"MODELLING THE CRITICAL SUCCESS FACTORS FOR EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT: AN ISM BASED MODEL"

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SUBMITTED BY

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I, HARSHIT VISHVAKARMA, 2K16/PIE/07 student of M.Tech, PRODUCTION ENGINEERING hereby declare that the project Dissertation titled "**MODELLING THE CRITICAL SUCCESS FACTORS FOR THE EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT: AN ISM BASED MODEL"**, which is submitted to the **Department of MECHANICAL ENGINEERING**, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "**MODELLING THE CRITICAL SUCCESS FACTORS FOR THE EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT: AN ISM BASED MODEL**" which is submitted by **Mr. HARSHIT VISHVAKARMA**, **2K16/PIE/07, Mechanical Engineering,** Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this university or elsewhere.

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ABSTRACT

The tremendous growth in the field of information and communication technology, combined with rapidly increasing obsolescence of products because of the unexpectedly changing choices of the consumers has brought in a new kind of waste – electronic waste or e-waste. E-waste is a global issue which possesses threats to environment and health. E-waste in itself is not a problem, problem comes with its disposal. E-waste contains many hazardous but also valuable and scarce materials. The E-waste management has come to be a necessary affair for almost every country and increasing concern for the environment regulation and social responsibility. E-waste management is a matter of strategic importance, which is affected by a number of factors, for example proficient infrastructure, real-time aid, proper governance, awareness among the consumers, and many more different facets. In this study we aim to identify the factors which are critical for the successful implementation of e-waste management in India. An Interpretive Structural Modelling (ISM) approach has been employed to understand the logical relationship among the eleven critical success factors identified, and subsequently to formulate a hierarchal structured model. The ISM model indicates that the awareness about recycling e-waste among the general public and befitting rules & regulations labeled under e-waste management are the most influencing critical success factors.

Keywords: e-waste, Interpretive structural modelling (ISM), e-waste management, SSIM

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ABBREVIATIONS

ABBREVIATION	DESCRIPTION
WEEE	Waste electrical & electronic equipment
ICT	Information & communication technology
PCB	Printed circuit boards
CRT	Cathode ray tubes
OECD	Organization for economic cooperation & development
StEP	Solving the e-waste problem
EPR	Extended producer's responsibility

CHAPTER 1
INTRODUCTION

1.1 RESEARCH MOTIVATION

The developing need to facilitate our life and the journey to advancement has definitely prompted an enormous increase in the utilization of electrical and electronic equipment (Vats and Singh, 2014). This expansion as an outcome of quick economic development, ultimately results in the production of huge amount of what is known as E-waste or Electronic waste. E-waste is growing immensely due to the towering growth in the discipline of information and communication technology and increasing obsolescence of products due to unexpectedly changing choices of the consumers. E-waste in itself is not a problem, problem comes with its disposal. This ever-rising waste possesses very complicated traits and requires an equivalently complicated bunch of effective innovations in technology and procedures to tackle with it (Srivastava and Sharma, 2015). The management of E-waste has come to be a necessary affair for almost every country and it has been raising concern for the environment regulation and social responsibility. Managing e-waste is a matter of strategic importance, which is affected by a number of sources, for example, proficient infrastructure, actual-time aid, proper governance, awareness among the consumers, and many more different facets. The restoration of substances from electronic waste and dumping of the remaining waste depends on the e-waste strategies and approach structure. Electronic waste flood and the existence of endless unsafe substances inside it, for example, mercury, lead, cadmium, polybrominated diphenyl esters etc, have made the administration of e-waste a noteworthy worry for professionals and researchers (Kumar and Dixit, 2018).

Thus, it is now basic for individual organizations to sufficiently receive fitting projects and methodologies for effective management of e-waste with the goal that the negative effect of electronic waste on the ecological system can be decreased. This study, aims at finding the factors that are critical to achievement of effective e-waste management and building up an inter-connection among those critical success factors. Less research has been done on the critical success factors of effective implementation of e-waste management. Assessing the critical success factors and their inter-relationship for the powerful e-waste management is intricate and challenging. The presence of different criterion and the expert's interpretation of the factors offers intricacy in the assessment of the critical success factors. The present study means to evaluate the critical success factors for the advancement of an effective and sustainable e-waste management culture with the help of systematic approach that is defined through the inter-relationship between them.

1.2 WHAT IS E-WASTE?

In basic terms those electrical or electronic hardware which are disposed of and are never again being used are called as E-waste. E-waste is generally called as Waste from Electrical and Electronic Equipment (WEEE), comprises of electronic gadgets, Personal computers, mobile phones, video and audio appliances and versatile electronic gadgets to name a very few. E-waste additionally incorporates peripherals, assembly and sub-assembly parts and segments that have been discarded or disposed of by their clients for some reasons. Furthermore, the worry arises because of the huge changes brought by the modern technological innovations in the manner we arrange our lives, financial systems, enterprises and establishments (Awasthi et al. 2015). These advancements have become the part of the day to day life and have redesigned the nature of living. The information & communication technology department is adding to the worldwide economy to a great extent. In the meantime, it is generating main parts of e-waste. In developing nations like India the electronic waste has turned into an enormous issue which happens to be either produced within the boundaries of our country or imported from international markets, which makes real and genuine dangers to human beings and the surroundings (Kumar and Dixit, 2018).

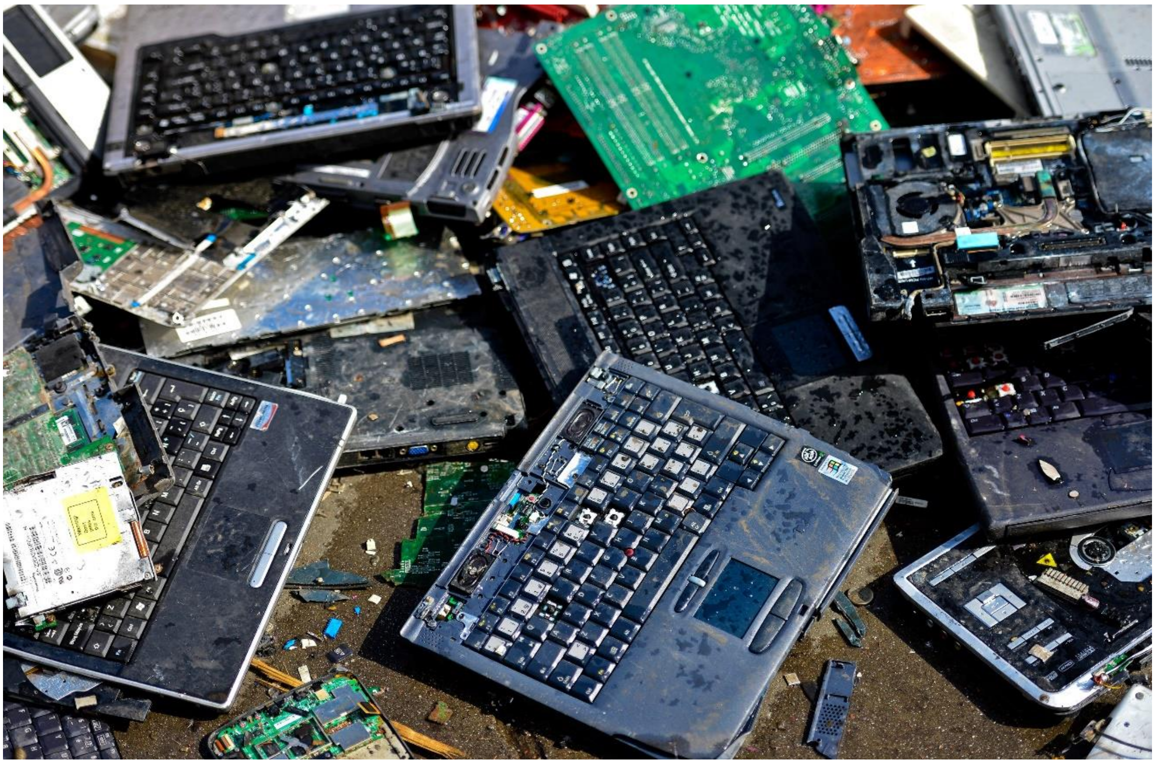

Fig 1.1 E-waste from PCs

The matter of more prominent distress is that there is no standard meaning of e-waste. The definition and use of the expression "e-waste" has been distinctive for various nations. The generally acknowledged definition and portrayal of e-waste is according to the order by Union of Europe (Verma and Agrawal, 2014). The order 2002/96/EC of the Parliament of Europe on e-waste extends to every single one of the electrical and electronic gear utilized by customer. The definition as per the order is "E-waste or Electronic waste refer to electronic items that are considered as useless or scrap with in the statements of Article 1(a) of Directive 75/442/ EEC, together with each and every element, assemblies and their sub parts and valuables which are a piece of the electronic item at the time of dumping" (Gaidajis et al. 2010). In accordance to Basel action network the electronic waste is stated as "Waste that incorporates an extensive and emerging range of electronic instruments ranging from large household instruments, such as fridges, air-conditioners, phones, stereo systems and consumable electronic items abandoned by the customers (Verma and Agrawal, 2014).

