A

Dissertation Report

On

# Development of an Interpretive Structure Model for Drivers in Environmentally Conscious Manufacturing in Textile Industry

*Dissertation submitted in fulfillment of the requirements for the Degree of*

**MASTER OF TECHNOLOGY**
**IN**
**INDUSTRIAL ENGINEERING**

by

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**UNDER THE GUIDANCE OF**
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**June, 2015**

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# CERTIFICATE

This is to certify that the dissertation entitled "**Development of an Interpretive Structure Model for Drivers in Environmentally Conscious Manufacturing in Textile Industry**" being submitted by **Mohit Vats (2013PIE5090)** is a bonafide work carried out by him under my supervision and guidance, and hence approved for submission to **the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the requirements for the award of the degree **of Master of Technology (M.Tech.)in Industrial Engineering.** The matter embodied in this dissertation report has not been submitted anywhere else for award of any other degree or diploma.

**Dr. G.S. Dangayach**
Professor,
Department of Mechanical Engineering,
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Place: Jaipur
Dated: June 2015

## CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **"Development of an Interpretive Structure Model for Drivers in Environmentally Conscious Manufacturing in Textile Industry"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial 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 2014 to June 2015 under the guidance and supervision of **Prof.** (**Dr.) G.S.Dangayach**of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for award of any other degree or diploma.

**Mohit Vats**
**(2013PIE5090)**

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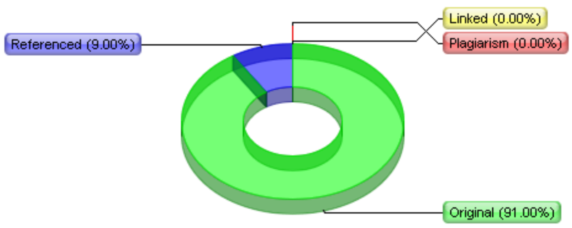


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**- Mohit Vats**

## ABSTRACT

India's textiles sector is one of the anchor of the national economy. It is largest contributing sector of India's exports in world. The textiles industry is labour intensive and is one of the largest employers. Every year billions of square meter textiles are produced in India. It is well known that every product has an impact on the environment. Any product, which is made, used or disposed of in a way that significantly reduces the harm it would otherwise cause to the environment, could be considered as eco-friendly product and Environmentally Conscious Manufacturing (ECM) can play a vital role to manufacture the textile in an eco-friendly manner. Slowly, in India many factors are taking lead in prompting manufacturers to adopt clean practices to manufacture eco-friendly products. Also in textile industry there can be many drivers which can force industries and organizations to implement ECM.

This research project aims at identifying and ranking the drivers for developing a model of identified drivers after validation and qualitative analysis of drivers using interpretive structural modeling (ISM) for studying the interrelationship among identified factors. For identification of drivers literature is explored and consulted with industrial experts and academicians, which led to selection of eighteen drivers. Survey is conducted for validation of drivers to find out up to which extent drivers can influence the industries to implement ECM. ISM is used to develop a model understand the interactions, mutual influence and relationship among the drivers. This study seeks to identify which driver is acting as the most influential one for the implementation of ECM in Indian textile industry.

The research shows some drivers have high driving power and low dependency requiring maximum attention and of strategic importance, and some drivers having high dependence and low driving power and are resultant effects of other drivers.

The identification, ranking and validation of the models of drivers is expected to provide better understanding to decision makers in government to develop policies and prioritize them to facilitate ECM adoption and implementation. The ranking and hierarchy of drivers will provide better understanding to the management in industry to develop and prioritize their business strategies to facilitate smooth implementation of ECM. In addition, the interrelationship among drivers and their driver-driven relationship is expected to provide the managers/executives the better understanding of the complex relations to develop effective implementation plan.

Key words: Environmentally conscious manufacturing, Driver, motivators, cleaner practices, ISM.

# CONTENTS

**CERTIFICATE** ........ i

**CANDIDATE'S DECLARATION** ........ ii

**PLAGIARISM DETECTION CHART** ........ iii

**ACKNOWLEDGEMENT** ........ iv

**ABSTRACT** ........ v

**CONTENTS** ........ vii

**LIST OF FIGURES** ........ ix

**LIST OF TABLES** ........ x

**LISTOF ABBREVIATIONS** ........ xi

**CHAPTER-1** ........ 1

**INTRODUCTION** ........ 1

1.1Motivation for Research ........ 3
1.2 Objectives ........ 4
1.3 Structure of Dissertation ........ 4

**CHAPTER -2** ........ 6

**LITERATURE REVIEW** ........ 6

2.1 Introduction ........ 6
2.2 Environmentally Conscious Manufacturing (ECM) ........ 8
2.3 Identification of Drivers for ECM ........ 12
2.4 Interpretive Structural Modeling ........ 18

**CHAPTER -3** ........ 21

**RESEARCH METHODOLOGY** ........ 21

3.1 Collection of literature ........ 21
3.2 Survey Instrument Development ........ 22
3.3 Questionnaire Design ........ 22
3.4 Data Collection ........ 23
3.5 Data Analysis ........ 23
3.6 ISM Methodology ........ 23
3.7 MICMAC Analysis ........ 25

**CHAPTER -4** ........ 27

**ANALYSIS AND MODEL DEVELOPMENT** ........ 27

4.1 Cronbach's alpha .......... 27
4.2 Descriptive Statistics .......... 27
4.3 Ranking of Drivers .......... 29
4.4 ISM .......... 30
4.5MICMAC Analysis .......... 46

**CHAPTER -5 .......... 49**

**CONCLUSION .......... 49**

**CHAPTER-6 .......... 51**

**LIMITATION AND FUTURE SCOPE .......... 51**

**REFERENCE .......... 52**

**APPENDIX .......... 60**

## LIST OF FIGURES

Figure 1: Structure of dissertation....................................................................................5
Figure 2: Interactions among the activities in a product life cycle ................................7
Figure 3: Responses to Emerging Environmental Problems .........................................8
Figure 4: Environmentally conscious manufacturing....................................................9
Figure 5: Environmentally conscious manufacturing .................................................11
Figure 6: Flow diagram for preparing ISM model.......................................................25
Figure 7: ISM Model .....................................................................................................45
Figure 8: MICMAC Analysis .......................................................................................47

## LIST OF TABLES

Table 1: List of Drivers for ECM in Textile industry .................................................. 14
Table 2: Cronbach's alpha (α) test results for reliability .......................................... 28
Table 3: Descriptive statistics for Drivers of ECM .................................................... 29
Table 4: Ranking of Drivers for ECM .......................................................................... 30
Table 5: List of Drivers .................................................................................................. 31
Table 6: Structural self-interaction matrix .................................................................. 33
Table 7: Initial reachability matrix ............................................................................... 35
Table 8: Final reachability matrix ................................................................................. 36
Table 9:Final reachability matrix with Driving and Dependence Power .................... 37
Table 10: Level - I Iteration ........................................................................................... 39
Table 11: Level - II Iteration .......................................................................................... 40
Table 12: Level - III Iteration ......................................................................................... 41
Table 13: Level - IV Iteration ......................................................................................... 41
Table 14: Level - V Iteration .......................................................................................... 42
Table 15: Level - VI Iteration ......................................................................................... 42
Table 16: Level - VII Iteration ........................................................................................ 42
Table 17: Level - VIII Iteration ...................................................................................... 43
Table 18: Drivers at various iteration levels ................................................................ 43
Table 19: Conical matrix ................................................................................................ 44
Table 20: Drivers with driving power and dependence power ................................... 46

## LISTOF ABBREVIATIONS

| | |
|---|---|
| T&C | Textile and Clothing |
| ECM | Environmentally Conscious Manufacturing |
| GDP | Gross Domestic Product |
| MSW | Municipal Solid Waste |
| GM | Green Manufacturing |
| EOL | End of Life |
| LCA | Life Cycle Analysis |
| DFR | Design for Recycling |
| DFE | Design for Environment |
| EC | Environmentally Conscious |
| EBM | Environmental Benign Manufacturing |
| ECD | Environmentally Conscious Product Design |
| ECP | Environmentally Conscious Production |
| LCE | Life cycle engineering |
| LCD | lifecycle design |
| ANP | Analytical Network Process |
| FMS | Flexible Manufacturing Systems |
| SSIM | Structural Self-Interaction Matrix |
| MICMAC | Cross-Impact Matrix Multiplication Applied to Classification |
| ISM | Interpretive Structural Modeling |
| SD | Standard Deviation |

# CHAPTER-1

## INTRODUCTION

At present, the Indian T&C (Textile and Clothing) sector holds a significant position in the nation's economy. The sector provides direct employment to more than 35 million people (Ministry of Textiles, 2011-12) and indirect employment to more than 50 million [1]. T&C contribution to industrial production, GDP, and export earnings stand at 14 percent, 4 percent, and 17 percent respectively. The sector accounts for 26 percent of manufacturing output and 18 percent of industrial employment [1].

Manufacturing firms consume the natural resources in highly unsustainable manner and release large amounts of greenhouse gases leading to many economic, environmental and social problems from global warming to local waste disposal [2].Now India is beginning to face one of the consequences of the rapid development of the last decade. Wide diffusion of consumer goods and shortening of product lifecycles have caused there to be an increasing quantity of used products being discarded. In the Urban India generates 188,500 tones per day (68.8 million tones per year) of municipal solid waste (MSW) at a per capita waste generation rate of 500 grams/person/day [3] and in this MSW textile has a major part for itself.

The textile industry is shared between natural fibers such as wool, silk, linen, cotton and hemp, and man-made ones, the most common of which are synthetic fibers (polyamide, acrylic) made from petrochemicals. Most of the clothes in our wardrobes contain polyester, elastane or Lycra. These cheap and easy-care fibers are becoming the textile industry's miracle solution. However, their manufacture creates pollution and they are hard to recycle (with nylon taking 30 to 40 years to decompose).The development of genetically modified cotton adds environmental problems at another level. Growing cotton uses 22.5 percent of all the insecticides used globally. Growing enough cotton for one t-shirt requires 257 gallons of water [4]. The chemicals that are used to bleach and colour textiles can damage the environment and people's health. Old clothes that we throw away take up precious space in landfill sites, which is filling up rapidly.

Textile products affect the environment at many points in their lifecycles. These environmental effects result from the interrelated decisions made at various stages of a product's life. Once a product moves from the drawing board into the production line, its environmental attributes are largely fixed. Therefore, it is necessary to support the design function with tools and methodologies that enable an assessment of the environmental consequences (such as emissions, exposure, and effects) in each phase. At this stage Environmentally conscious manufacturing (ECM) is a view of manufacturing that includes the social and technological aspects of the design, synthesis, processing, and use of products in continuous or discrete manufacturing industries [5].It is also known by plenty of names like green manufacturing(GM), environmentally benign manufacturing(EBM), sustainable manufacturing(SM), sustainable production, cleaner production(CP), clean manufacturing(CM) etc.ECM deals with green principles which deal with developing methods for manufacturing products from conceptual design to final delivery, and ultimately to the end of life disposal, that satisfy environmental standards and requirements [6]. ECM addresses a number of manufacturing practices including recycling, waste management, green purchasing & marketing, using a cleaner & renewable source of energy, end-of-life management of products, green logistics etc [7].

Adopting and implementation of these green practices under the strategy of ECM for the production of textile products is very beneficial in alleviation of the problem of environmental pollution. Green manufacturing is not an option but a necessity for our well-being and survival in today's competitive environment. The multinational enterprises, especially in Europe, have started to enforce regulations (RG) and "green barriers" to protect themselves from devastating environmental effects on the suppliers [7,8].Manufacturing firms face multiple motivating and/or forcing factors to implement ECM. These factors are referred as ECM drivers. These drivers may be related to economy, policy, organization, environment, society, etc. The driving factors can play an active role in the diffusion of ECM in industry. Hence, identification, synthesis, and validation of these drivers is the first step toward effective implementation of ECM [9].

However, the implementation of GM in the industry is not an easy task particularly in emerging economies because of many issues. There is a need to understand the role and potential of various motivations (drivers) facilitating the implementation of ECM in textile industry.

