B13	$\Sigma(v_j^*-v_{ij})^2$	$[\Sigma(v_j^*-v_{ij})^2]_{1/2}$
A1	0.0045	0.0021	0.005	0.0049	0.0028	0.0036	0.0086	0.0014	0.0051	0	0.006	0.008	0.0002964	0.0172
A2	0	0.0064	0.0034	0.0049	0	0	0	0	0.009	0.0168	0	0.0007	0.00044026	0.0209
A3	0.0084	0.0051	0.0033	0.0028	0.0064	0.0057	0.0085	0.0077	0.0058	0.0041	0.0097	0	0.00046483	0.0215
A4	0.0012	0	0	0	0.0069	0.0042	0.0016	0.0064	0	0.0102	0.0118	0.0033	0.00036438	0.0191

Step 5: Evaluate the relative closeness to the ideal solution $C_i^* = S'_i / (S_i^* + S'_i)$

Table 4.41: Topsis Step 5 for Barriers

	$S_i' / (S_i^* + S_i')$	C_i^*	Ranking
Automobile	0.0172/0.0378	0.455	4
Machinery	0.0209/0.0427	0.489	3
Process	0.0215/0.0372	**0.578**	**1**
Electrical	0.0191/0.0375	0.509	2

Table 4.41 shows that Process industries shows high hindrance towards the adoption of PRRP and are ranked I[st] in analysis, followed by Electrical industries, Machinery industries and then Automobile industries.

CHAPTER 5

RESULT AND DISCUSSION

In this study the enablers and barriers to sustainable product returns and recovery practices(PRRP) were found out through literature study and then ISM and TOPSIS were applied. The methodology suggested recognized the hierarchy of actions to be taken to handle the different types of enablers and barriers to implement PRRP. Minitab 17 is also used to inspect the reliability of the data.

From the study following results are obtained:

- When the ISM Methodology is applied on the Enablers to PRRP following inferences are drawn:

  Level I: Customer Satisfaction [E7] and Environmental Cost [E8]

  Level II: Technological Opportunities [E2], Improvement of Product Characteristics [E9], Financial Performance [E6], Improving Quality [E15], Low Manufacturing Cost [E12], Continuous Improvement [E4]

  Level III: Innovation [E1], Customer Demands [E16], Government Regulation [E11]

  Level IV: Competitive Pressure [E3]

  Level V: Availability of Funds [E25]

  It shows that Availability of Funds is the most crucial enabler to PRRP as it has the maximum driving power and minimum dependence power and it can drive other enablers. Similarly Competitive process is also another crucial enabler. On the other hand after analysis it is seen that Customer satisfaction and environmental cost are least important enablers occupying the top position in hierarchy of ISM model but can force industries to implement PRRP.

- When the ISM Methodology is applied on the Barriers to PRRP following inferences are drawn:

  Level I: Resistance to Technological Advancement [B3], Explicitness of Technology [B15], Lack of IT Implementation [B4], Higher Cost associated with returned Product [B8]

Level II: Financial Constraints [B17], Lack of Awareness & Information [B5], Improper Training of Employees [B22], Employee Attitude [B24]

Level III: Lack of Financial & Human Resource [B7], Insufficient Equipment [B25]

Level IV: Lack of Top Management Commitment [B1], Lack of Organization Encouragement [B13]

It shows that Lack of Top Management Commitment and Lack of Organization Encouragement are the most crucial barriers towards the adoption of PRRP as they have the maximum driving power and minimum dependence power and it can forces other barriers. On the other hand after analysis it is seen that Resistance to Technological Advancement, Explicitness of Technology, Lack of IT Implementation and Higher Cost associated with returned Product are least important barriers occupying the top position in hierarchy of ISM model and creates less problem in the implementation of PRRP.

- ❖ On the implication of TOPSIS on Enablers to PRRP it is found that Automobile industries rank 1st in adoption of such Practices followed by Process industries, Machinery industries and then Electrical industries.

  It shows that Automobile industries shows highest tendency towards the adoption of PRRP in Manufacturing industry and shows a great concern over the returned products and then for Refurbishing to make value of the used product. It reduces the stress on environment for raw material and contributes towards sustainable manufacturing while the Electrical industries shows least tendency towards the adoption of PRRP.

- ❖ On the implication of TOPSIS on Barriers to PRRP it is found that Process industries rank 1st which hinder the adoption of such Practices followed by Electrical industries, Machinery industries and then Automobile industries.

  It shows that Process industries shows highest hindrance towards the adoption of PRRP in Manufacturing industry and does not want to implement PRRP in industries. It increases the stress on environment for raw material as there is no interest towards capturing the value of used product while the Automobile industries shows least hindrance towards the adoption of PRRP.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

The level of factors proposed in the ISM model is very important to understand the implementation of Product Returns & Recovery Practices (PRRP) in Manufacturing industry in India. ISM model for Enablers to PRRP shows that Availability of Funds is at the bottom of the ISM model. So, it can play a pivotal role in implication of PRRP in Manufacturing industry because it has the maximum driving power and it can drive other enablers. Similarly Competitive pressure can motivate industries to implement PRRP. In addition, Customer Satisfaction and Environmental Cost occupy the top most position in the hierarchy and mostly dependent on other factors but forces Manufacturing industry to implement PRRP.

For barriers to PRRP it can be concluded that Lack of Top Management Commitment and Lack of Organization Encouragement play a pivotal role and hinder the adoption of PRRP in Manufacturing industry in India. Similarly, in addition Resistance to Technological Advancement, Explicitness of Technology, Lack of IT Implementation, Higher Cost associated with returned Product occupy the top most position in the ISM model for Barriers and mostly depend on other factors but they oppose Manufacturing industry to implement PRRP.