Table 1.1 Overview of selected definitions of e-waste (Widmer R. et al., 2005)

References	**Definition**
EU WEEE Directive (EU, 2002a)	"E-waste or Electronic waste refer to electronic items that are considered as useless or scrap with in the statements of Article 1(a) of Directive 75/442/ EEC, together with each and every element, assemblies and their sub parts and valuables which are a piece of the electronic item at the time of dumping".
Basel Action Network (Puckett and Smith, 2002)	"Electronic waste encompasses all electronic devices or items from the simple household use to larger market use and which are being consequently discarded."
OECD (2001)	"Any power-supplied appliance which has achieved the after limit of its maximum usage"
SINHA (2004)	"An electrically controlled instrument that no more fulfills its fundamental purpose for current consumer".
StEP (2014)	"E-Waste is an expression utilized to cover things of a wide range of electrical and electronic items and their assemblies that have been disposed of by the consumer as scrap without the aim of reusing it".

1.3 E-WASTE IN INDIA

1.3.1 E-waste generation in India

India is among those few countries which are said to be quickly rising economies on the planet. A yearly development of 25 percent can be observed in India's electronic waste production. A calculation conducted by Manufacturers Association of Information Technology (MAIT) states that India creates just about 4 lac tons of electronic waste yearly. Among the nation's aggregate electronic waste, merely 5% is reused and recycled whereas around 40% of electronic waste rot in houses and stockrooms as abandoned electronic items. (Vats and Singh, 2014). Because of speedier rate of new innovations in technology, new and improved electronic items are getting introduced in the market and due to this e-waste is piling up at a rapid rate in India's market. The significance of managing electronic waste in India is more prominent not just because of its intrinsic e-waste generation but also because of the imports coming from the developed nations. Because of the absence of any appropriate dumping system in our nation, a huge measure of electronic waste has been produced in most recent sixty years. And it leads to the prerequisite of an appropriate dumping and recycling framework with the goal that the ecological contamination is to be diminished (Chatterjee S, 2009).

Table 1.2 Top e-waste generating cities of India

City	E-waste (Metric Tonnes/Year)
Mumbai	120000
Delhi-NCR	98000
Bengaluru	92000
Chennai	67000
Kolkata	55000
Ahemdabad	36000

As indicated by UNEP report, by 2020, electronic waste arising out of PCs will develop likely to 500 percent in relation to what was presented in 2007 in India. Because of development in cell phone division in India, electronic waste arising out of disposed telephones would develop likely to 18 times in relation to the status in 2007 (Ramkrishna & Saha, 2015).

1.3.2 E-waste composition

E-waste comprises of entire waste coming out of electrically powered machines, that have achieved their limit of maximum use and will never again be used as per their functional requirement and are bound for recuperation or final dumping. It incorporates PCs and its supplements like screens, printing device, consoles, CPU, typewriters, cell phones and charging device, remote control, earphones, Plasma TVs, cooling systems, fridge and various household instruments. The composition of electronic waste is distinctive in nature and falls under 'hazardous' and 'non-hazardous' classes. Extensively, it comprises of ferrous and non-ferrous metals, plastics, glass, wood and pressed wood, PCB, concrete, ceramics, elastic rubber and various different objects. Iron & steel constitute around half of the squander, trailed by plastics (21%), non-ferrous metals (13%) and different various components. Non-ferrous metals comprise of metals like copper, aluminum and valuable metals like silver, gold, platinum, palladium and so on. The existence of components like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants past threshold amounts make electronic waste unsafe in nature. It holds more than thousand distinct matter & materials, a large number of which are lethal, and makes genuine contamination upon disposal (Sabha R, 2011; Verma and Agrawal, 2015).

Fig 1.2 Cameras, calculators, remote control devices compiled as e-waste

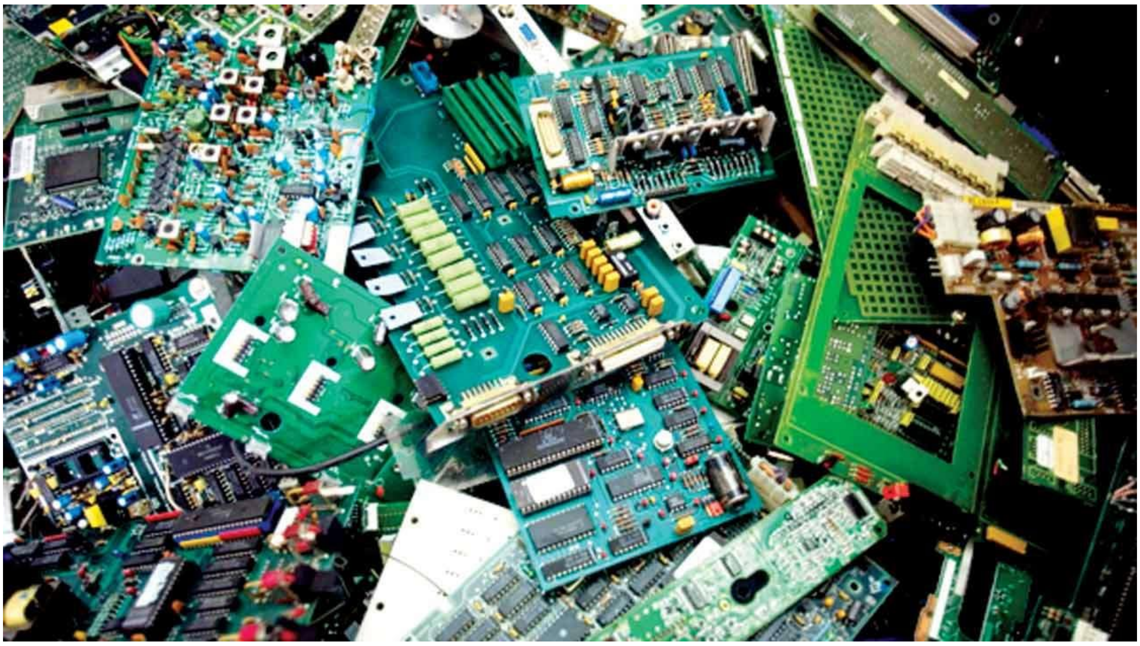

Fig 1.3 Printed circuit boards (PCBs)

1.3.3 E-waste Hazards

E-waste at a dumping site which is nothing but a landfill produces infected leachates which in the end contaminate the ground water. Acids and sludge acquired from dissolving PC chips, when abandoned on the ground causes acidification of soil. For instance, Guiyu (Hong Kong) a flourishing zone of unlawful e-waste recycling is confronting intense water deficiencies because the water resources present there have been severely contaminated due to the leachates coming from landfills. Burning of e-waste can emit poisonous vapor and gases which contaminates the encompassing air. Inappropriately managed landfills can cause environmental risks. Mercury will drain when certain electronic gadgets, for example circuit breakers are obliterated. The same is valid for polychlorinated diphenyls. Not exclusively does the draining of mercury poses particular issues, the vapourization of metallic mercury is of same concern (Ramkrishna & Saha, 2015). What's more, uncontrolled flames may emerge at landfills, and at the point when presented to flame, metals and other synthetic substances to a great degree discharges dangerous dioxins from halogenated flame retardants items. The most hazardous type of burning e-waste is the outdoor burning of plastics with a specific end goal to recover copper and different metals. The poisonous air from outdoor burning influences both the local environment and more extensive worldwide air streams (Ramachandra and Varghese, 2013).

Fig 1.4 E-waste dumping site

Table 1.3 Hazardous effects of e-waste components and their sources

Components	Sources of E-waste	Hazards/Health effects
1. Mercury	PCBs, relays and switches	Influences the Central nervous system, kidneys. It hinders embryo development. Harms liver.
2. Lead	PCBs, glass panels, gaskets in computer screens	Influence kidneys, reproductive system, Induces blood and cerebrum issue, at times might be lethal.
3. Cadmium	Semiconductors	Induces joints pain, weakening of bones

4. Hexavalent Chromium	Corrosion protection of untreated and galvanized steel plates, hardener for steel housings	Lung cancer, ulceration, kidney and liver damage, eye irritation and damage
5. PVC	Cabling and computer housing	Affects respiratory system by producing HCl through chlorine present in it.
6. Brominated flame retardants	Plastic housing of electronic items and PCBs	Induces hormonal disorder
7. Barium	CRTs	Affects heart muscle which in turn makes improper contraction and relaxation
8. Beryllium	Motherboard	Induces lung sickness
9. Dioxin	Plastics, PCBs, halogenated flame retardants	Leads to foetus malfunction, decreased reproduction and immunity.

1.4 E-WASTE MANAGEMENT

In quite simple terms "E-waste management" means to manage the waste electrical and electronic items or to administer and organize e-waste such that its disposal can be done in an environment friendly manner. Through an evaluation made, it is found that 75% of electronically powered items are thrown away because of vulnerability they possess in ways of managing them. The above mentioned electronic scraps lie neglected and abandoned at homes, workstations, storehouses and ordinarily blended with household wastes which is at last dumped at landfills. This requires management measures that can be put into effect (Awasthi et al. 2016)

There is not any remarkable or perfect model for managing electronic waste in developing nations because every country has its intrinsic particular ecological, societal, technical, financial and social circumstances and surroundings. Managing electrical & electronic gadgets in an environmentally friendly manner perceives the use of 3 R(s) i.e. Reduce, Reuse and Recycle. The intent needs to be reducing the production of electronic waste by means of assembling, processing and maintenance, reusing the electronic gear by another person till it is working properly and recycling those parts which can't be restored (Sivakumaran et al. 2015).