A number of studies have been carried out in various countries in many industries set up in different geographical locations, and also with various methodological approaches; there is one common aim to find out and understand the different drivers for implication of ECM for industries. But how these drivers will influence the implementation or adopt the ECM in textile industry in Indian scenario will be quite beneficial to Indian textile industry as well as for the environment.

The purpose of this research is to explore the drivers of ECM covered by the literature by previous researchers. This research requires investigating the level of influence of the drivers, as perceived by the textile industry professionals and implementation of the identified success factors in Indian textile industry. This is done by identifying the drivers or motivating factor from literature on ECM, and through empirical investigations by conducting surveys in Indian textile industries.

Further, interpretive structural modeling (ISM) is used which is an interactive learning process. In this technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model [10,11]. Hence, ISM is used here to analyze the interactions among the identified drivers. In this research, ISM approach has been utilized to understand the mutual influences amongst the drivers of ECM.

## 1.1Motivation for Research

A number of literatures are available for the drivers, enablers or motivating factors for implementation or adoption of ECM for different geographical areas, Industries, countries and economies. In previous literature we found that drivers can help in implementation of ECM in organizations. But there was no availability of literature or any research for drivers especially for the textile industry in Indian scenario. There is a gap to understand how these drivers or factors influence each other, how they interact with each other. So research is required to understand the mutual relationship between the drivers and how they influence each other; to develop a relationship model of ECM drivers for textile industry.

Therefore, this research is carried out to provide a detailed insight into the drivers that can largely influence the adoption of ECM, and also the level of implementation of these factors in practice within the Indian textile industries. To understand the relationship ISM approach is used for the mutual interaction of these factors and identify the "driving factors‟ (i.e. which influence other factors) and the "dependent factors‟ (i.e. which are influenced by others).

Hence, the purpose of this research is to identify critical drivers of ECM in Indian Textile industry to find out the influence of various drivers, and develop a structured relationship model providing their driving power and dependence power.

## 1.2 Objectives

The key objectives of this dissertation are as follows:

- Identification of the drivers for Environmentally conscious manufacturing(ECM) through analysis of literature review;
- Identification of direct or indirect relationships among drivers of ECM using ISM approach and prepare an ISM model;
- Clustering of the identified drivers based on their driving and dependence power using MICMAC analysis;
- To illustrate application of the ECM concept so as to incorporate environmental protection into business performance; and
- To suggests options for promoting ECM within the industry.

## 1.3 Structure of Dissertation

There are following five 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 the dissertation is described.
- ***Chapter 2 – Literature Review*** **–**This chapter covers the literature review on ECM, drivers of ECM and ISM. Drivers are identified from analysis of previous literature. These drivers are compiled in the tabular form and

description is also given in this chapter to get the better understanding of the drivers of ECM for textile industry.

- ***Chapter 3 – Research Methodology*** –Describes the methodology followed in conducting this research work. Discusses about the questionnaire of survey and the organization of the survey. This chapter describes the tool used to analyze the collected data from the survey. The ISM methodology and MICMAC analysis also discussed here.
- ***Chapter 4 – Analysis and Model Development*** –Responses from the survey are analyzed in this chapter. After the validation of the drivers ISM model is developed to understand the interactions and relationship between the drivers for ECM.
- ***Chapter 5 – Conclusion***– In this chapter after the development of Model the result drawn from the analysis and model development is discussed. Some advices are also provided in the last for the successful implication of ECM
- ***Chapter 6 – Limitation and future Scope***– In this chapter the limitation of this research are explained and future scope of this research is also provided in this chapter.

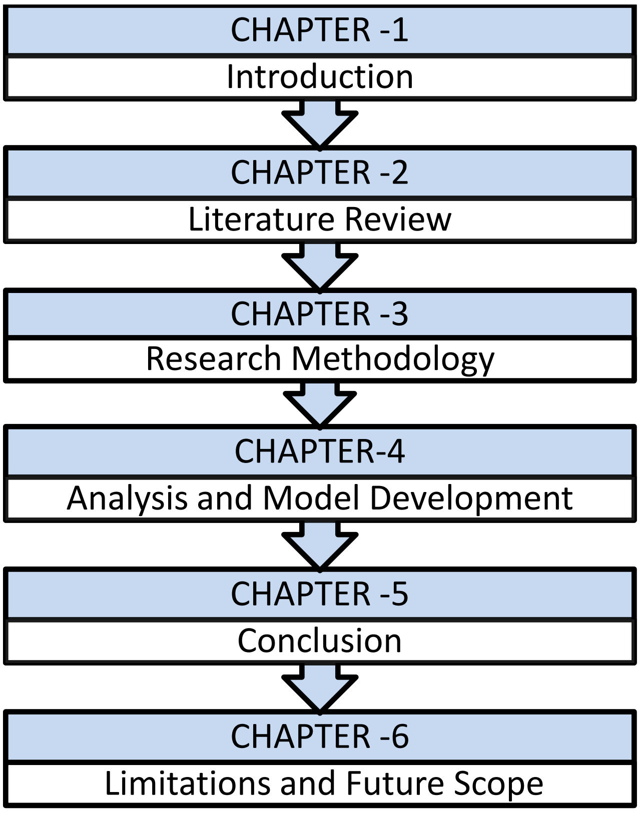


**Figure 1: Structure of dissertation**

# CHAPTER -2

## LITERATURE REVIEW

A review of prior, relevant literature is an essential feature of any academic project. Literature review is of significant importance to gather in-depth information on the topic so that a better understanding of the issue. The literature review is the basis for a study and contributes to the formulation of answer to the proposed research question [12].A researcher cannot perform significant research without first understanding the literature in the field [13]. The goal of literature review is to integrate and generalize findings across units, treatments, outcomes, and settings; to resolve a debate within a field; or to bridge the language used across fields [14].

### 2.1 Introduction

Environmentally conscious manufacturing (ECM) is concerned with developing methods for manufacturing new products from conceptual design to final delivery and ultimately to the end-of-life (EOL) disposal such that the environmental standards and requirements are satisfied [15].ECM deals with green principles which deal with developing methods for manufacturing products from conceptual design to final delivery, and ultimately to the end of life disposal, that satisfy environmental standards and requirements [6] , on the other hand Environmentally conscious manufacturing (ECM), aims to minimize the amount of waste sent to landfills by recovering materials and parts from old or out dated products by means of recycling and remanufacturing (including reuse of parts and products).Figure 2 depicts the interactions among the activities that take place in a product life cycle. ECM is mainly driven by the escalating deterioration of the environment. Today's high-tech society requires thousands of different products which ultimately result in billions of tons of materials discarded, most of which end up in landfills. As a consequence of fast depletion of the raw materials and an increasing amount of different forms of waste (solid waste, air and water pollution etc.), two commonly accepted primary objectives have been gaining momentum: (1) create environmentally friendly products,(i.e. green products); and (2) develop techniques for product recovery and waste management. In order to design a product which is environmentally benign, the life cycle of the product should be well understood [16].

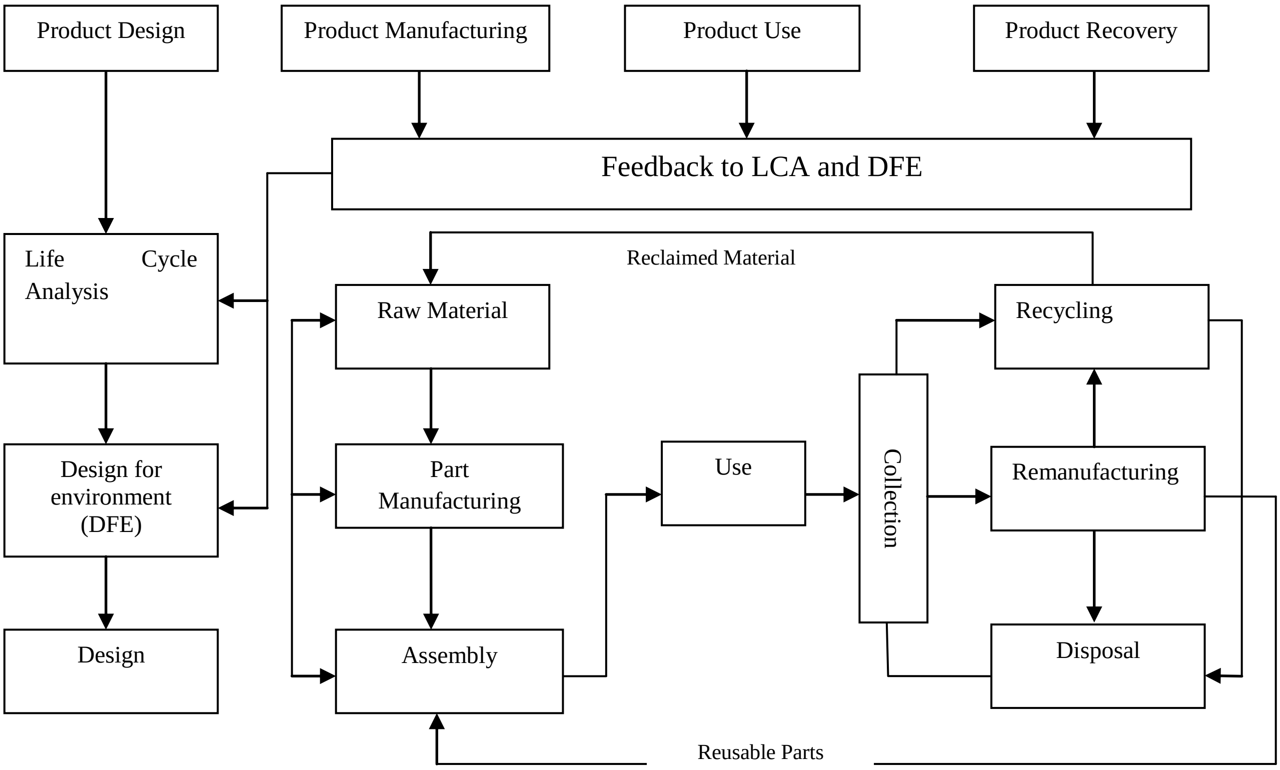


**Figure 2: Interactions among the activities in a product life cycle[3]**

Life cycle analysis (LCA) spans over the development, manufacturing, use and disposal stages of the product (Figure 2). At each of these stages, environmentally friendly decisions need to be made [17-19]. These have prompted campaigns such as design for recycling (DFR), design for environment (DFE) and design for disassembly Even though LCA may seem to be the most important solution to environmental problems; its immediate effect is in the early stages of new product development. However, the biggest damage to the environment occurs when the product completes its useful life. Thus, understanding and developing techniques for end-of-life management of the products by means of product/material recovery [20] are extremely crucial considering the millions of products that have already been developed without incorporating their undesired effects on the environment. Recovery of products is usually performed in two ways: recycling and remanufacturing. Recycling aim at recovering the material content of retired product by performing the necessary disassembly, sorting and chemical operations. On the other hand, remanufacturing preserves the product's (or the part's) identity and performs the required disassembly, sorting, refurbishing and assembly operations in order to bring the product to a desired level of quality. Disassembly has proven its role in material and product recovery by allowing selective separation of desired parts and materials