In this study TOPSIS is imposed to improve the quality of decision making for ranking alternatives. The proposed TOPSIS method involves in MCDM problem with group decision, criteria or attributes and the performance values embedded in the decision matrix. When the TOPSIS is applied on Enablers to PRRP it can be concluded that Automobile industries shows higher tendency in the adoption of PRRP than other industries. On the other hand, when TOPSIS is applied on Barriers to PRRP it can be concluded that Process industries shows highest hindrance towards the adoption of PRRP than other industries.

In this study, through ISM, an inter-related model among enablers and barriers is framed. This model has been framed on the basis of input from industry professionals. However, this model has not been statistically authenticated. Structural Equation Modeling (SEM), also known as the linear structural relationship method, has the potential of examining the authentication of such a hypothetical model. Therefore, the examination of the authenticity of this model may be a topic for future scope. It is to be noted here that although SEM has the potential of statistically examining an already framed theoretical model, it cannot construct an initial model for testing. So due to the harmonious nature of these techniques, future research may be targeted first towards framing an initial model using ISM and then authenticate it using SEM.

In this study, through TOPSIS the industries are ranked to implement PRRP in Manufacturing industries but for the future work in this field a method can be applied which would rank all the barriers and enablers to PRRP so as to find which barrier or enabler stands at which position and affect the practices. Certain limitations of this study could also be countered by increasing the number of responses so as to make the data more reliable and more effective results can be obtained. Another future scope can be to rank all the industries from which response is taken not by classifying them into groups.

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APPENDIX 1

Survey to Identify Enablers to Product Returns and Recovery Process for Sustainable Manufacturing

The objective of this study is to identify the enablers which promote the practices of Product Returns & Recovery Process in Manufacturing Industry in India. Please spare 5 minutes of your valuable time to provide responses to the questions asked below, based on your personal choice, you have to tell how much they can influence your decision in adoption of such practices. Please rate the following questionnaire on a scale from 1 to 5: 1 - not at all influential, 2 - slightly influential, 3 - somewhat influential, 4 - very influential, 5 - extremely influential

	1	2	3	4	5
Innovation	O	O	O	O	O
Technological Opportunities	O	O	O	O	O
Competitive Pressure	O	O	O	O	O
Continuous Improvement	O	O	O	O	O
Top Management Commitment	O	O	O	O	O
Financial Performance	O	O	O	O	O
Customer Satisfaction	O	O	O	O	O
Environmental Cost	O	O	O	O	O
Improvement of Product Characteristics	O	O	O	O	O
Public Pressure	O	O	O	O	O
Government Regulation	O	O	O	O	O
Low Manufacturing Cost	O	O	O	O	O
Education & Training	O	O	O	O	O
Attracting Foreign direct Investment	O	O	O	O	O
Improving Quality	O	O	O	O	O
Customer Demands	O	O	O	O	O
Reduction in Carbon emissions	O	O	O	O	O
Green Technology adoption	O	O	O	O	O
Use of IT Tools	O	O	O	O	O

Information Sharing	O	O	O	O	O
Employee Involvement	O	O	O	O	O
Benchmarking	O	O	O	O	O
Availability of Expertise Training	O	O	O	O	O
Organizational Culture & Infrastructure	O	O	O	O	O
Availability of Funds	O	O	O	O	O
Involvement of Stakeholders	O	O	O	O	O
Communication	O	O	O	O	O
Incentive	O	O	O	O	O

General Information

All the personal details will be held Confidential.

Name (optional)

[ ]

Email Id

[ ]

Organization

[ ]

Designation

[ ]

APPENDIX 2

Survey to Identify Barriers to Product Returns and Recovery Process for Sustainable Manufacturing

The objective of this study is to identify the barriers which hinder the practices of Product Returns & Recovery Process in Manufacturing Industry in India. Please spare 5 minutes of your valuable time to provide responses to the questions asked below, based on your personal choice, you have to tell how much they can influence your decision in adoption of such practices. Please rate the following questionnaire on a scale from 1 to 5: 1 - not at all influential, 2 - slightly influential, 3 - somewhat influential, 4 - very influential, 5 - extremely influential

	1	2	3	4	5
Lack of Top Management Commitment	O	O	O	O	O
Lack of government support system	O	O	O	O	O
Resistance to Technological Advancement	O	O	O	O	O
Lack of IT Implementation	O	O	O	O	O
Lack of Awareness & Information	O	O	O	O	O
Lack of Internal Communication	O	O	O	O	O
Lack of Financial & Human Resource	O	O	O	O	O
Higher Cost associated with returned product	O	O	O	O	O
Lack of Implementing green practices	O	O	O	O	O
Market Competition & Uncertainty	O	O	O	O	O
Fear of Failure	O	O	O	O	O
Difficult to Change	O	O	O	O	O
Lack of Organization Encouragement	O	O	O	O	O
Understanding & Perception	O	O	O	O	O
Explicitness of Technology	O	O	O	O	O
Company Policies	O	O	O	O	O
Financial Constraints	O	O	O	O	O
Problems With Product Quality	O	O	O	O	O
Customer Demands	O	O	O	O	O

Unsupportive Behavior among employees	O	O	O	O	O
Supplier Reluctance to Change	O	O	O	O	O
Improper Training of employees	O	O	O	O	O
Infrastructure Requirement	O	O	O	O	O
Employee Attitude	O	O	O	O	O
Insufficient Equipment	O	O	O	O	O

General Information

All the personal details will be held Confidential.

Name (optional)

Email Id

Organization

Designation