The principle aspects to be considered for management of e-waste for emerging nations are:

- Administering the recycling sector by promoting the formal sector and providing training for the informal sector. In 2009, classified formal recyclers established the e-waste recycler's association, however they are confronting tensed rivalry from the informal division, they have been able to cover 10% of the aggregate proportion of the e-waste market. An issue that the formal division is facing is the absence of legitimate accumulation and transfer systems and proper technological advances (Kumar and Dixit, 2018).

Table 1.4 Differences between Informal and formal recycling

Informal sector	Formal sector
1. CRTs are shattered physically to particular its segments – glass, metal copper. The glass, having lead in it, is traded with bread makers or bangle makers. The CRTs are also sold to non-branded TV producers.	1. Elements of the CRTs are removed by providing heat to it in a confined enclosure, that absorbs away phosphorous from the elements. They are later crumbled in shredder tools. Glass accommodating lead is traded with the agencies manufacturing the CRTs.
2. PCBs have gold laminated brass pins, microchips that are divided by the application of heat. Brass pins that are gold laminated are drowned in acid to retrieve gold and brass independently. Microchips are provided with heat in	2. PCBs are squashed in shedder tools. They are discharged to authorized smelters overseas, where subsequently smelting at 1200 degrees centigrade, the metals present in the PCBs are collected at once. Smelting is

massive vessels loaded with acid to retrieve metallic chunks.	performed in confined containers at elevated temperatures, it is non-perilous in nature.
3. No safety precautions followed.	3. Protective equipment – masks, gloves, shoes etc are provided to workers.
4. Minimal capital investment	4. High initial capital investment for a recycling plant.

- Policies and regulations covering import and export of WEEE according to the guidelines of every nation and with universal enacted laws.
- Designating authorities and responsibilities to prime partners at the level of government, supply chain, purchasers of ICT gear and substances for dumping of e-waste.
- Creating awareness among the people especially users and characterizing their responsibilities all through the discrete phases of the gadget's life cycle.

1.5 CRITICAL SUCCESS FACTORS FOR IMPLEMENTATION OF EFFECTIVE E-WASTE MANAGEMENT

E-waste management is a critical and timely question for the developing country like India that captures expanding worries over its adequacy. Identification of critical success factors (CSFs) responsible for effective and sustainable e -waste management and evaluating their contextual relationships has the potential to affect the process, future strategies and operations.

Different perspectives taken into account for CSFs of e-waste management:

(a) **Raw Material perspective**: For recycling unit to work, adequate measure of raw materials is required. Raw material specified here are the discarded electronic equipment. There are very little collection centers accessible in India. Neither the producer nor the representatives are interested with setting up the collection centers as the value returns are not good (Sivakumaran et al. 2015).

(b) **Operational perspective**: The people who involve in disposing the electronic waste play an important role. Formal sector is highly shadowed by the informal sector. In Informal sector e-waste collection and it's dumping is done by unapproved people. Collection of e-waste is done from the household and market and then separation of the useful and useless part is done by breaking the e-waste in illegitimate way, which is exceptionally unsafe for the environment (Krueger et al. 2011).

(c) **Environmental perspective**: The hazardous materials are contained by e-waste but they also contain valuable and scarce materials. The valuable parts include Gold, Silver, Platinum etc. Even though the quantity of these materials present in the electronic waste is low, the value for that is more. To recycle the resources there are some steps involved in recycling process and each step involves some machinery and machinery means better processing technology for instance smelting furnace.

(d) **legal and policies perspective**: Many rules and regulations have been adopted and implemented by government and international organizations for e-waste management. Such as the "Transboundary movement rules" from Basel convention, EPR from e-waste management rules 2016 (Govt. of India).

1.6 PROBLEM STATEMENT AND OBJECTIVES

The present work "MODELLING THE CRITICAL SUCCESS FACTORS FOR EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT: AN ISM BASED MODEL" includes the identification of the critical success factors for effective e-waste management, and from those identified critical success factors developing an ISM (Interpretive structural modelling) model.

The objective of the present project work includes:

1. Identifying the CSFs of e-waste management.

2. Discovering out the interrelationship among the identified CSFs.

3. Developing a hierarchal model of the CSFs depicting their various levels utilizing the ISM technique.

1.7 ORGANIZATION OF THE THESIS

Thesis has been organized in five different chapters as summarized beneath:

- Chapter 1 covers the Introduction about the e-waste and e-waste management and it includes the sources and hazards of it. It focuses upon the need for effective implementation of e-waste management. The chapter also incorporates the problem statement and research objective.
- Chapter 2 includes the extensive literature review on e-waste and its management and the factors affecting the management. It also includes the literature review on the application of ISM methodology & MICMAC analysis in various different work areas.
- Chapter 3 describes the methodology used in this research work. Research methodology of ISM has been thoroughly stated in this chapter.
- Chapter 4 includes the model formation based on ISM approach. It includes the list of identified critical success factors for the effective implementation of e-waste management. It also incorporates the results & discussion arising out of the model and MICMAC analysis.
- Chapter 5 includes the conclusion and future scope for the work done.

CHAPTER 2

LITERATURE REVIEW

Verma and Agrawal, (2014) discusses the condition of e-waste in India, the problem associated with e-waste, the method used for used for e-waste management and focuses light on the legislation work done regarding e-waste in India. As per the study it has been found that there is an instant need to address the issue related to e-waste in India in order to avoid its ill effect in future**.** Chatterjee S, (2009) founded that recycling of e-waste is carried out in the non-formal sector using primitive and hazardous methods. Adequate legislative measures and cost-effective, environmental friendly, technological solution would be needed to address the issue. Sivakumaran et al. (2015) talked about the issues of e-waste recycling in India. There are several issues connected with recycling of e-waste in India such as legal, social, policy, raw material and so on. The method and procedures involved in the disposal of electronic waste is a complex one. Implementing the 3R concept for disposing electronic waste in India is little more complex. The 3R factors of waste management Reduce, reuse and Recycle are the best and acceptable methods to deal with electronic waste also. Reduce deals with the reduction in the consumption. Reuse deals with the second hand using of the electronic products. The used items are put into reuse. Recycle is the process of collecting and processing materials that would otherwise considered as waste. The best way to reduce the generation of waste is not creating it (Sivakumaran et al. 2015). Kumar A et al. (2018) identified ten barriers based on the literature and the perceptions of experts involved in e-waste management issues. In this paper, author employed an interpretive structural modeling (ISM) and Decision Making Trail and Evaluation Laboratory (DEMATEL) for understanding the hierarchal and contextual relationship structure among the barriers of e-waste management. The study shows that no autonomous barriers are present in the course of study. The result suggests that the lack of public awareness about e-waste recycling and the lack of policies addressing e-waste issues are the root cause barriers as depicted by the novel ISM-DEMATEL based methodology.

Sthiannopkao and Wong, (2013) observed that the developing nations are larger producers of e-waste, and it will become twice than that of the developed nations within the next six to eight years. It has also been evaluated that by the end of 2030, the developed and developing nations will dispose of 200–300 million and 400–700 million obsolete computers, respectively (Sthiannopkao and Wong, 2013). Predictions made through computer modeling state that the developing countries will be more responsible for dumping computer systems rather than the developed countries by 2016 (Wath et al. 2010). Nnorom et al. (2009) explained the initiative of consumers' willingness to pay (WTP) for greener product purchasing and developed a model depicting consumers' awareness and attitude toward environment protection.

Dwivedy and Mittal, (2013) determined that consumer's attitude toward recycling, household income and other economic profits has substantially influenced consumer's willingness to take part in the process of recycling of e-waste in India. Sarkhel et al. (2016) examined the pre and post payment made by consumers for meliorated waste management in Bally Municipality in India. For the appropriate management of the environmental concerns, the establishment of the following setups, that is, installation of adequate infrastructure such as transport facilities, collection centers, recycling plants and disposal of electronic waste both at regional as well as national levels is essential (Cucchiella et al. 2015). Hence, to facilitate the management of e-waste, the regulatory authorities need to provide these services and associate incentives for enhanced performance. The administration needs to encourage the manufacturers and non-governmental organization (NGO) for establishing electronic waste collection centers, exchange programs, and recycling facilities at different levels (i.e., district, state, and national). Therefore, the development of suitable skill and proper training of recycling processes will be required to acquire environmentally sound recycling of e-waste (Wath et al. 2010).

Shagun et al. (2013) proposed the key players in e-waste such as

- Consumers as in (a) Office and (b) Domestic
- Scrap Dealers
- Recyclers

Shagun et al. (2013) also proposed the solution for the same such as

- Impart training to generators on e-waste handling
- Awareness program on recycling
- Fix duties and responsibilities to recyclers

- Tax incentives for scrap dealers
- Reward and reprimand schemes for performance and non-compliance of e-waste management

Srivastava and Sharma, (2015) founded out the factors affecting e-waste management. And out of the ten factors they discovered the factor 'government support' is the most crucial for the e-waste management. In the last two decades, e-waste management has become a complicated issue and needs to be deeply analyzed; hence, several multi criteria decision making (MCDM) models have been developed.

Ramkrishna & Saha, (2015) made an approach towards assessing the present situation of e-waste management globally as well as in India, considering the present regulations and guidelines. It is found that major part of recycling of e-waste is being handled by informal sector who have little/no knowledge about the consequences of exposure to hazardous substances. They addressed the issue of e-waste management in a sustainable method with the concept of EPR (extended producer responsibility), which will be helpful if the regulations incorporate monitoring and penalty clauses. The reuse of EEE has greater environmental and social benefits than recycling as it increases the useful life time of the ICT equipment and enables greater resource efficiency and energy efficiency. In developing nations, it can help in uplifting the status of the informal sector with help of education and employment. In addition to the technical, social and organizational aspects of the EEE-waste management system, it is also crucial to consider the economic aspects, if the system has to be made financially viable and sustainable along with being socially acceptable.