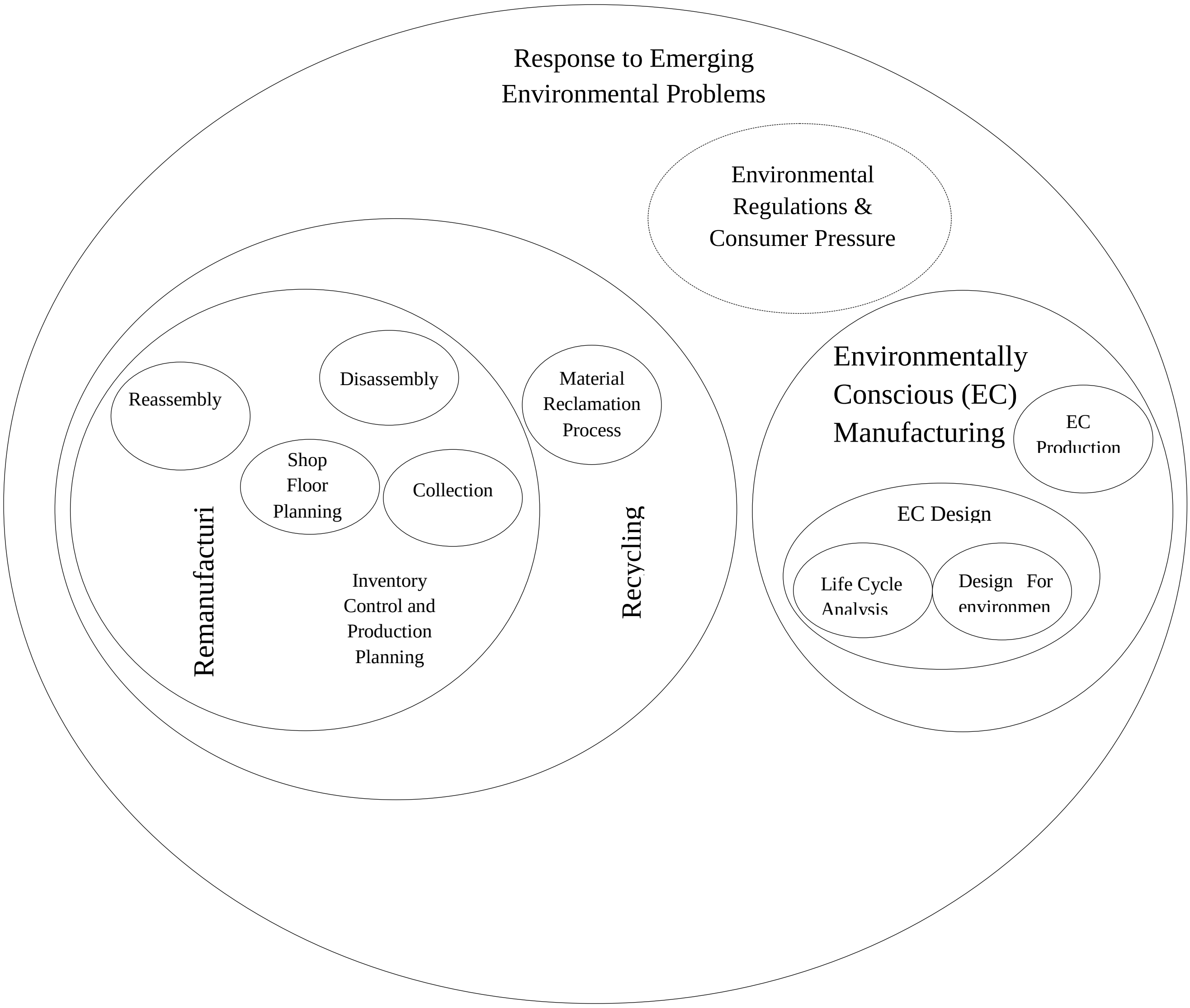


**Figure 3: Responses to Emerging Environmental Problems[3]**

Besides being able to recover valuable precious materials by material recovery, good component removal via disassembly could provide parts for discontinued products and reduce the lead times in the assembly of new products [21,22].

## 2.2 Environmentally Conscious Manufacturing (ECM)

Before discussing the body of literature as it pertains to ERM, it is first important to define what we mean exactly by this term. This is an important because of the confusion surrounding this concept. Part of this confusion is due to the various terms that have been used to describe a company's effort to integrate environmental thinking into its decision-making processes. Industrial Ecology, Environmentally

Conscious Manufacturing and Environmental Benign Manufacturing are among the most popular labels used. A close examination of these terms highlights that they differ mostly by their labels and not in definition. We will use the definition presented by Melnyk and Handfield[23]. According to this definition, ECM is:

a system which integrates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess and manage the flow of environmental waste with the goal of reduce and ultimately minimizing its impact on the environment while also trying to maximize resource efficiency[23]. This definition focuses on proactive as compared remedial solutions. With the latter (also called "end of pipe" solutions), environmental problems are corrected once they have been created. Typically, this approach focuses on symptoms, rather than the underlying causal factors. In general, remedial solutions have been found to be highly inefficient.

ECM involves producing products such that their overall negative environmental effects are minimized [24]. ECM consists of the following two key issues:

- Understanding the life cycle of the product and its impact on the environment at each of its life stages and
- Making better decisions during product design and manufacturing so that the environmental attributes of the product and manufacturing process are kept at a desired level.

The first issue is necessary for drawing lines to determine how the product will evolve from the drawing board and how it will affect the environment throughout its life stages. If we fully understand the life cycle of the product, we can then transfer this information

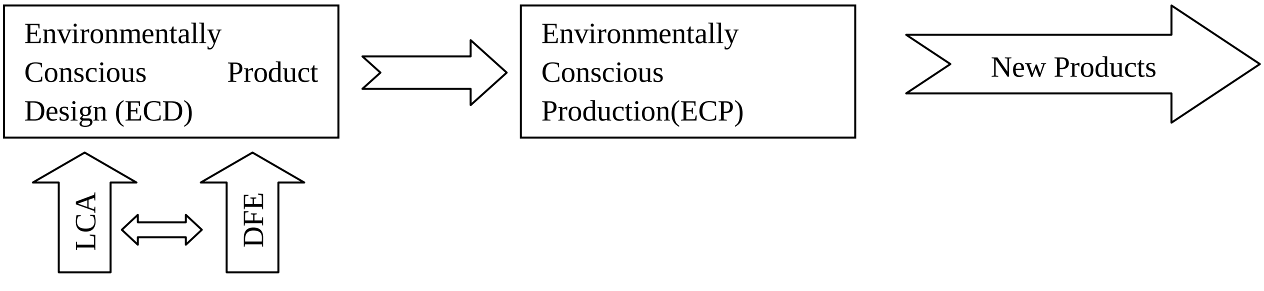


**Figure 4: Environmentally conscious manufacturing[4]**

The first issue is necessary for drawing lines to determine how the product will evolve from the drawing board and how it will affect the environment throughout its life stages. If we fully understand the life cycle of the product, we can then transfer this information onto the actual development of the product (which addresses the second issue of ECM). In addition, understanding the end-of-life stage of the product is critical since one of the largest impacts on the environment occurs at that stage. During the design stage of the product, there are different objectives that the designers may focus on. Depending on the end-of-life strategy of the product, the design of the product can be realized to increase recyclability, manufacturability, disassemblability and to minimize the effect on the environment. When designing a product with environmental features, material selection should also be considered as a key element. Once the design decisions of a product are complete and the materials for its production are identified, the product's environmental attributes are pretty much set. However, in addition to design and materials decisions, issues involving selection of energy source, cooling systems and handling of hazardous byproducts etc. must be controlled during the manufacturing process to achieve a complete ECM concept.

### *2.2.1 Environmentally Conscious Design (ECD)*

Traditional product development aims at achieving improvements in design with respect to cost, functionality and manufacturability. However, increasing importance of the environmental issues forces product designers to consider certain environmental criteria in the design process. In order to help product designers make environmentally friendly design choices, ECD aims to design products with certain environmental considerations. In the literature, for the product life cycle analysis (LCA) and Design for Environment both are discussed.

### *2.2.2 Life Cycle Analysis or Assessment (LCA)*

An LCA is a mapping and/or a comparison between different alternative life cycles or between different parts of the life cycle. LCA has a major advantage as a sorting tool to separate major and minor environmental impacts from each other. Thus defining the “hot spots” With the use of LCA it is possible to identify which kind of environmental impact will be affected by different choice of alternatives and thereby also make clear what is not changed. This can be applied to present situations as well as changes that are to be made in the future. LCA is intended to provide information that may be used for environmental improvements but can also be used to identify processes, substances and systems in a life cycle that are major contributors to environmental impacts.

Life cycle engineering (LCE) may also be referred to as lifecycle design (LCD).Boothroyd and Alting [25] distinguished six phases in the product lifecycle: need recognition, design development, production, distribution, use, and disposal. All of the phases must be considered during the conceptual stage, where it is possible to inexpensively change solutions to accommodate the requirements in each phase and inthe total lifecycle. Lifecycle assessment is a family of methods for assessing materials, services, products, processes, and technologies over the entire product life. The definition of product lifecycle assessment, developed by the Society of Environmental Toxicology and Chemistry, [26] is as follows: energy and material uses and releases to the environment, and to evaluate and implement opportunities to affect environmental improvements. The assessment includes the entire lifecycle of the product, process, or activity, encompassing extracting and processing

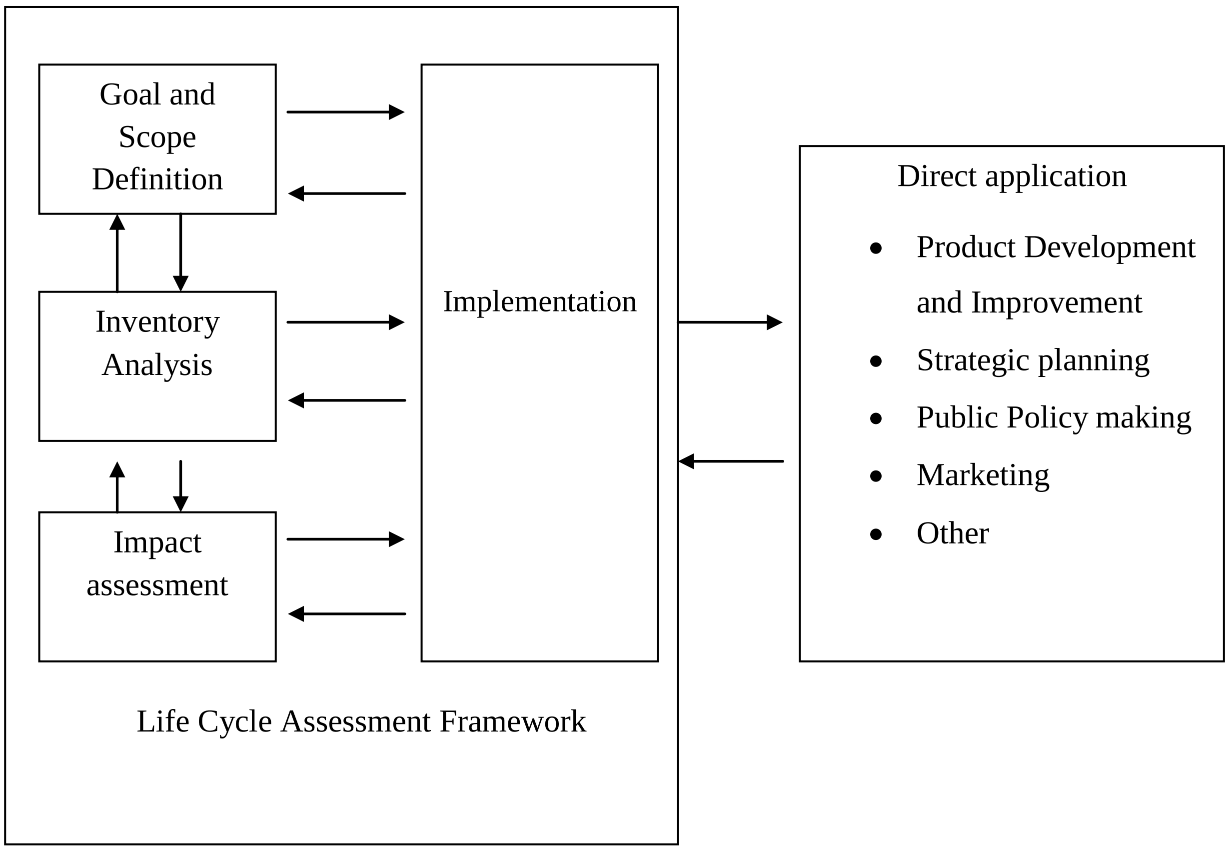


**Figure 5: Environmentally conscious manufacturing [17]**

raw materials; manufacturing, transportation and distribution; use, reuse, maintenance; recycling and final disposal. The steps involved in LCA[27] are as follows:-

- Goal definition and scoping
- Inventory analysis
- Impact assessment
- Improvement assessment

### *2.2.3 Design for environment (DFE)*

Definition provided by Fiksel [34] of DFE is "the systematic consideration during new production and process development of design issues associated with environmental safety and health over the full product life cycle."

The three main goals of DFE are:

- Minimize the use of nonrenewable resources
- Effectively manage renewable resources
- Minimize toxic release to the environment

## 2.3 Identification of Drivers for ECM

The driver helps in recycling, waste management, green purchasing & marketing, using a cleaner & renewable source of energy, end-of-life management of products, green logistics and many more by implementation of ECM. Identification the drivers that are important to implementing ECM practices involves a literature review and includes experts from the industry. From which we found various drivers which are discussed here.

Walker et al. (2008)[28] reviewed the literature and identified the factors that drive or hinder organizations to implement green supply chain management initiatives on interviews bases conducted at seven different private and public sector organizations these includes internal drivers such as organizational factors, and external drivers such as regulation, customers, competitors, society and suppliers, based on interviews conducted at seven different private and public sector organizations.

Rao (2002)[29] observed that greening different phases of the supply chain leads to an integrated green supply chain, which in turn leads to competitiveness and better economical and operational performance. Lee (2008)[30] identified the main drivers for companies to participate in GSCM (Green supply chain management) practices as buyer influence, government involvement and green supply chain (GSC) readiness. Wee and Quazi (2005)[31] identified seven critical factors in their research into environmental management: top management commitment; total involvement of employees; training; green products/process design; supplier management; measurement; and information management.

According to Zhu et al. (2013)[32] Environmental regulations can be considered as the coercive pressures driving Chinese manufacturers to implement extended supply chain (ESC) practices to achieve Energy Saving and Emission Reduction (ESER) goals. Due to decreasing resource and increasing environmental problems, both central and regional governments in China have released many environmental regulations.

Curkovic (2003)[33]Environmentally Responsible Manufacturing (ERM) is also an advanced technique for controlling the industrial pollution. By Fiksel(2013)[34] the renovated concept which later on proved as a most existing driver of GM practices is Environmental health and safety (EHS) of the working employees in a particular firm. Brown (2008)[35] suggests that Greening of the supply chain provides a significant opportunity to improve overall environmental performance and also opportunity to reduce costs. Green practices and Performance parameters among various manufacturing organizations.

Sarkis et al. (2007)[36] says that further work in this field of greening the manufacturing practices enhanced its growth in to chemicals, mining and resource, oil, gas and petroleum, transport and tourism, construction, food and household sectors for their research to find environmental sensitiveness.

In this research from the previous literature eighteen drivers are identified by the brainstorming with the experts which can force the industries to implement the ECM in the textile industries in India. The identified drivers are summarized in the given below Table 1along with their sources.

**Table 1: List of Drivers for ECM in Textile industry**

| S.NO. | DRIVERS | SOURCES |
|---|---|---|
| D1 | Customer Awareness/Customer Pressure | [37], [38], [32], [39], [40], [41], [28],[42], [43], [54], [55], [56], [58] |
| D2 | Public Pressure | [37], [38], [32], [44], [45], [40],[46], [47], [48], [49], [42], [57], [71] |
| D3 | Cost Reduction/Cost Saving | [37], [38], [32], [45], [40],[46], [28], [47], [48], [50], [49] ,[42], [52] |
| D4 | Organizational Awareness | [37], [44], [28], [51], [52] |
| D5 | Organizational Capabilities | [37], [41], [46], [64], [65] |
| D6 | Social and Environmental Responsibility | [37], [39], [45], [40], [46], [38], [41], [42], [50] |
| D7 | Competitiveness | [37], [38], [44], [32], [40], [41], [45], [28], [47], [52], [53], [66], [67], [63] |
| D8 | Marketing | [37], [48], [42], [52], [43], [68], [73] |
| D9 | Green Image | [37], [38], [32], [50], [49], [42], [67] |
| D10 | Employee Motivation ,Health and Safety | [37], [45], [49] |
| D11 | Organization Policy | [32], [39], [44], [41], [28], [47], [62], [72] |
| D12 | Government Policy | [32], [39], [42], [43], [62] |
| D13 | Market Trend | [44], [69], [70] |

| | | |
|---|---|---|
| D14 | Technology | [46] |
| D15 | Legislation | [37], [38], [32], [39], [40], [41], [28], [70],[47], [48], [49], [42], [43], [71] |
| D16 | Management Commitment | [44], [41], [28], [47], [49] |
| D17 | Supply Chain Demand | [45], [40], [41], [46], [50], [49], [42], [52], [43] |
| D18 | Demand from Banks | [40] |

All identified drivers for implementation of ECM are described below:-

- ***Customer Awareness/Customer Pressure*:** The role of purchasing in environmental management it is found that customer awareness and pressure that forces a more positive influence on implementation of environmental conscious manufacturing. Customer awareness and pressure is that driver of Green Manufacturing which states that the understanding and knowledge that a buyer should have of his rights as a customer.
- ***Public Pressure*:** Public pressure: The influence exerted by local communities, NGOs, the media and the public at large on polluting plants can act as an effective driver to adopt environmental practice like ECM. This type of public pressure has been documented by a number of recent studies.
- ***Cost Reduction/Cost Saving*:** ECM can improve production efficiency by cutting down the costs of wasteful energy, water and material input use. If management is aware of the cost-reducing potential of ECM options, they are likely to adopt ECM as way to reduce costs.
- ***Organizational Awareness*:** Organizational Awareness is a Social and Emotional Intelligence competency that can also be defined as situational awareness, or even empathy on an organizational scale. It is the ability to read social and political currents in organizations, teams, communities, and situations that motivates the organization to adopt ECM.

- ***Organizational Capabilities*****:** Organizational Capability is the firm’s ability to manage people to gain competitive advantage. Organizational Capability is that driver of Cleaner manufacturing which is most important to adoption and implementation of ECM in manufacturing.
- ***Social and Environmental Responsibility*****:** Social & Environmental responsibility is that driver of ECM which initiative to assess and take responsibility for the company's effects on the environment and impact on social welfare.
- ***Competitiveness*****:** Competitiveness is that driver of ECM which states that the existence of competition among diverse organizations that serve customers. Competition is used to describe the market, and the struggle of different companies or businesses to prevail over the other.
- ***Marketing*****:** Marketing on a worldwide scale to merge or take business advantages of the international differences, opportunities and likeness in operation so as to meet the objectives. ECM can open new opportunities for industries in marketing.
- ***Green Image*****:** Green image is that driver of ECM which provides a greening image where a manufacturing product is to be used. It is most important driver of Green Manufacturing (GM) to adoption of ECM in manufacturing industries.
- ***Employee Motivation, Health and Safety*****:** Employee health and safety are that driver of ECM which is more helpful to implementation and adoption of Green Manufacturing (GM) in Industries. Health and safety should aim to promotion and maintenance of the highest degree of physical, mental and social well-being of workers; the prevention amongst workers of departures from health caused by their working conditions; the placing and maintenance of the workers in an occupational environment adapted to their capabilities .Motivating employees about work is the blend of satisfying the employee's requirements and prospect from work and workplace factors that facilitate employee motivation
- ***Organization Policy*****:** If Organization and its policies are concerned about environment and the adverse effect on environment. Then Organization policy can be a important driver for implication of ECM in their industry.

- ***Government Policy*:** If Government makes policy that will motivates industries to adopt green practices that can be a very crucial driver for implication of ECM in industries. Policies like relaxation in taxes and give honors and awards for adopting ECM will encourage industries to follow green practices.
- ***Market Trend*:** In recent trends, green products are popular and gain support from all external stakeholders. This trend pressures the manufacturers to produce green products via green manufacturing activities.
- ***Technology*:** Available green technology can improve efficiency and give more advantages to the industries. It can also give more opportunities to the industries.
- ***Environmental image*:** good environmental performance of competitors may motivate plant managers to adopt EST to improve their own environmental reputation and keep up with their competitors.
- ***Legislation*:** Government Rules & legislation is a major driver for company's environmental management Regulations increases the threats of penalties and fines for non-compliance among companies. This driver is most helpful for implementing and adoption of Green Manufacturing in industries.
- ***Management Commitment*:** Top management has significant ability to influence, support and champion the actual formulation and deployment of environmental initiatives across the organization. Top management must realize that supporting ECM must be visible and seen as a commitment.
- ***Supply chain demands*:** environmental requirements of a industry's business partners (primarily supply chain buyers), and also customers increasingly act as drivers for ECM adoption in plants that are active in supply chains. This pressure increases in product market segments that are close to final consumers.
- ***Demand from Banks*:** Many industries took loans from banks for facilities. Banks can demand the industries to follow environmental practices to give relaxation in loans and payments. And it can be a crucial driver.

## 2.4 Interpretive Structural Modeling

ISM is an interactive learning process. ISM has been found as a useful tool for exploring the relationships and interaction between various factors[10,11].ISM methodology helps to impose order and direction on the complexity of relationship among elements of a system [74]. ISM methodology is an interactive learning process and helps to improve order and direction on the complex relationships among variables of a system [10]. ISM was proposed for complex situations as a communication tool [75]. In this, a set of different and directly related variables affecting the system under consideration is structured into a comprehensive systemic model. The model so formed portrays the structure of a complex issue, a system of a field of study, in a carefully designed pattern employing graphics as well as words [76-78].

The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words [76,77,79,80].ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue [81].This technique transformed unclear and poorly articulated system models into visible and well-defined models [10,75].

ISM is an influential approach, which can be applied in various fields [79].Saxena and Vrat (1990) [74] have identified the key variables using direct as well as indirect interrelationships amongst the variables and presented the results of the application of ISM methodology to the case of energy conservation in Indian cement industry. Mandal and Deshmukh (1994) [82] used the ISM methodology to analyze some of the important vendor selection criteria and have shown the interrelationships of criteria and their levels. Singh et al. (2003) [76] have utilized this technique for the implementation of knowledge management in engineering industries .Ravi and Shankar (2005) [77] identified 11 barriers of reverse logistics in automobile industries and used ISM methodology to analyze the interaction among these barriers. Bolanos et al. (2005) [83] applied ISM methodology in improving decision making process among executives working in different functional areas while Qureshi et al. (2007) [84] developed a model for the logistics outsourcing relationship variables to enhance shipper's productivity and competitiveness in logistical supply chain using ISM based approach. Faisal et al. (2006) [78] found ISM application in supply chain risk mitigation in Indian manufacturing SMEs. Hasan et al. (2007) [85] explored various barriers in adopting agile manufacturing and established a relationship among these barriers through the ISM methodology. Beside this, Raj et al. (2008) [79] conducted a case a study and applied ISM approach for modeling the enablers of flexible manufacturing system. Sharma et al. (1995) [86] used the ISM methodology to develop a hierarchy of action required to achieve the future objective of waste management in India.

A study conducted by Sahney et al. (2010) [87] proposed a quality framework for Indian higher education system particularly for administrative staff. The framework was developed through the application of ISM. Huang et al. (2005) [88] proposed a method by integrating ISM and ANP to analyze subsystems' interdependence and feedback relationships. Kannan et al. (2009) [89] used ISM and fuzzy TOPSIS as a hybrid approach for the analysis and selection of third-party reverse logistics provider. Kannan and Haq (2007) [90] used the ISM methodology to analyze the interactions among the criteria and sub-criteria, which influences the supplier selection for the built-in-order supply chain environment. Diabat and Govindan (2011) [75] used the same ISM methodology to analyze the drivers affecting the implementation of green supply chain management. Raj et al. (2010) [79] used ISM approach to understand the mutual interaction of the enablers that help in the implementation of flexible manufacturing systems (FMS) and identify the driving enablers and the dependent enablers. Singh and Kant (2008) [91] used ISM methodology to evolve mutual relationships among the identified knowledge management barriers.

### *2.4.1. Characteristics of ISM*

Raj et al. (2010) gives some of the important characteristics of ISM[79] are:

- This methodology is interpretive as the judgment of the group decides whether and how the different elements are related.
- It is structural, too, 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 digraph model.

- It helps to impose order and direction on the complexity of relationships among various elements of a system.
- It is primarily intended as a group learning process, but individuals can also use it.