Fitzpatrick et al. (2013) explored the barriers that hamper re-use practices and the factors that help organisations successfully refurbish and redistribute used equipment. The top set of barriers relates to obtaining enough used equipment. Sourcing sufficient quantities of good-quality used equipment is a major concern. Some of the reasons for this include current legislation that does not support reuse organisations by providing adequate financial incentives for and enforcement of e-waste re-use. In addition, re-use options are not being incorporated into collection and recycling initiatives. Furthermore, some equipment manufacturers do not allow their products to be re-used, to avoid competition with new products. Instead, these manufacturers require used equipment to be recycled, even when it could be re-used. The second set of barriers relates to the informal and illegal disposal of e-waste. This creates a negative public perception of re-using e-waste. For example, workers' health and the environment could be harmed when informal collectors send e-waste to developing countries with inadequate health and safety controls. Issues related to regulations, standards and product design are grouped together in the third set of barriers. It can be costly for organisations, particularly those that operate globally, to comply with different standards and regulations, especially as there is no internationally recognised re-use standard. Although not considered a major barrier, many products are not designed with re-use in mind.

Satapathy S, (2017) used the ISM methodology to investigate the interrelationship among the barriers for plastic recycling in the Indian plastic industry. Srivastava and Sharma, (2015) formulated the association among the identified e-waste management variables and even evaluated variables that influence the driving barriers as well as those that are influenced by the dependable variable using ISM to develop mutual association among these variables.

Gaidajis et al. (2010) reviewed the environmental problems related with the discarded electronic appliances, known as e-waste. Moreover he reviewed, the current and the future production of e-waste, the potential environmental problems associated with their disposal and management practices are discussed whereas the existing e-waste management schemes in Greece and other countries (Japan, Switzerland) are also quoted. And they are indicated as, many technological changes have been effectuated, for example:

- The replacement of CRT screens with LCD screens (Pb elimination but Hg introduction),
- The introduction of optical fibres (Cu elimination from the cablings, but F, Pb, Y and Zr introduction),
- The introduction of rechargeable batteries (Ni, Cd reduction, but Li increase), etc.

Non-governmental organizations and citizens movements press for the elimination of hazardous substances in electronic appliances, resulting to manufacturers competing for a more "green" profile. Some indicative results of the above pressures are:

- The production of “halogen-free” appliances, not contributing to the production of PCBs and dioxins (but their pro-duction is more expensive environmentally),
- The replacement of bromide combustion retarders with more environment-friendly ones based on phosphorus, and
- The introduction of legislative restrictions (Pb, Hg, Cr, PBBs and PBDE up to 1000 mg/kg, Directive RoHS (Restriction on Hazardous Substances)

Janse et al. (2010) employed the ISM methodology for evaluating the barriers and for managing the reverse logistics in the electronics industries. Sharma et al. (2011) employed the ISM approach to analyze the barriers that hinder the adoption of reverse logistics and to determine the relationship among them**.** Welfens et al. (2016) analyzed the key enablers and barriers that affect the returning and recycling of mobile phones through the use of the ISM approach. Chandramowli et al. (2011) employed ISM to evaluate the barriers related to the development of landfill communities.

Gupta et al. (2012) provided an Interpretive Structural Modeling based approach to implement and initiate green activities in supply chains. Variables such as supplier and stakeholder commitment, cost benefits, environmental issue, and customer redundancy, etc., had been identified and categorized under enablers.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTERPRETIVE STRUCTURAL MODELLING (ISM) METHODOLOGY

Interpretive Structural Modeling (ISM) is an approach to understand, study and solve a complex problem involving elements or factors which may or may not interact and affect each other. ISM processes ambiguous and difficult to communicate factors of a system into clear and visible structural model. The interrelationship structural model among the different factors address the problem far more accurately than the individual factors. The strategy is interpretive in nature as the expert's perception and knowledge chooses whether and how things are connected (Sage, 1977). Hence, through ISM an insight is formulated into understanding the relationships in a collective manner.

For the first time it was formulated in 1970. This methodology was developed by Warfield in 1970 when he tried to link science with the lay man involved in the problem and served as a guiding tool for policy making (Warfield, 1974). Dealing with complex problems or systems is usually a tedious and difficult job. The difficulty is because of a large number of factors and their interactions among themselves. ISM is methodology to deal with such problems. This approach requires simple knowledge of graph theory, algebra and basic computation. In ISM approach graphical representations of a system structure is developed. In this methodology graphical models in the form of digraphs are constructed in which points represents factors and directed arrow represents the orientation of the relationship among those factors. This the beauty of digraphs that the structural model for the relationships of the factors is expressed rather than just expressing a mere list of factors (Attri et al. 2013).

3.1.1 Characteristics of ISM

- Interpretive: This methodology is interpretive in nature because a group of experts or (and) researchers in relation to that very problem interpret the various factors and the interrelationship among them is decided on the basis of their interpretation.

- Structural: It is structural in nature because an overall structure of the interrelationships of complex set of factors is derived in this methodology.
- Modelling: It has modelling characteristic because the structure in graphically represented in the form of directed graph (digraph).

3.1.2 Steps involved in the ISM methodology

Step 1: Structural Self-Interaction Matrix (SSIM):

First of all, the relevant factors for the system that has been taken in consideration are determined. After determining the factors, the experts who are well conversant and ought to be well familiar with the problem under consideration are to be consulted to define the nature of logical relationship amid factors. For the analysis of the variables, a logical relationship of 'ameliorating' nature must be selected. The aforesaid statement implies that one element would be helping in leading another element. Making this as basis, a logical relationship needs to be established between the identified variables.

Keeping the logical relationship for every factor in mind, two factors at a time are taken and subsequently questioned for the presence of any connection between those two factors and also questioned for related orientation of the connection present between them. Four letters have been utilized so that the orientation of relationship amid the factors (i and j) can be indicated and these are as follows:

V: factor i would be ameliorating factor j;

A: factor j would be ameliorating factor i;

X: factors i & j would be ameliorating each other;

O: factors i & j are not related to each other;

Step 2: Initial Reachability Matrix:

In the following step, the development of reachability matrix has been done through the utilization of the matrix developed in the previous section i.e. SSIM. The initial reachability matrix is constructed out as a result of converting the data of every cell of SSIM into a binary form (i.e. zeros & ones) through the application of few rules that have been discussed below.

- 'V' present at any (i, j) position in SSIM has to be replaced by 1 and the corresponding (j, i) position should be changed to 0.
- 'A' present at any (i, j) position in SSIM has to be replaced by 0 and the corresponding (j, i) position should be changed to 1.
- 'X' present at any (i, j) position in SSIM has to be replaced by 1 and the corresponding (j, i) position should also be changed to 1.
- 'O' present at any (i, j) position in SSIM has to be replaced by 0 and the corresponding (j, i) position should also be changed to 0.

Step 3: Final Reachability matrix

Initial reachability matrix has been created against the structural SSIM and the matrix is checked upon for any transitivity that could be present in the matrix. The logical relation's transitivity is a basic assumption made in ISM which expresses that if A & B are related to each other, B & C are related to each other, then A & C will also be necessarily related to each other.

Following the rules, and subsequently by incorporation of the transitivity the final reachability matrix is developed.

Step 4: Level partitions:

From the final reachability matrix that has been shown in table 4.5, the reachability and the antecedent set for all the factors are determined. The reachability set is a set comprising of the component itself and other different components to which the component might be helpful in accomplishment, while antecedent set is a set comprising of the component itself and other various components which might be helpful in accomplishment of the component. After that, intersection of the two different above mentioned sets is inferred for each and every component. The component for which the reachability set and the intersection set came out to be identical happens to be that component which occupies the topmost level in the ISM hierarchy. The hierarchy's topmost level component would not be helpful in accomplishing some other component above them. Immediately after the component at topmost level is determined, it is segregated out from the other components.

Afterwards by the similar procedure, the following levels for the components are determined.

Step 5: Digraph and ISM model

The above discovered levels of components help in the digraph formation by putting the components at their respective levels and joining the components by the directed arrows and subsequently expelling the transitive links from the digraph. In this formulation, the highest point of the digraph is grabbed by the top-level factor and second position is taken by second level factor and so on, until the point that the base level is set at the lowest position in the digraph.

Digraph is changed over into an ISM model by substituting nodes of the components with statements.

3.2 ADVANTAGES OF ISM APPROACH

Advantages that are offered by ISM are as follows:

- The process is systematic: It is provided with the instructions to consider all conceivable pair wise relations of system components, either straightforwardly from the reactions of the members or by transitivity incorporation.
- Improves the quality of interpersonal and interdisciplinary communication by focusing on one question at a time.
- It helps and records the consequences of group thoughts on complicated issues in a proficient and systematic way.
- It produces an organized model or graphical portrayal of the original circumstances for a problem or issue, which can be communicated to others with much effectiveness.
- It fills in as a learning instrument by compelling members to build up a more profound understanding of the importance and significance of a predefined component list and relations.
- It grants policy analysis by helping members in identifying specific territories for policy action offering preferences or advantages in seeking particular purpose.

3.3 LIMITATIONS OF ISM APPROACH

- There could be a number of factors related to a problem and any further addition in the total number of factors stretches the intricacy of the ISM system. So, predetermined limited number of factors in the formulation of ISM model can only be considered.
- Different factors which are having only a slight influence on an issue or problem may be left alone and not considered in the formulation of ISM model, which means we can have a slight variation in theoretical model and practical implementation.
- One of the major limitations is that it is a theoretical model based on interpretations and is not validated through statistics.

3.4 APPLICATIONS OF ISM APPROACH

- ISM could be utilized where a system demands a good level of flexibility, for example Policy planning for a longer period of time.
- It could as well be used for a much solid purpose which happens to be for a short range of period, for example engineering problems, financial decision making, e-commerce, competitive analysis, strategic planning, process design, human resources.

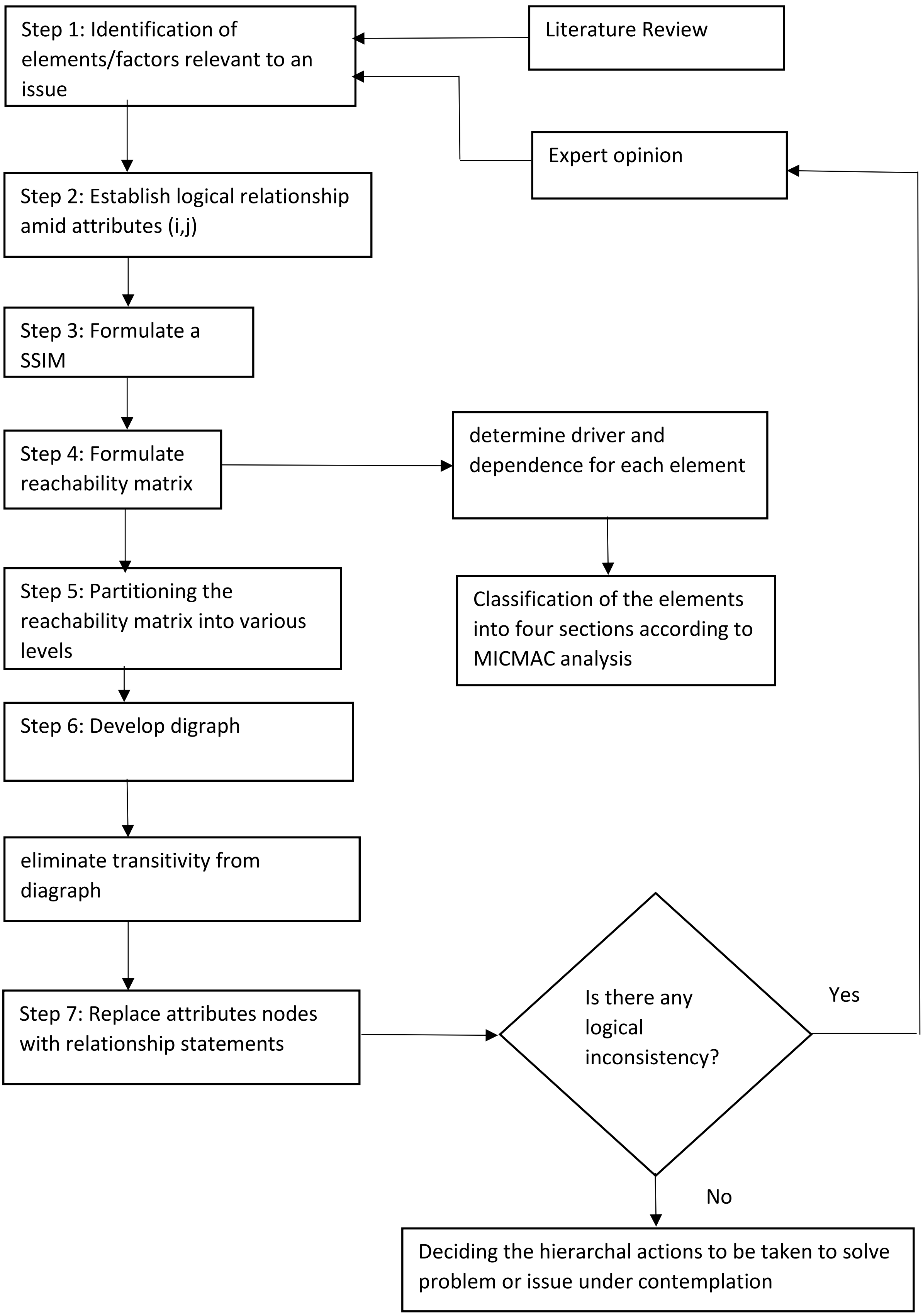

Fig 3.1 ISM flow chart for model formulation

3.5 MICMAC analysis

Matrice d'Impacts croises-multiplication appliqúe an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. Examining the driving power and dependence of elements is the main intent behind the MICMAC analysis. It is carried out to recognize the key factors that drives the framework in different categories. On the basis of the driving power and dependence power of the elements, a classification has been made for the factors to group into four different categories namely autonomous factors, linkage factors, dependent and independent factors.

I. Autonomous factors: The first quadrant comprises of 'autonomous factors', which are said to have feeble driving power and additionally feeble dependence. These elements are said to be comparatively separated from the system or just could be having very few weak connections with the others.

II. Dependent factors: The "dependent factors" comprise the second quadrant which are recognized for having feeble driving power and also for solid dependence power.

III. Linkage factors: Third quadrant comprises of 'linkage factors', which are said to have solid driving power and as well as solid dependence power. Aforesaid factors are not stable because of the fact that a single change striking them would be affecting others and furthermore will have a reaction on themselves.

IV. Independent factors: Fourth quadrant comprises of the 'independent variables' which are said to be having solid driving power and however feeble dependence. A factor called as the 'key factor', possessing a very solid driving power falls in the category of independent or linkage factors.

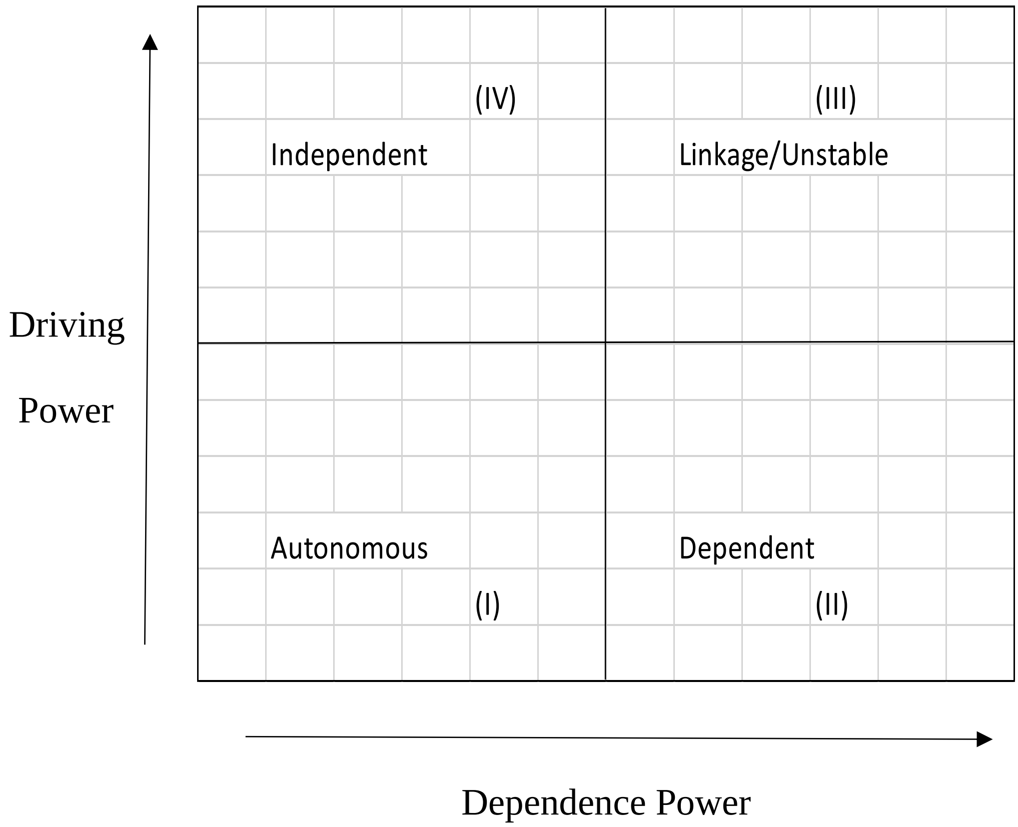

Fig 3.2 Cluster of MICMAC analysis

CHAPTER 4:

ISM MODELLING OF CSFs FOR EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT

4.1 INTRODUCTION

In the present situation, one of the aggressively extending markets in the developing countries is market of electronics. The enlarged demand and utilization of electronic items are made owing the quick financial development. The development and growth we are experiencing is because of the modernization, quickly changing technological innovations, increase competition in the market which enables trends in price drop for the electronic devices and also because of the changing choices of the people. This has provoked the fabrication of electronic items, therefore bringing about the tremendous increment of dangerous electronic waste (Dwivedi and Mittal, 2010). This electronic waste is dangerous and unsafe because it carries toxic and harmful substances which directly or indirectly affect human lives and our ecological system, but on the other hand it also contains few rare earth metals which are precious and are valued highly in the market. With the improper treatment and management of e-waste we are losing on our valuable resources and also developing severe problems for our environment and economy (Menikpura et al. 2014). After recognizing the significance of e-waste in relation to the resources and also the negative effect it produces in the environment, there are few adopted measures which have quite recently begun to roll, for example stakeholder's role, infrastructure investment in the form of collection centers and formal recycling units. These measures are constituted of various aspects considered for any developing nation such as financial, legal, social, technological and environmental (Konteh, 2009). According to the report published by the associated chamber of commerce (ASSOCHAM), India has been ranked fifth amid the nations that are rapidly developing on the planet and ranked second in the Asian continent and produces e-waste with 25% of yearly rise.