### 2.4.2 Advantages of ISM approach

ISM offers a variety of advantages observed by Raj and Attri (2011) [80]are:

- The process is systematic; the computer is programmed to consider all possible pair wise relations of system elements, either directly from the responses of the participants or by transitive inference.
- The process is efficient; depending on the context, the use of transitive inference may reduce the number of the required relational queries by from 50- 80 percent.
- No knowledge of the underlying process is required of the participants; they simply must possess enough understanding of the object system to be able to respond to the series of relational queries generated by the computer.
- It guides and records the results of group deliberations on complex issues in an efficient and systematic manner.
- It produces a structured model or graphical representation of the original problem situation that can be communicated more effectively to others. vi It enhances the quality of interdisciplinary and interpersonal communication within the context of the problem situation by focusing the attention of the participants on one specific question at a time.
- It encourages issue analysis by allowing participants to explore the adequacy of a proposed list of systems elements or issue statements for illuminating a specified situation.
- It serves as a learning tool by forcing participants to develop a deeper understanding of the meaning and significance of a specified element list and relation.
- It permits action or policy analysis by assisting participants in identifying particular areas for policy action which offer advantages or leverage in pursuing specified objectives.

# CHAPTER -3

## RESEARCH METHODOLOGY

The objectives of the study are to be achieved through the accomplishment of the following tasks:

### 3.1 Collection of literature

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

- Cleaner production in textile industry
- Drivers of Environmentally conscious manufacturing
- Issues in Environmentally responsible manufacturing
- Sustainable manufacturing and its motivating factors
- Implementation of Green manufacturing
- Driving factors of Environmentally benign manufacturing
- Clean manufacturing
- ISM methodology
- Interpretive structural modeling

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 (top) journal to include "all" published articles in this field. The extracted article types included journals, conference proceedings, books, book 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.

## 3.2 Survey Instrument Development

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 Questionnaire Design

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

In the first part of questionnaire survey participants have to tell how much driver can influence your decision in adoption or implementation of ECM practices/technologies in your organization. The participants have to rate drivers which drive your industry to implement environmentally conscious Manufacturing on a likert scale from 1 to 5:

- 1means not at all influential
- 2 means slightly influential
- 3 means somewhat influential
- 4 means very influential
- 5 means extremely influential

This type of scale is often used in research and due to the 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, job position, , and work experience.

### 3.4 Data Collection

The primary objective of the study was to develop an instrument to measure the participant's perception of ECM drivers, managers and above were considered as appropriate samples. The General Managers, Directors, Divisional General Managers, Sr. Managers, Chief Engineers are likely to be "thought" leaders with respect to environmental activities in their organizations, therefore, they were taken as the samples for this study.

The questionnaire was used for an online survey via Google forms website. An email was sent to about 250 senior executives (manager and above) working in the manufacturing/production departments or heads of different textile industry all over India. This email 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 even in some cases telephonic calls were made.

### 3.5 Data Analysis

The drivers will be useful for different applications, by different researchers, in different studies, only if they are statistically reliable and valid. Reliability reflects the driver's ability to consistently yield the same response. Reliable drivers will produce the same results each time it is administered to the same person in the same setting. Validity refers to the degree to which drivers truly measure the factors which they intend to measure.

### 3.6 ISM Methodology

The various steps involved in the ISM methodology are given below [89] as depicted in Figure-6:

- Step I — Variables (criteria) considered for the system under consideration are listed.
- Step II — From the variables identified in step I, a contextual relationship is established among the variables in order to identify as to which pairs of variables should be examined.

Step III A structural self-interaction matrix (SSIM) is developed for variables, which indicates pairwise relationships among variables of the system under consideration.

Step IV Initial reachability matrix is developed from the SSIM and the matrix is hecked for transitivity to obtain final reachability matrix. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

Step V The final reachability matrix obtained in step IV is partitioned into different levels on the basis of the reachability and antecedent sets for each of the variable and through a series of iterations.

Step VI On the basis of the levels of partitions obtained from step VI and final reachability matrix, a conical matrix is constructed.

Step VII A directed graph or digraph is drawn based on partition levels and transitive links are removed.

Step VIII The resultant digraph is converted into an ISM-based model, by replacing variable nodes with statements.

Step IX Finally, the ISM-based model developed in step VIII is reviewed for inconsistency and necessary modifications are incorporated through expert opinions.

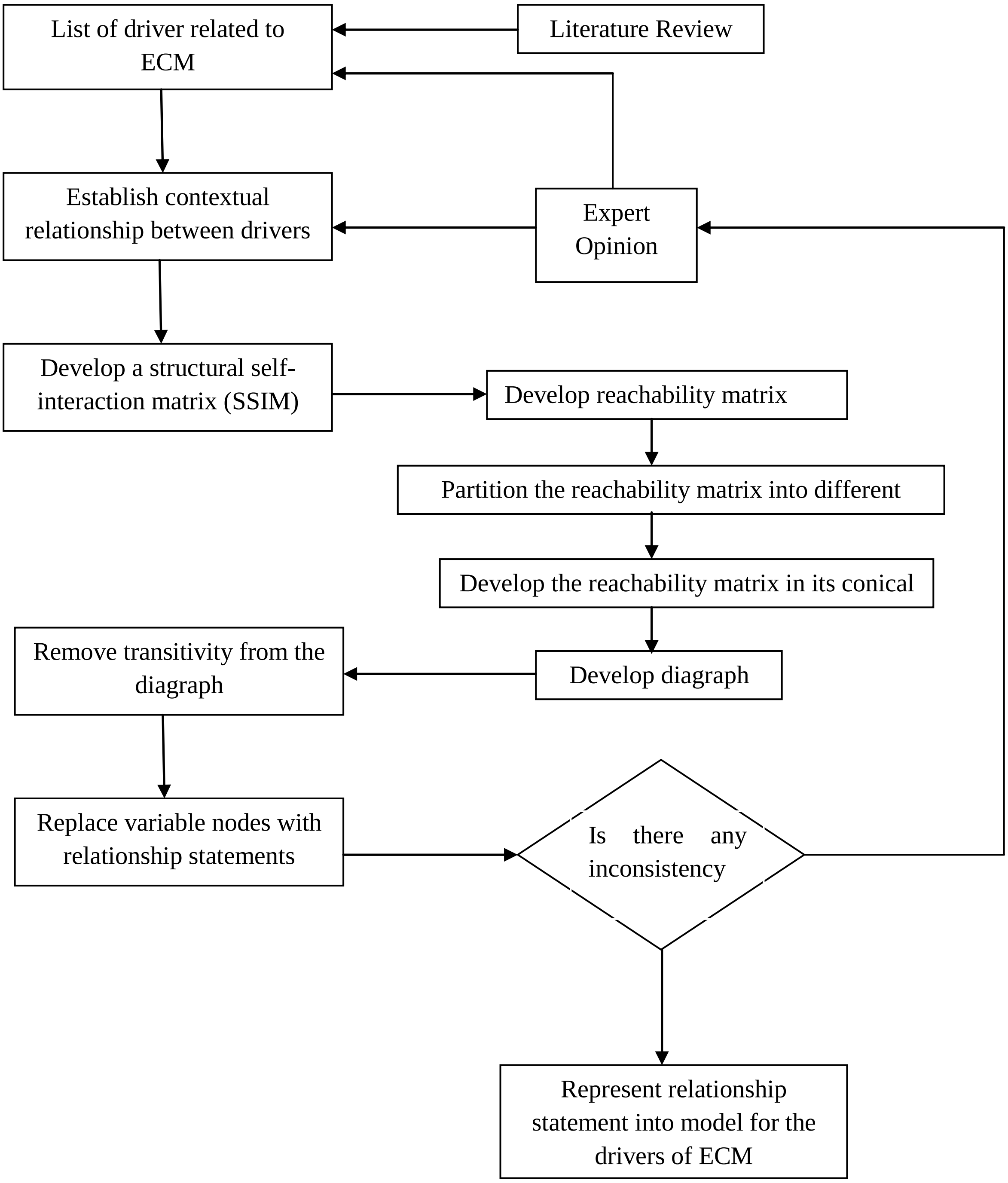


**Figure 6: Flow diagram for preparing ISM model**

## 3.7 MICMAC Analysis

Matriced'Impactscroises-multiplication appliqúe an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MICMAC analysis is to analyze the drive power and dependence power of drivers. MICMAC principle is based on multiplication properties of matrices [86]. It is done to identify the key factors that drive the system in various categories.

The drivers are categorized into four clusters based on their driving power and dependence power as follows:

- ***Autonomous drivers:*** These drivers have weak driving power and weak dependence. They are relatively disconnected from the system, with which they have few links, which may be very strong. These drivers are represented in quadrant I.
- ***Dependent drivers:*** This category includes those drivers which have weak driving power but strong dependence power and placed in Quadrant II. These drivers affected by any action on factors driving these drivers.
- ***Linkage drivers:*** These drivers have strong driving power as well as strong dependence and are placed in quadrant III. They are also unstable and so any action on them will have an effect on others and also a feedback effect on themselves.
- ***Independent drivers:*** These drivers have strong driving power but weak dependence power. These are represented in quadrant IV. These drivers are independent in nature which are not much affected by others, but cause effects on the factors dependent on them

# CHAPTER -4

## 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. This is particularly important in satisfaction. 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 consistency of a set of measurement items refers to the degree to which items in the set are homogeneous. Internal consistency can be estimated using reliability coefficient such as Cronbach's alpha. Internal consistency analysis was carried out by using SPSS16.0, to measure the reliability of the items under each driver in term of Cronbach's alpha. An alpha value of 0.70 is often considered as the criteria for establishing internallyconsistency. Items are eliminated in order to improve the Cronbach's alpha, if needed.

After reliability test reliability coefficient value is 0.734 which is above 0.7 that is quite acceptable. In Table 2 Cronbach's alpha value is presented for each driver with the value of Cronbach's alpha value if driver is deleted.

### 4.2 Descriptive Statistics

Descriptive statistics for drivers are presented in table 3. The minimum value of mean for drivers is more than 3.50 on a scale of 5, which represents that all the drivers are important. In Table 3 standard deviation is also presented for each driver. The examination of mean values shows that public pressure is the most important driver for the implementation of ECM in textile industries.

**Table 2: Cronbach's alpha (α) test results for reliability**

| Di | DRIVER | Cronbach's Alpha (α) | Cronbach's Alpha if item deleted |
|---|---|---|---|
| D1 | Customer Awareness | 0.734 | 0.726 |
| D2 | Public Pressure | 0.734 | 0.727 |
| D3 | Cost Reduction/Cost Saving | 0.734 | 0.737 |
| D4 | Organizational Awareness | 0.734 | 0.686 |
| D5 | Organizational Capabilities | 0.734 | 0.699 |
| D6 | Social and Environmental Responsibility | 0.734 | 0.728 |
| D7 | Competitiveness | 0.734 | 0.711 |
| D8 | Marketing | 0.734 | 0.751 |
| D9 | Green Image | 0.734 | 0.699 |
| D10 | Employee Motivation, Health and Safety | 0.734 | 0.720 |
| D11 | Organization Policy | 0.734 | 0.708 |
| D12 | Government Policy | 0.734 | 0.747 |
| D13 | Market Trend | 0.734 | 0.707 |
| D14 | Technology | 0.734 | 0.733 |
| D15 | Legislation | 0.734 | 0.724 |
| D16 | Management Commitment | 0.734 | 0.750 |
| D17 | Supply Chain Demand | 0.734 | 0.699 |
| D18 | Demand From Banks | 0.734 | 0.743 |

**Table 3: Descriptive statistics for Drivers of ECM**

| Di | DRIVER | MEAN | SD |
|---|---|---|---|
| D1 | Customer Awareness | 4.120 | 0.739 |
| D2 | Public Pressure | 4.310 | 0.563 |
| D3 | Cost Reduction/Cost Saving | 3.880 | 0.861 |
| D4 | Organizational Awareness | 3.930 | 0.677 |
| D5 | Organizational Capabilities | 3.900 | 0.759 |
| D6 | Social and Environmental Responsibility | 4.020 | 0.715 |
| D7 | Competitiveness | 3.900 | 0.617 |
| D8 | Marketing | 3.500 | 0.506 |
| D9 | Green Image | 3.980 | 0.811 |
| D10 | Employee Motivation, Health and Safety | 3.950 | 0.909 |
| D11 | Organization Policy | 4.100 | 0.692 |
| D12 | Government Policy | 3.710 | 0.508 |
| D13 | Market Trend | 3.810 | 0.804 |
| D14 | Technology | 4.050 | 0.623 |
| D15 | Legislation | 4.210 | 0.750 |
| D16 | Management Commitment | 3.900 | 0.692 |
| D17 | Supply Chain Demand | 3.860 | 0.566 |
| D18 | Demand From Banks | 3.930 | 0.601 |

## 4.3 Ranking of Drivers

In Table 4 ranking of each driver are presented on the basis of their mean on the scale of 5. After inspection of mean values of each driver it shows that public pressure got the first rank on the basis of mean value. Legislation, Customer awareness and all other drivers follows the public pressure in this ranking table.