4.2 PROBLEM DESCRIPTION

Over the most recent twenty years, managing e-waste has turned into a complex problem which is required to be profoundly examined. The effective and sustainable implementation of e-waste management in India is definitely challenging due to various factors. The e-waste management can be successfully implemented when the practices possess social and ecological feasibility and receives support as well as coordination from the government and different stakeholders. To implement the effective e-waste management, we must identify certain drivers or critical success factors which when implemented properly can help in achieving the effective management of e-waste. In the present work, eleven such critical success factors have been identified through extensive literature review. The list of critical success factors for effective implementation of e-waste management are discussed in Table 4.1, and a hierarchically structured model is formulated for the identified critical success factors so that it provides better understanding of these factors and the interrelationship among them so that it can help in strategic planning for the effective implementation of e-waste management.

4.3 CRITICAL SUCCESS FACTORS FOR THE EFFECTIVE IMPLEMENTATION OF E-WASTE MANAGEMENT

Table 4.1 Critical success factors for the effective implementation of e-waste management

S.No	CSF	Explanation	References
1.	Public awareness	The majority of the people particularly mass customers and huge electronic organizations like Nokia and Dell are currently getting mindful of arrangements, policies and rules for recycling of their waste electronic items which prompts effective e-waste management through formal recycling. In spite of the fact there is need to aware people at general level	Vats and Singh, (2014) Kumar A et al. (2018)

		to make it further more effective and sustainable.	
2.	Rules & regulations	The tenets and rules are formed by the legislature of our country India and endorsed by ministry of environment and forest and central pollution control board (CPCB). The goal of such rules is to give direction to spotting the different e-waste sources and the approach and philosophy for transfer, handling and dumping of e-waste in a way which is cordial with the environment. E-waste management rules 2016 holds numerous such rules, for example, EPR.	Sivakumaran et al. (2015) Verma and Agarwal, (2014) E- waste management rules, (2016)
3.	Stakeholder's participation	Characterizing duties of prime stakeholders at the level of government, inventory network, buyers of ICT items and substances for e-waste disposal. EPR is presented. Setting responsibility of management of e-waste on the makers of electronics hardware by presenting the idea of "extended producer responsibility" (EPR) by collection of e-waste, reusing, recycling and bringing awareness to people. EPR is one primary component of the rules, where the makers manage electrical and electronic equipment after its 'life ends' by financing and sorting out a	Vishvakarma H, Agrawal S, (2018) Ramkrishna and Saha, (2015)

		framework to act in accordance with EPR.	
4.	Formal sector	In formal segment the e-waste is gathered and arranged by government approved agencies or organizations which carries out the work of managing e-waste in an environment cordial way. Such associations play out the e-waste management process by utilizing legitimate gear and furthermore provide with appropriate protective measures and safety equipment to the working staff on the site where recycling is done. CPCB making new endeavors in bridging the informal to formal by welcoming a wide range of professionals in the workshops on a common platform.	Harivardhani et al. (2015) Verma and Agarwal, (2014) Tiwari and Gauba, (2014)
5.	Process technology	Technology incorporated in the processing of e-waste, such as smelting in closed furnace. Formal sector incorporates the right technology for e-waste in order to manage it in an environment friendly manner.	Kumar A et al. (2018) Borthakur A et al. (2012)
6.	Increasing collection centers	There comes the idea of collection center which can be organized individually or jointly. In the collection centers, the gathered e-waste is received and put away to dismantle or recycling. With the implementation of take back system	Rajya Sabha (research unit) report, (2011) Sivakumaran et al. (2015)

		and EPR, the stakeholders are introducing collection centers.	
7.	Less Transboundary movement	The transboundary movement is the transit of the hazardous wastes through any part of India. And it is going to get less with the producer applying RoHS (restriction of hazardous susbstances) as green product design in the forth coming manufacturing and also with the adoption of Basel convention on the control of Transboundary movement of hazardous waste.	Vats and Singh, (2014) Ghansela S, (2013) Saoji A, (2012)
8.	Take back system	Take back system is characterized as collecting back utilized electronic gadgets to recycle or reuse. Take back framework is a critical factor for the effective management of e-waste. Take back initiatives by OEMs (original equipment manufacturers) have started by Nokia, Wipro, Dell and others in the country.	Gaidajis G et al. (2010) E- waste management rules, (2016)
9.	Better recovery and reuse	The recovery of valuable metals and materials by units in formal division is done in ensured environment and with due care to limit any harm to nature or society. The utilization of advanced procedures and innovations make better recovery of metals. Formal sector's efficiency of recovery is high Productivity of recuperation in the formal reusing is high and metals at the trace level can likewise be	Chatterjee S, (2009) Pascale et al. (2016)

		recovered. Some innovations are carried out with zero-landfill approach. Attero recycling in India are recovering 99% of gold.	
10.	Raw material availability	Raw material mentioned here are the disposed electronic items. For recycling unit to function, sufficient amount of raw material are required.	Sivakumaran et al. (2015) Verma et al. (2014)
11.	Cost effective recycling	Recycling innovation by units in formal division will be financially viable as the staggering expense of capital hardware and required systems & techniques can be shared by the volume of items. For each 1 million cell phones recycled, 35,274 lbs of copper, 772 lbs of silver, 75 lbs of gold, and 33 lbs of palladium can be recovered.	Vishvakarma H, Agrawal S, (2018) Harivardhini et al. (2015)

Fig 4.1 Collection center by Ecoreco in Mumbai

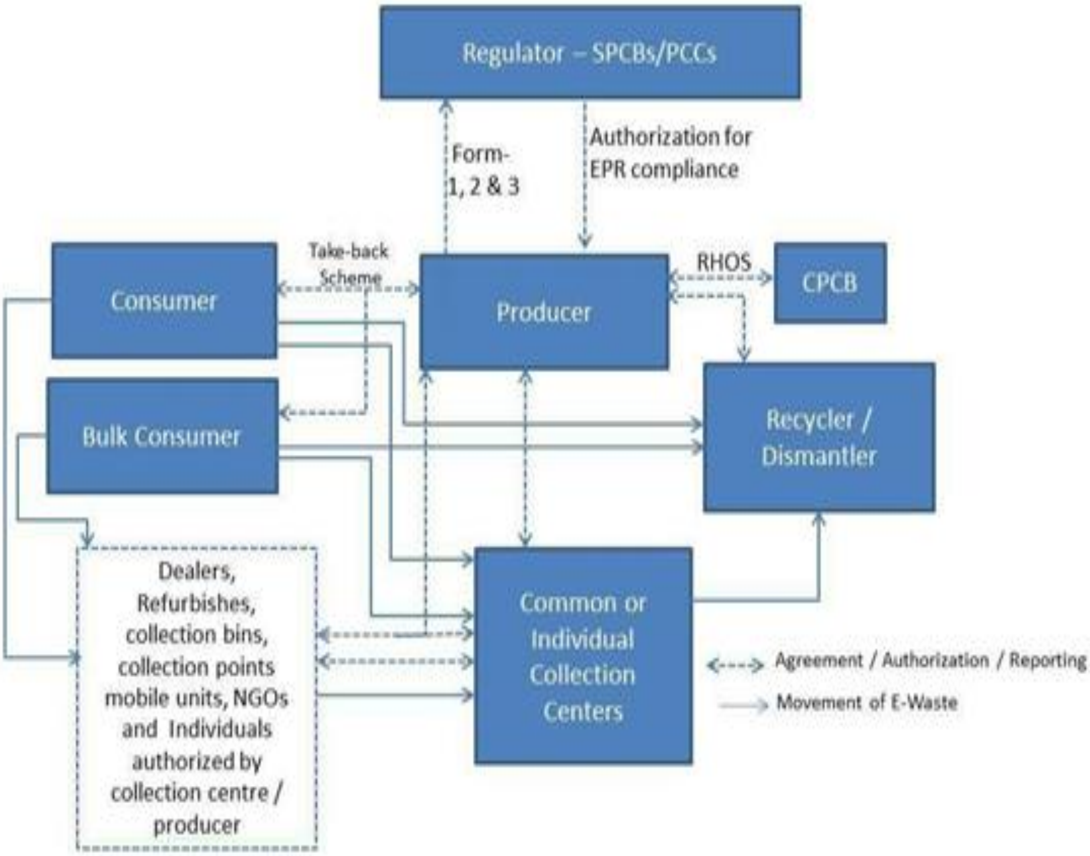

Fig 4.2 Scope of implementing EPR

4.4 INTERPRETIVE STRUCTURAL MODELLING (ISM)

The ISM approach utilized as a part of this research is quite interpretive in nature because of the fact that a group of experts decides whether the factors have a connection between them or not and if they have any connection then how are they connected. It is structural in its approach as well because by making inter-relationships among the factors as its basis an overall structure is extricated from the complicated group of factors. It is a modeling approach in which depiction of particular relations among the factors and the overall structure of the framework under contemplation is done through a directed graph. ISM is fundamentally proposed as a process where things are learnt in groups, yet it could likewise be utilized by an individual.

4.4.1 Steps in ISM technique

Step 1: Determination of the factors that puts an effect on the effective implementation of the e-waste management.

Step 2: Setting up a logical relationship amid the factors identified in the first step, by taking the factors in pairs for the analysis.

Step 3: Formulating a SSIM for the factors through which pair wise interrelationships amid factors of the framework under contemplation has been shown.

Step 4: Initial reachability matrix is created against the SSIM and the matrix is checked upon for any transitivity that it could possess. The logical relation's transitivity is a basic assumption made in ISM which expresses that if A & B are related to each other, B & C are related to each other then A & C will also be necessarily related to each other.

Step 5: Partition into various levels is carried out of the reachability matrix acquired in previous step.

Step 6: Making the relationship shown above in reachability matrix as the basis a digraph is drawn and removal of transitive links from digraph is exercised.

4.4.2 Structural Self Interaction Matrix (SSIM)

To examine the factors for the effective implementation of e-waste management, a logical relationship of 'ameliorating' nature has been chosen. Aforesaid implies that one variable will be helping in leading to another variable. On the basis of this, logical relationship has been established among the various factors that have been identified earlier.

Keeping the logical relationship for every factor in mind, two factors at a time are taken and subsequently questioned for the presence of any connection between those two factors and also questioned for related orientation of the connection present between them. Four letters have been utilized so that the orientation of relationship amid the factors (i and j) can be indicated and these are as follows:

V: factor i would be ameliorating factor j;

A: factor j would be ameliorating factor i;

X: factors i & j would be ameliorating each other;

O: factors i & j are not related to each other;

The utilization of the letters V, A, X, and O would be explained in Structural Self Interaction Matrix, which is shown in table 4.2.

Table 4.2 Structural self-interaction matrix (SSIM)

CSFs	1	2	3	4	5	6	7	8	9	10	11
1. Public awareness		X	V	V	O	V	O	V	V	V	V
2. Rules and regulations			V	V	O	V	V	V	V	V	O
3. Stakeholder's participation				O	O	V	O	V	V	O	O
4. Formal sector					V	V	A	A	V	A	A
5. Process technology						O	A	A	V	O	O
6. Increasing collection centers							O	X	V	V	O
7. Less transboundary movement								O	O	V	O
8. Takeback system									V	V	O
9. Recovery and reuse										A	V
10. Increased material availability											V
11. Cost effective recycling											

4.4.3 Initial reachability matrix

In the following step, the development of reachability matrix has been done through the utilization of the matrix developed in the previous section i.e. SSIM. The initial reachability matrix is constructed out as a result of converting the data of every cell of SSIM into a binary form (i.e. zeros & ones) through the application of few rules that have been discussed below.

The rules to be followed for this replacement are:

- 'V' present at any (i, j) position in SSIM has to be replaced by 1 and the corresponding (j, i) position should be changed to 0.

- ‘A’ present at any (i, j) position in SSIM has to be replaced by 0 and the corresponding (j, i) position should be changed to 1.
- ‘X’ present at any (i, j) position in SSIM has to be replaced by 1 and the corresponding (j, i) position should also be changed to 1.
- ‘O’ present at any (i, j) position in SSIM has to be replaced by 0 and the corresponding (j, i) position should also be changed to 0.

Complying with the above mentioned rules the initial reachability matrix is developed in Table 4.3.

Table 4.3 Initial reachability matrix

CSFs	1	2	3	4	5	6	7	8	9	10	11
1. Public awareness	1	1	1	1	0	1	0	1	1	1	1
2. Rules and regulations	1	1	1	1	0	1	1	1	1	1	0
3. Stakeholder’s participation	0	0	1	0	0	1	0	1	1	0	0
4. Formal sector	0	0	0	1	1	1	0	0	1	0	1
5. Process technology	0	0	0	0	1	0	0	0	1	0	0
6. Increasing collection centers	0	0	0	0	0	1	0	1	1	1	0
7. Less transboundary movement	0	0	0	1	1	0	1	0	0	1	0
8. Takeback system	0	0	0	1	1	1	0	1	1	1	0
9. Recovery and reuse	0	0	0	0	0	0	0	0	1	0	1
10. Increased material availability	0	0	0	1	0	0	0	0	1	1	1
11. Cost effective recycling	0	0	0	0	0	0	0	0	0	0	1

4.4.4 Final reachability matrix

Initial reachability matrix has been created against the structural SSIM and the matrix is checked upon for any transitivity that could be present in the matrix. The logical relation’s transitivity is a basic assumption made in ISM which expresses that if A & B are related to each other, B & C are related to each other, then A & C will also be necessarily related to each other.

In Table 4.4 we incorporate the transitivity.

Table 4.4 Transitivity check for Initial reachability matrix

CSFs	1	2	3	4	5	6	7	8	9	10	11
1. Public awareness	1	1	1	1	0*	1	0*	1	1	1	1
2. Rules and regulations	1	1	1	1	0*	1	1	1	1	1	0*
3. Stakeholder’s participation	0	0	1	0*	0*	1	0	1	1	0*	0*
4. Formal sector	0	0	0	1	1	1	0	0*	1	0*	1
5. Process technology	0	0	0	0	1	0	0	0	1	0	0*
6. Increasing collection centers	0	0	0	0*	0*	1	0	1	1	1	0*
7. Less transboundary movement	0	0	0	1	1	0*	1	0	0*	1	0*
8. Takeback system	0	0	0	1	1	1	0	1	1	1	0*
9. Recovery and reuse	0	0	0	0	0	0	0	0	1	0	1
10. Increased material availability	0	0	0	1	0*	0*	0	0	1	1	1
11. Cost effective recycling	0	0	0	0	0	0	0	0	0	0	1

‘0*’ shows the transitivity present in the matrix

As a result of the transitivity check and as depicted in Step (4) of the ISM procedure, the final reachability matrix is developed and has been shown in Table 4.5. For developing final reachability matrix all the ‘0*’ are replaced by 1. In table 4.5, two new things are additionally appeared, first is ‘Driving power’ and the other one is ‘Dependence power’. Driving power for every component is simply the aggregate no. of components (counting), which it might help to accomplish. Whereas, dependence power is simply the aggregate no. of components (counting), which might be helpful in accomplishing it. These driving power and dependencies would be helpful on a later stage for classifying the components into 4 clusters of autonomous, dependent, linkage and drivers (independent).

Table 4.5 Final reachability matrix

CSFs	1	2	3	4	5	6	7	8	9	10	11	DP
1. Public awareness	1	1	1	1	1	1	1	1	1	1	1	11
2. Rules and regulations	1	1	1	1	1	1	1	1	1	1	1	11
3. Stakeholder’s participation	0	0	1	1	1	1	0	1	1	1	1	8
4. Formal sector	0	0	0	1	1	1	0	1	1	1	1	7
5. Process technology	0	0	0	0	1	0	0	0	1	0	1	3
6. Increasing collection centers	0	0	0	1	1	1	0	1	1	1	1	7
7. Less transboundary movement	0	0	0	1	1	1	1	0	1	1	1	7
8. Takeback system	0	0	0	1	1	1	0	1	1	1	1	7
9. Recovery and reuse	0	0	0	0	0	0	0	0	1	0	1	2
10. Increased material availability	0	0	0	1	1	1	0	0	1	1	1	6
11. Cost effective recycling	0	0	0	0	0	0	0	0	0	0	1	1
Dependence	2	2	3	8	9	8	3	6	10	8	11	

Where ‘DP’ is Driving Power

4.4.5 Level Partition

From the final reachability matrix that has been shown in table 4.5, the reachability and the antecedent set for all the factors are determined. The reachability set is a set comprising of the component itself and other different components to which the component might be helpful in accomplishment, while antecedent set is a set comprising of the component itself and other various components which might be helpful in accomplishment of the component. After that, intersection of the two different above mentioned sets is inferred for each and every component. The component for which the reachability set and the intersection set came out to be identical happens to be that component which occupies the topmost level in the ISM hierarchy. The hierarchy's topmost level component would not be helpful in accomplishing some other component above them. Immediately after the component at topmost level is determined, it is segregated out from the other components. Afterwards by the similar procedure, the following levels for the components are determined. The above discovered levels of components aides in the digraph formation and also in the formulation of the final model. From Table 4.6, it could be observed that the 'Cost effective recycling' happens to be at level I. In this way, it happens to be situated at the highest point in the ISM hierarchy. This cycle is performed again till every component's level are identified. These iterations are appeared in Table 4.6 to 4.12. The determined levels of components help in formation of the final model of ISM.