**Table 4: Ranking of Drivers for ECM**

| RANK | Di | DRIVER | Mean |
|---|---|---|---|
| 1 | D2 | Public Pressure | 4.310 |
| 2 | D15 | Legislation | 4.210 |
| 3 | D1 | Customer Awareness | 4.120 |
| 4 | D11 | Organization Policy | 4.100 |
| 5 | D14 | Technology | 4.050 |
| 6 | D6 | Social and Environmental Responsibility | 4.020 |
| 7 | D9 | Green Image | 3.980 |
| 8 | D10 | Employee Motivation, Health and Safety | 3.950 |
| 9 | D4 | Organizational Awareness | 3.930 |
| 10 | D18 | Demand From Banks | 3.930 |
| 11 | D5 | Organizational Capabilities | 3.900 |
| 12 | D7 | Competitiveness | 3.900 |
| 13 | D16 | Management Commitment | 3.900 |
| 14 | D3 | Cost Reduction/Cost Saving | 3.880 |
| 15 | D17 | Supply Chain Demand | 3.860 |
| 16 | D13 | Market Trend | 3.810 |
| 17 | D12 | Government Policy | 3.710 |
| 18 | D8 | Marketing | 3.500 |

## 4.4 ISM

ISM methodology 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 that are involved in ISM approach for identified drivers shown in

Table 5are explained below in following sections:

**Table 5: List of Drivers**

| Di | DRIVERS NAME |
|---|---|
| D1 | Customer Awareness |
| D2 | Public Pressure |
| D3 | Cost Reduction/Cost Saving |
| D4 | Organizational Awareness |
| D5 | Organizational Capabilities |
| D6 | Social and Environmental Responsibility |
| D7 | Competitiveness |
| D8 | Marketing |
| D9 | Green Image |
| D10 | Employee Motivation, Health and Safety |
| D11 | Organization Policy |
| D12 | Government Policy |
| D13 | Market Trend |
| D14 | Technology |
| D15 | Legislation |
| D16 | Management Commitment |
| D17 | Supply Chain Demand |
| D18 | Demand From Banks |

### *4.4.1 Structural Self-Interaction Matrix (SSIM)*

ISM methodology suggests the use of expert opinions based on various management techniques such as brainstorming, nominal technique, etc. in developing the contextual relationship among the variables. Thus, for identifying the contextual relationship among the interactions ECM drivers for Indian textile industry, experts from the industry and from academia were consulted for the above work.

Four symbols used to denote the direction of relationship between the drivers are given below (*i* and *j*)

- Type *V*: driver *Di* relate to driver *Dj*
- Type *A*: driver *Dj* relate to on driver *Di*
- Type *X*: driver *Di* and *Dj* relate to each other
- Type *O*: driver *Di* not relate to driver *Dj* and vice versa

The following statements explain the use of symbols V, A, X, and O in the SSIM:

- Customer awareness [D1] will relate to cost Reduction/Cost Saving [D3], so the relationship between factors D1 and D3 is denoted by "*V*" in the SSIM.
- Organization Policy[D11] will relate to Competitiveness [D7], so the relationship between factors D11 and D7 is denoted by "*A*" in the SSIM.
- Organizational Awareness [D4] and Organizational Capabilities [D5] will relate to each other, so the relationship between factors D4 and D5 is denoted by "*X*" in the SSIM.
- No relationship exists between Employee Motivation, Health and Safety [D10]and Market Trend [D13], so the relationship between factors D10 and D13 is denoted by "*O*" in the SSIM.

Based on the contextual relationship between drivers, the SSIM has been developed. Based on their responses, SSIM has been finalized and is presented in Table 6.

**Table 6: Structural self-interaction matrix**

| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *0* | *1* | *2* | *3* | *4* | *15* | *16* | *17* | *18* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D1* | *X* | *A* | *V* | *V* | *V* | *V* | *V* | *V* | *O* | *V* | *V* | *X* | *V* | *V* | *A* | *V* | *V* | *O* |
| *D2* | | *X* | *V* | *V* | *V* | *V* | *V* | *V* | *O* | *V* | *V* | *V* | *V* | *V* | *V* | *V* | *V* | *O* |
| *D3* | | | *X* | *A* | *A* | *O* | *A* | *O* | *O* | *O* | *A* | *O* | *O* | *A* | *O* | *A* | *A* | *A* |
| *D4* | | | | *X* | *X* | *V* | *V* | *V* | *V* | *V* | *A* | *A* | *A* | *A* | *A* | *A* | *A* | *A* |
| *D5* | | | | | *X* | *A* | *V* | *O* | *V* | *O* | *A* | *A* | *A* | *A* | *O* | *A* | *A* | *A* |
| *D6* | | | | | | *X* | *V* | *V* | *V* | *V* | *O* | *A* | *A* | *O* | *A* | *A* | *O* | *O* |
| *D7* | | | | | | | *X* | *V* | *O* | *O* | *A* | *A* | *A* | *A* | *A* | *A* | *A* | *O* |
| *D8* | | | | | | | | *X* | *X* | *A* | *A* | *A* | *A* | *A* | *O* | *A* | *O* | *O* |
| *D9* | | | | | | | | | *X* | *V* | *A* | *A* | *A* | *A* | *A* | *A* | *O* | *O* |
| *D10* | | | | | | | | | | *X* | *A* | *A* | *O* | *O* | *A* | *A* | *O* | *A* |
| *D11* | | | | | | | | | | | *X* | *A* | *X* | *V* | *A* | *A* | *V* | *A* |
| *D12* | | | | | | | | | | | | *X* | *V* | *V* | *X* | *V* | *V* | *V* |
| *D13* | | | | | | | | | | | | | *X* | *V* | *A* | *O* | *V* | *O* |
| *D14* | | | | | | | | | | | | | | *X* | *A* | *A* | *X* | *A* |
| *D15* | | | | | | | | | | | | | | | *X* | *V* | *V* | *V* |
| *D16* | | | | | | | | | | | | | | | | *X* | *V* | *O* |
| *D17* | | | | | | | | | | | | | | | | | *X* | *O* |
| *D18* | | | | | | | | | | | | | | | | | | *X* |

### *4.4.2 Initial Reachability Matrix*

The SSIM is transformed into a binary matrix, called the initial reachability matrix. The rules for the substitution of 1 and 0 are the following:

- If the $(i, j)$ entry in the SSIM is *V*, then the $(i, j)$ entry in the reachability matrix becomes 1 and the $(j, i)$ entry becomes 0.
- If the $(i, j)$ entry in the SSIM is *A*, then the $(i, j)$ entry in the reachability matrix becomes 0 and the $(j, i)$ entry becomes 1.
- If the $(i, j)$ entry in the SSIM is *X*, then the $(i, j)$ entry in the reachability matrix becomes 1 and the $(j, i)$ entry also becomes 1.
- If the $(i, j)$ entry in the SSIM is *O*, then the $(i, j)$ entry in the reachability matrix becomes 0 and the $(j, i)$ entry also becomes 0.

Table 7 shows the initial reachability matrix for main drivers. The initial reachability matrix for the main drivers is derived from the SSIM by substituting the concerned binary values.

### *4.4.3 Final Reachability Matrix*

The final reachability matrix for the factors is obtained by incorporating the transitivities as explained in Step IV of the ISM methodology. The final reachability matrix for the drivers is obtained by incorporating the transitivity. It is a basic assumption made in ISM.

It states that

If driver 1 is related to 2, and

driver 2 is related to 3,

then driver 1 is necessarily related to 3.

Table 8shows the final reachability matrix for main attributes. Table 9shows the final reachability matrix with driving power and dependence for main attributes.

**Table 7: Initial reachability matrix**

| *Drivers* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* |
| *D2* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* |
| *D3* | *0* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D4* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D5* | *0* | *0* | *1* | *1* | *1* | *0* | *1* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D6* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D7* | *0* | *0* | *1* | *0* | *0* | *0* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D8* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D9* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D10* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D11* | *0* | *0* | *1* | *1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* |
| *D12* | *1* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D13* | *0* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* |
| *D14* | *0* | *0* | *1* | *1* | *1* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *1* | *0* | *0* | *1* | *0* |
| *D15* | *1* | *0* | *0* | *1* | *0* | *1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D16* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *1* | *0* | *1* | *1* | *0* |
| *D17* | *0* | *0* | *1* | *1* | *1* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *0* | *0* | *1* | *0* |
| *D18* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *1* | *1* | *0* | *0* | *1* | *0* | *0* | *0* | *1* |

**Table 8: Final reachability matrix**

| *Drivers* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D2* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D3* | *0* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D4* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D5* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D6* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D7* | *0* | *0* | *1* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D8* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D9* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D10* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| *D11* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* |
| *D12* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D13* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* |
| *D14* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *1* | *0* | *0* | *1* | *0* |
| *D15* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* |
| *D16* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *1* | *0* | *1* | *1* | *0* |
| *D17* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *0* | *0* | *1* | *1* | *0* | *0* | *1* | *0* |
| *D18* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *1* |

**Table 9:Final reachability matrix with Driving and Dependence Power**

| *Drivers* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* | *Driving Power* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *D1* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *17* |
| *D2* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *18* |
| *D3* | *0* | *0* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* |
| *D4* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *8* |
| *D5* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *8* |
| *D6* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *8* |
| *D7* | *0* | *0* | *1* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *4* |
| *D8* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *3* |
| *D9* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *3* |
| *D10* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *1* | *1* | *1* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *3* |
| *D11* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* | *12* |
| *D12* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *17* |
| *D13* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *0* | *12* |
| *D14* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *0* | *1* | *0* | *0* | *1* | *0* | *10* |
| *D15* | *1* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *17* |
| *D16* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *0* | *1* | *0* | *1* | *1* | *0* | *12* |
| *D17* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *0* | *0* | *1* | *1* | *0* | *0* | *1* | *0* | *10* |
| *D18* | *0* | *0* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *1* | *0* | *1* | *1* | *0* | *0* | *1* | *1* | *13* |
| *Dependence Power* | *4* | *1* | *15* | *13* | *13* | *13* | *14* | *17* | *16* | *16* | *8* | *4* | *8* | *10* | *4* | *5* | *10* | *5* | *176* |

### *4.4.4 Level Partitions*

From the final reachability matrix, the reachability and antecedent set for each driver 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 drivers. The drivers for which the reachability and the intersection sets are the same occupy the top level in the 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. These levels help in building the diagraph and the final model

In Table 10 for driver [D3] and [D8, D9, D10] reachibility set and intersection set are same. Therefore driver D3, D8, D9 and D10 will occupy the top level i.e. level I. After this driver 3,8,9 and 10 is eliminated from the rest of the table. And the process is again repeated to find out the same drivers in the reachability and intersection set to get the next level. From Table 10 to Table 17 shows how these level are achieved to build the model.

### *4.4.5 Conical Matrix*

Conical matrix is developed by clustering drivers 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 the columns. Next, drive power and dependence power ranks are calculated by giving highest ranks to the drivers that have the maximum number of ones in the rows and columns, respectively. The conical matrix helps in the generation of the digraph and later on structural model. Table: 16 shows the conical matrix

**Table 10: Level - I Iteration**

| *Iteration 1* | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D1* | *1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| *D2* | *1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18* | *2* | *2* | |
| *D3* | *3* | *1,2,3,4,5,6,11,12,13,14,15,16,17,18* | *3* | *I* |
| *D4* | *3,4,5,6,7,8,9,10,* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D5* | *3,4,5,6,7,8,9,10* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D6* | *3,4,5,6,7,8,9,10* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D7* | *7,8,9* | *1,2,4,5,6,7,11,12,13,14,15,16,17,18* | *7* | |
| *D8* | *8,9,10* | *1,2,4,6,7,8,9,10,11,12,13,14,15,16,17,18* | *8,9,10* | *I* |
| *D9* | *8,9,10* | *1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18* | *8,9,10* | *I* |
| *D10* | *8,9,10* | *1,2,4,5,6,8,9,10,11,12,13,14,15,16,17,18* | *8,9,10* | *I* |
| *D11* | *3,4,5,6,7,8,9,10,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| *D12* | *1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18* | *1,2,12,15* | *12,15* | |
| *D13* | *3,4,5,6,7,8,9,10,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| *D14* | *3,4,5,6,7,8,9,10,14,17* | *1,2,11,12,13,14,15,16,17,18* | *14,17* | |
| *D15* | *1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| *D16* | *3,4,5,6,7,8,9,10,11,14,16,17* | *1,2,12,15,16* | *16* | |
| *D17* | *3,4,5,6,7,8,9,10,14,17* | *1,2,11,12,13,14,15,16,17,18,* | *14,17* | |
| *D18* | *3,4,5,6,7,8,9,10,11,13,14,17,18* | *1,2,12,15,18* | *18* | |

**Table 11: Level - II Iteration**

| *Iteration 2* | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D1* | *1,4,5,6,7,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| *D2* | *1,2,4,5,6,7,11,12,13,14,15,16,17,18* | *2* | *2* | |
| *D4* | *4,5,6,7* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D5* | *4,5,6,7* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D6* | *4,5,6,7* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | |
| *D7* | *7* | *1,2,4,5,6,7,11,12,13,14,15,16,17,18* | *7* | *II* |
| *D11* | *4,5,6,7,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| *D12* | *1,4,5,6,7,11,12,13,14,15,16,17,18* | *1,2,12,15* | *12,15* | |
| *D13* | *4,5,6,7,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| *D14* | *4,5,6,7,14,17* | *1,2,11,12,13,14,15,16,17,18* | *14,17* | |
| *D15* | *1,4,5,6,7,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| *D16* | *4,5,6,7,11,14,16,17* | *1,2,12,15,16* | *16* | |
| *D17* | *4,5,6,7,14,17* | *1,2,11,12,13,14,15,16,17,18,* | *14,17* | |
| *D18* | *4,5,6,7,11,13,14,17,18* | *1,2,12,15,18* | *18* | |

**Table 12: Level - III Iteration**

| *Iteration 3* | | | | |
|---|---|---|---|---|
| **Drivers** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| D1 | *1,4,5,6,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| D2 | *1,2,4,5,6,7,11,12,13,14,15,16,17,18* | *2* | *2* | |
| D4 | *4,5,6* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | *III* |
| D5 | *4,5,6* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | *III* |
| D6 | *4,5,6* | *1,2,4,5,6,11,12,13,14,15,16,17,18* | *4,5,6* | *III* |
| D11 | *4,5,6,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| D12 | *1,4,5,6,11,12,13,14,15,16,17,18* | *1,2,12,15* | *12,15* | |
| D13 | *4,5,6,11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| D14 | *4,5,6,14,17* | *1,2,11,12,13,14,15,16,17,18* | *14,17* | |
| D15 | *1,4,5,6,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| D16 | *4,5,6,11,14,16,17* | *1,2,12,15,16* | *16* | |
| D17 | *4,5,6,14,17* | *1,2,11,12,13,14,15,16,17,18,* | *14,17* | |
| D18 | *4,5,6,11,13,14,17,18* | *1,2,12,15,18* | *18* | |

**Table 13: Level - IV Iteration**

| *Iteration 4* | | | | |
|---|---|---|---|---|
| **Drivers** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| D1 | *1,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| D2 | *1,2,7,11,12,13,14,15,16,17,18* | *2* | *2* | |
| D11 | *11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| D12 | *1,11,12,13,14,15,16,17,18* | *1,2,12,15* | *12,15* | |
| D13 | *11,13,14,17* | *1,2,11,12,13,15,16,18* | *11,13* | |
| D14 | *14,17* | *1,2,11,12,13,14,15,16,17,18* | *14,17* | *IV* |
| D15 | *1,11,12,13,14,15,16,17,18* | *1,2,12,15* | *1,12,15* | |
| D16 | *11,14,16,17* | *1,2,12,15,16* | *16* | |
| D17 | *14,17* | *1,2,11,12,13,14,15,16,17,18,* | *14,17* | *IV* |
| D18 | *11,13,14,17,18* | *1,2,12,15,18* | *18* | |

**Table 14: Level - V Iteration**

| *Iteration 5* | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D1* | *1,11,12,13,15,16,18* | *1,2,12,15* | *1,12,15* | |
| *D2* | *1,2,7,11,12,13,15,16,18* | *2* | *2* | |
| *D11* | *11,13* | *1,2,11,12,13,15,16,18* | *11,13* | *V* |
| *D12* | *1,11,12,13,15,16,18* | *1,2,12,15* | *12,15* | |
| *D13* | *11,13* | *1,2,11,12,13,15,16,18* | *11,13* | *V* |
| *D15* | *1,11,12,13,15,16,18* | *1,2,12,15* | *1,12,15* | |
| *D16* | *11,16* | *1,2,12,15,16* | *16* | |
| *D18* | *11,13,18* | *1,2,12,15,18* | *18* | |

**Table 15: Level - VI Iteration**

| *Iteration 6* | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D1* | *1,12,15,16,18* | *1,2,12,15* | *1,12,15* | |
| *D2* | *1,2,7,12,15,16,18* | *2* | *2* | |
| *D12* | *1,12,15,16,18* | *1,2,12,15* | *12,15* | |
| *D15* | *1,12,15,16,18* | *1,2,12,15* | *1,12,15* | |
| *D16* | *16* | *1,2,12,15,16* | *16* | *VI* |
| *D18* | *18* | *1,2,12,15,18* | *18* | *VI* |

**Table 16: Level - VII Iteration**

| *Iteration 7* | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D1* | *1,12,15* | *1,2,12,15* | *1,12,15* | *VII* |
| *D2* | *1,2,12,15* | *2* | *2* | |
| *D12* | *1,12,15* | *1,2,12,15* | *1,12,15* | *VII* |
| *D15* | *1,12,15* | *1,2,12,15* | *1,12,15* | *VII* |

**Table 17: Level - VIII Iteration**

| Iteration 8 | | | | |
|---|---|---|---|---|
| ***Drivers*** | ***Reachability Set*** | ***Antecedent Set*** | ***Intersection Set*** | ***Level*** |
| *D2* | *2* | *2* | *2* | *VIII* |

**Table 18: Drivers at various iteration levels**

| ***LEVELS*** | ***Drivers*** | | | |
|---|---|---|---|---|
| ***I*** | *3* | *8* | *9* | *10* |
| ***II*** | *7* | | | |
| ***III*** | *4* | *5* | *6* | |
| ***IV*** | *14* | *17* | | |
| ***V*** | *11* | *13* | | |
| ***VI*** | *16* | *18* | | |
| ***VII*** | *1* | *12* | *15* | |
| ***VIII*** | *2* | | | |

### *4.4.6Digraph*

From the conical form of reachability matrix, the preliminary digraph including transitive links is obtained. It is generated by nodes and lines of edges. After removing the indirect links, a final digraph is developed. A digraph is used to represent the elements and their interdependencies in terms of nodes and edges or in other words digraph is the visual representation of the elements and their interdependence. In this development, the top level factor is positioned at the top of the digraph and second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. As presented in Table 19.

**Table 19: Conical matrix**

| Drivers | 8 | 9 | 10 | 3 | 7 | 4 | 5 | 6 | 14 | 17 | 11 | 13 | 16 | 18 | 1 | 12 | 15 | 2 | Driving Power |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| D8 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| D9 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| D7 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| D10 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| D4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| D5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| D6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| D14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| D17 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| D11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| D13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| D16 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 12 |
| D18 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 13 |
| D1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 17 |
| D12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 17 |
| D15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 17 |
| D2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 18 |
| Dependence Power | 17 | 16 | 16 | 15 | 14 | 13 | 13 | 13 | 10 | 10 | 8 | 8 | 5 | 5 | 4 | 4 | 4 | 1 | 176 |

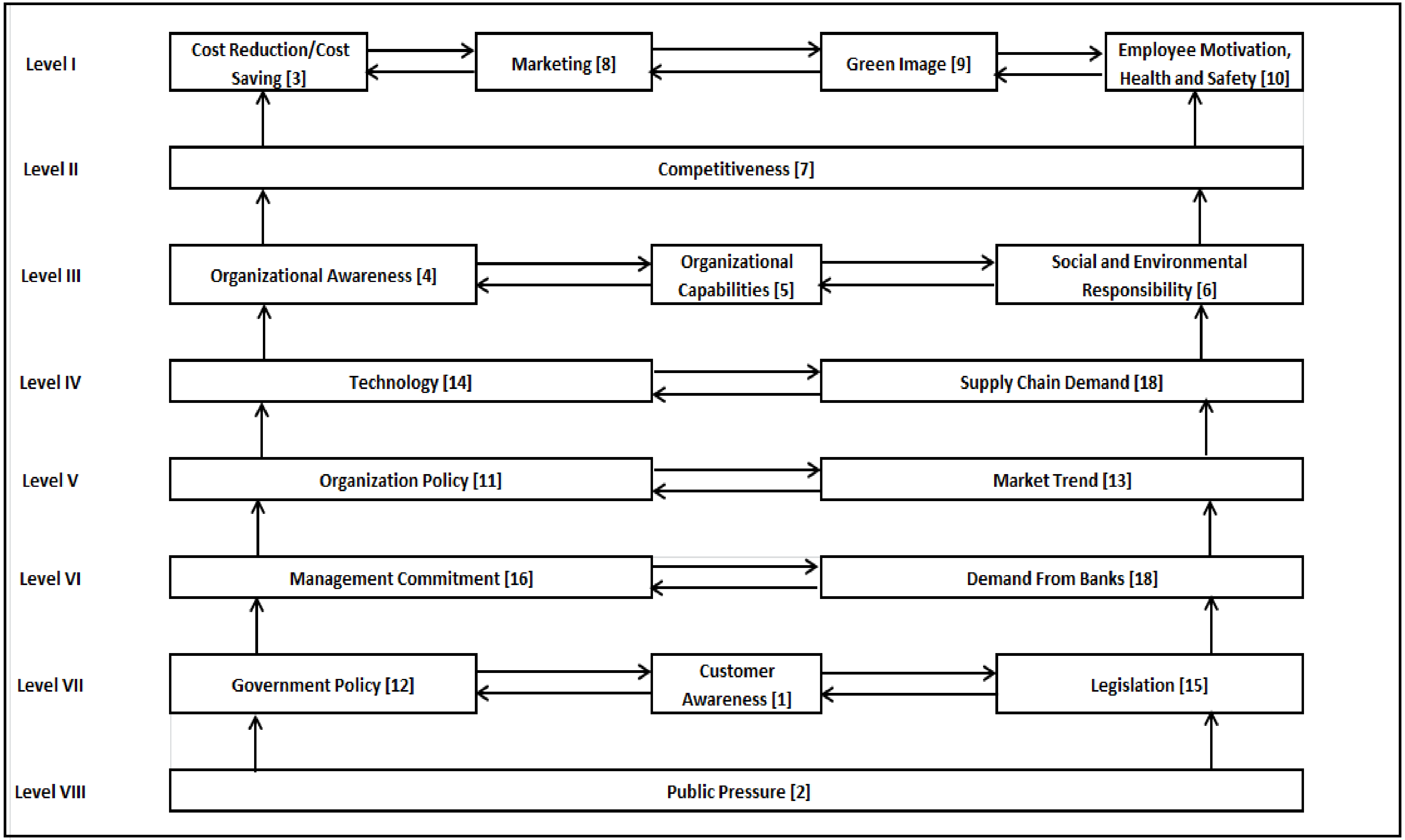


**Figure 7: ISM Model**

## 4.5MICMAC Analysis

The MICMAC principle, also called as cross-impact matrix multiplication applied to classification, is based on multiplication properties of matrices. The purpose of MICMAC analysis is to analyze the driver power and dependence power.

The Driving power and Dependence power for each driver is shown in Table 20which derived from the reachability matrix by summation of rows to find out driving power and summation of column to find out dependence power.

**Table 20: Drivers with driving power and dependence power**

| ***Di*** | ***Drivers Name*** | ***Dependence Power*** | ***Driving Power*** |
|---|---|---|---|
| *D1* | *Customer Awareness* | *4* | *17* |
| *D2* | *Public Pressure* | *1* | *18* |
| *D3* | *Cost Reduction/Cost Saving* | *15* | *1* |
| *D4* | *Organizational Awareness* | *13* | *8* |
| *D5* | *Organizational Capabilities* | *13* | *8* |
| *D6* | *Social and Environmental Responsibility* | *13* | *8* |
| *D7* | *Competitiveness* | *14* | *4* |
| *D8* | *Marketing* | *17* | *3* |
| *D9* | *Green Image* | *16* | *3* |
| *D10* | *Employee Motivation, Health and Safety* | *16* | *3* |
| *D11* | *Organization Policy* | *8* | *12* |
| *D12* | *Government Policy* | *4* | *17* |
| *D13* | *Market Trend* | *8* | *12* |
| *D14* | *Technology* | *10* | *10* |
| *D15* | *Legislation* | *4* | *17* |
| *D16* | *Management Commitment* | *5* | *12* |
| *D17* | *Supply Chain Demand* | *10* | *10* |
| *D18* | *Demand From Banks* | *5* | *13* |

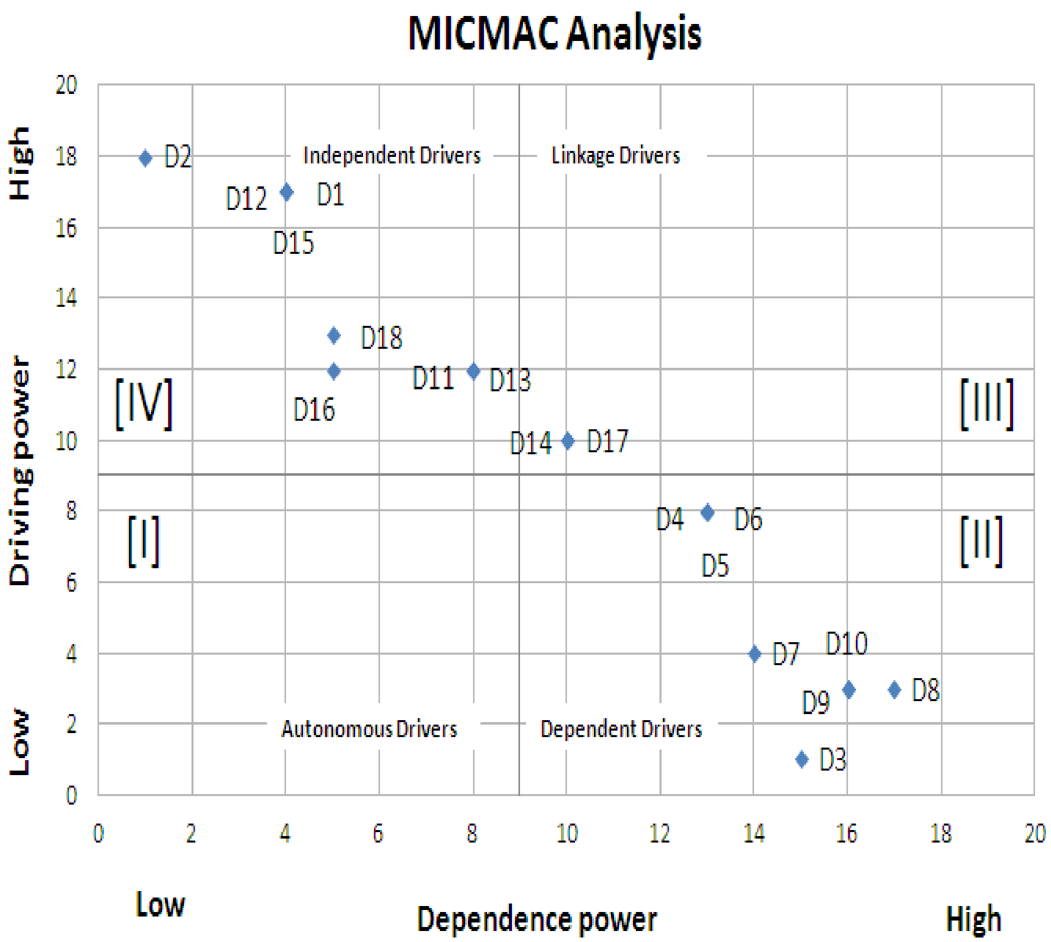


**Figure 8: MICMAC Analysis**

The factors are categorized into four clusters as presented in Figure 8 based on their driving power and dependence power as follows:

- **Autonomous drivers:** In analysis no driver lies in this quadrant. It means that from the identified drivers no one have weak dependence power as well as weak driving power. It shows that all the drivers are relatively connected to each other. The autonomous drivers are shown in quadrant I.
- **Dependent drivers:** In this category includeOrganizational Awareness, Organizational Capabilities, Competitiveness Marketing, Green Image Employee Motivation, Health and Safety, Social and Environmental Responsibility and Cost Reduction/Cost Saving lie.All these above mentioned drivers placed in quadrant II have weak driving power but strong dependence power.

- **Linkage drivers:** In identified drivers Technology and Supply Chain Demand have strong driving power as well as strong dependence and are placed in quadrant III. They are also unstable and so any action on them will have an effect on others and also a feedback effect on themselves.
- **Independent drivers:** Drivers Customer Awareness, Public Pressure, Organization Policy, Government Policy, Market Trend, Legislation, Management Commitment and Demand from Banks have Strong Driving power and weak dependence power. All these drivers are placed in quadrant IV.

# CHAPTER -5

## CONCLUSION

The level of drivers which is proposed in model is very important to understand the implementation of ECM in textile industry in India. Model shows that the Public pressure is in the bottom of the hierarchy of the ISM based model. So, it can play a critical role in implication of ECM in textile industries because it has the maximum driving power and it can drive other drivers Government policy, Customer awareness and Legislation also to implement the ECM in textile industries. Government policy can motivate industries to adopt ECM and it can also create awareness in the customers about eco friendly products. Government policies provide better understanding to the management in industry to develop and prioritize their business strategies to facilitate smooth implementation of ECM.Legislation can control industries for acting in non eco friendly practices as well as push them to implement ECM in textile industries. All above mentioned drivers have much more driving power than other drivers. These are the most important drivers to be considered.

As per the hierarchy Management commitment and Demand from banks are driven by customer awareness and government policy. In India as we know that the financial condition of many textile industries is not so good at that time banks can play leading role to motivate industries to adopt ECM and government policies can easily influence industries to implement ECM. If management is in favour of eco friendly practices than organisation policies can be made environmental conscious practices. Management commitment and their organisation polices can change market trend to use environment friendly products. Organisation policy can push organisation to use green technologies (ECM) and if eco friendly product is in trend it will also lead entire supply chain to demand eco friendly products. Technology and supply chain demand can create awareness in organisation it will also increase the capabilities of organisation and increase the social and environmental responsibility of the industries. Increased organisation capabilities and their awareness will give more competitive advantage to the ECM adopted industries. Cost reduction/saving, marketing, green image and employee motivation, health and safety are in the top most position of the hierarchy and mostly dependent on their drivers but forces textile industry to adopt

ECM.. In addition, the interrelationship among drivers and their driver-driven relationship is expected to provide the managers/executives the better understanding of the complex relations to develop effective implementation plan.

MICMAC analysis present that drivers Customer Awareness, Public Pressure, Organization Policy, Government Policy, Market Trend, Legislation, Management Commitment and Demand from Banks have strong driving power and weak dependence power. They are the independent drivers and have the more driving power than the other drivers. So, these drivers become more critical for the implementation of the ECM in textile industry. These drivers should be considered more for the implementation of ECM. It is found that Technology and Supply chain demand are the linkage drivers. They are unstable drivers and any change in these drivers will lead any change in other drivers as well as in themselves. These changes can be positive and can be negative for the adoption for the ECM in the textile industries.

Dependent category include Organizational Awareness, Organizational Capabilities, Competitiveness, Marketing, Green Image ,Employee Motivation, Health and Safety, Social and Environmental Responsibility and Cost Reduction/Cost Saving these drivers have very less driving power and mostly dependent on other drivers. But due to this there importance should not be decreased because they can play a crucial role in adoption of ECM.

# CHAPTER-6

## LIMITATION AND FUTURE SCOPE

Finally, it is interesting to examine the scope of future research. In this research, through ISM, a relationship model among enablers has been developed. This model has been developed on the basis of input from experts, as suggested in the ISM technique.

However, this model has not been statistically validated. Structural equation modeling (SEM), also commonly known as the linear structural relationship approach, has the capability of testing the validity of such a hypothetical model. Therefore, testing the validity of this model may be a topic for future research. It is to be noted here that although SEM has the capability of statistically testing an already developed theoretical model, it cannot develop an initial model for testing.

On the other hand, ISM has the capability to develop an initial model through managerial techniques such as brainstorming etc. Normally, management may not have enough time to conduct a survey, and therefore the scope for a statistically validated model is limited. ISM is a supportive analytic tool for this situation. However, it may be that, due to the complementary nature of these techniques, future research may be directed first towards developing an initial model using ISM, and then validating it using SEM.

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# APPENDIX

## Survey for Drivers in Environmentally Conscious Manufacturing (ECM)

### Introduction

The objective of this study is to identify the factors which drive the adoption of Environmentally Conscious Manufacturing (ECM) or Green Manufacturing (GM) technologies/practices of textile industry in India. There are some drivers given, you have to tell how much they can influence your decision in adoption or implementation of ECM practices/technologies in your organization. Please rate the following drivers which drive your company to implement Environmentally Conscious Manufacturing on a scale from 1 to 5: 1 – not at all influential 2 – slightly influential 3 – somewhat influential 4 – very influential 5 – extremely influential

### DRIVERS

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Customer Awareness | ○ | ○ | ○ | ○ | ○ |
| Public Pressure | ○ | ○ | ○ | ○ | ○ |
| Cost Reduction/Cost Saving | ○ | ○ | ○ | ○ | ○ |
| Organizational Awareness | ○ | ○ | ○ | ○ | ○ |
| Organizational Capabilities | ○ | ○ | ○ | ○ | ○ |
| Social and Environmental Responsibility | ○ | ○ | ○ | ○ | ○ |
| Competitiveness | ○ | ○ | ○ | ○ | ○ |
| Marketing | ○ | ○ | ○ | ○ | ○ |
| Green Image | ○ | ○ | ○ | ○ | ○ |
| Employee Motivation, Health and Safety | ○ | ○ | ○ | ○ | ○ |
| Organization Policy | ○ | ○ | ○ | ○ | ○ |
| Government Policy | ○ | ○ | ○ | ○ | ○ |
| Market Trend | ○ | ○ | ○ | ○ | ○ |
| Technology | ○ | ○ | ○ | ○ | ○ |
| Legislation | ○ | ○ | ○ | ○ | ○ |

| | | | | | |
|---|---|---|---|---|---|
| Management Commitment | | | | | |
| Supply Chain Demand | | | | | |
| Demand From Banks | | | | | |

## General Information

All the personal details will be held CONFIDENTIAL

**Name of Respondent (optional)**

**Name of Organization**

**Respondent's Designation**

**Experience in industry**