Table 4.6 Level Partition (Iteration 1)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	11,10,9,8,7,6,5,4,3,2,1	2,1	2,1	
2.	11,10,9,8,7,6,5,4,3,2,1	2,1	1,2	
3.	11,10,9,8,6,5,4,3	3,2,1	3	
4.	11,10,9,8,6,5,4	10,8,7,6,4,3,2,1	4,6,8,10	
5.	11,9,5	10,8,7,6,5,4,3,2,1	5	
6.	11,10,9,8,6,5,4	10,8,7,6,4,3,2,1	4,6,8,10	
7.	11,10,9,7,6,5,4	7,2,1	7	
8.	11,10,9,8,6,5,4	8,6,4,3,2,1	4,6,8	
9.	11,9	10,9,8,7,6,5,4,3,2,1	9	
10.	11,10,9,6,5,4	10,8,7,6,4,3,2,1	4,6,10	
11.	11	11,10,9,8,7,6,5,4,3,2,1	11	I

Table 4.7 Level Partition (Iteration 2)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	10,9,8,7,6,5,4,3,2,1	2,1	2,1	
2.	10,9,8,7,6,5,4,3,2,1	2,1	2,1	
3.	10,9,8,6,5,4,3	3,2,1	3	
4.	10,9,8,6,5,4	10,8,7,6,4,3,2,1	10,8,6,4	
5.	9,5	10,8,7,6,5,4,3,2,1	5	
6.	10,9,8,6,5,4	10,8,7,6,4,3,2,1	10,8,6,4	
7.	10,9,7,6,5,4	7,2,1	7	
8.	10,9,8,6,5,4	8,6,4,3,2,1	8,6,4	
9.	9	10,9,8,7,6,5,4,3,2,1	9	II
10.	10,9,6,5,4	10,8,7,6,4,3,2,1	10,6,4	

Table 4.8 Level Partition (Iteration 3)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	10,8,7,6,5,4,3,2,1	2,1	2,1	
2.	10,8,7,6,5,4,3,2,1	2,1	2,1	
3.	10,8,6,5,4,3	3,2,1	3	
4.	10,8,6,5,4	10,8,7,6,4,3,2,1	10,8,6,4	
5.	5	10,8,7,6,5,4,3,2,1	5	III
6.	10,8,6,5,4	10,8,7,6,4,3,2,1	10,8,6,4	
7.	10,7,6,5,4	7,2,1	7	
8.	10,8,6,5,4	8,6,4,3,2,1	8,6,4	
10.	10,6,5,4	10,8,7,6,4,3,2,1	10,6,4	

Table 4.9 Level Partition (Iteration 4)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	10,8,7,6,4,3,2,1	2,1	2,1	
2.	10,8,7,6,4,3,2,1	2,1	2,1	
3.	10,8,6,4,3	3,2,1	3	
4.	10,8,6,4	10,8,7,6,4,3,2,1	10,8,6,4	IV
6.	10,8,6,4	10,8,7,6,4,3,2,1	10,8,6,4	IV
7.	10,7,6,4	7,2,1	7	
8.	10,8,6,4	8,6,4,3,2,1	8,6,4	
10.	10,6,4	10,8,7,6,4,3,2,1	10,6,4	IV

Table 4.10 Level partition (Iteration 5)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	8,7,3,2,1	2,1	2,1	
2.	8,7,3,2,1	2,1	2,1	
3.	8,3	3,2,1	3	
7.	7	7,2,1	7	V
8.	8	8,3,2,1	8	V

Table 4.11 Level partition (Iteration 6)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	3,2,1	2,1	2,1	
2.	3,2,1	2,1	2,1	
3.	3	3,2,1	3	VI

Table 4.12 Level partition (Iteration 7)

CSFs	Reachability set	Antecedent set	Intersection set	Level
1.	2,1	2,1	2,1	VII
2.	2,1	2,1	2,1	VII

4.4.6 Constructing the ISM model

From the above tables we have seen that there are 7 levels of the model formation for the identified factors in this research. Cost effective recycling (CSF11) settled in at level I. Level II and III are taken by Recovery and reuse (CSF9) and Process technology (CSF5) respectively. Level IV is occupied by Formal sector (CSF4), Increasing collection centers (CSF6) and Increased material availability (CSF10). Take back system (CSF8) and Less transboundary movement (CSF7) are at level V. Level VI has Stakeholder's participation (CSF3). And the final level VII has two factors which are, Public awareness (CSF1) and Rules and regulations (CSF2).

For the factors identified in this study the ISM model constructed illustrates that for effective and sustainable e-waste management it is imperative to facilitate public awareness (CSF1) among the people of the country and especially those using electrical and electronic items. Along with the public awareness, befitting rules & regulations (CSF2) are equally imperative in nature and should be focused upon too. Both would help each other in their procedure. Once the public awareness and rules & regulations are facilitated well, it will lead to increased stakeholder's participation (CSF3) as per the concept of EPR which has been presented in the e-waste management rules formulated by the government. Further EPR will lead to implementation of take-back system (CSF8) which will further have an impact on transboundary movement (CSF7) of e-waste. Once the take-back system is implemented well and the results of less transboundary movements simply reflects in increasing collection centers (CSF6) and also in increased material availability (CSF10) at the collection center for managing e-waste. Increasing collection centers and material availability would have an impact on formal sector (CSF4) and it will certainly grow. The comprehensive viewpoint of formal sector will help in organizing the e-waste with better process technology (CSF5), such as smelting rather than open air incineration. Better processing technology will lead us to increased recovery and reuse (CSF9) of metals and other materials, that too in an environmentally friendly manner. Increased material recovery and reuse will eventually help and give rise to cost effective recycling (CSF11) as the staggering expense of capital hardware, required systems and required techniques can be shared by the volume of items coming under the process of recycling.

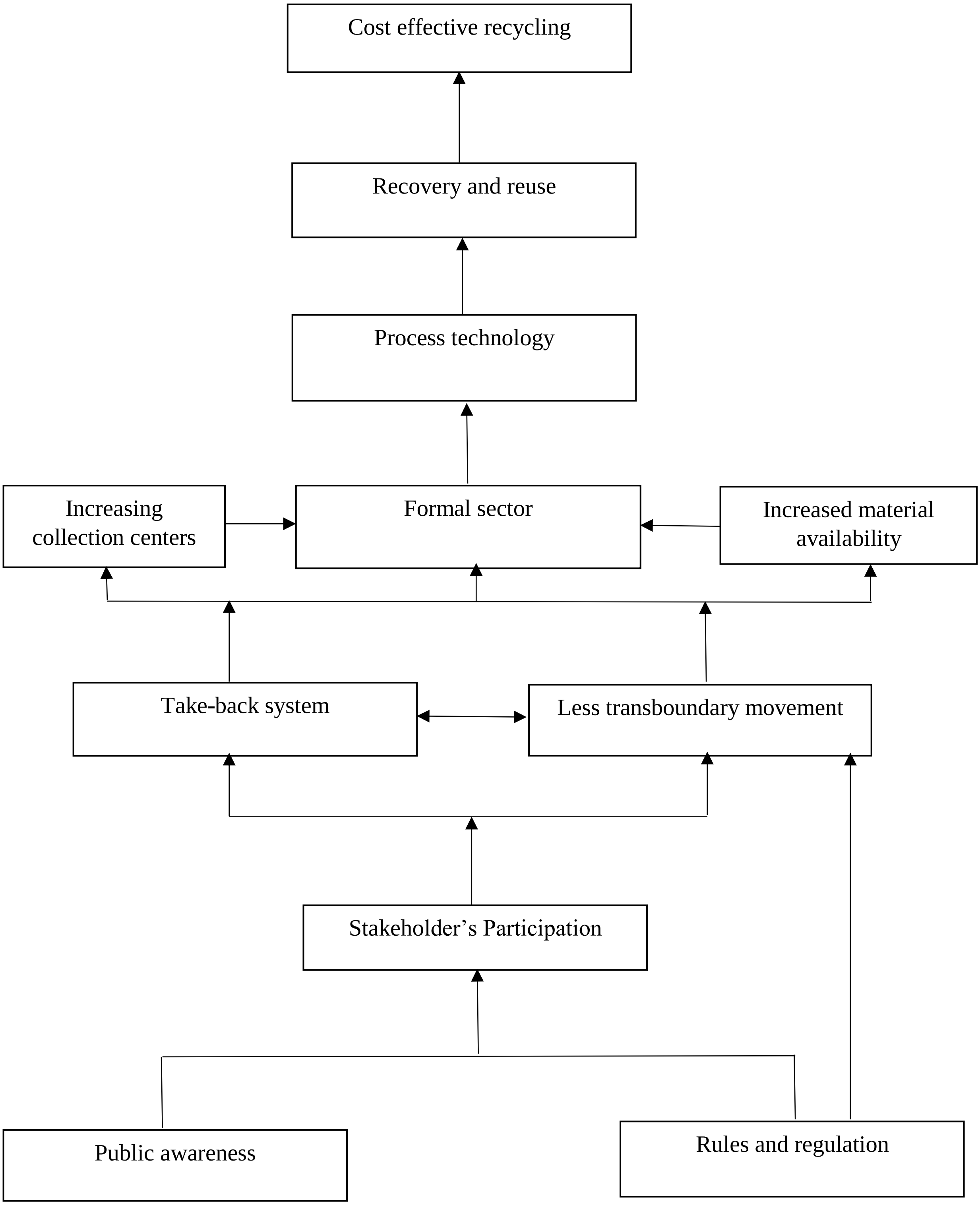

Fig 4.3 ISM model for effective implementation of e-waste management

4.5 MICMAC Analysis

The purpose of the MICMAC (Matriced' Impacts Croise's Multiplication Appliquée a UN Classement) analysis is to examine the driver power and the dependence power of the factors (Mandal and Deshmukh, 1994).

To begin with is the Ist quadrant which is characterized by the 'Autonomous factors' that possess feeble driving power and additionally feeble dependence. These factors are said to be comparatively disconnected from the system or just could be possessing very weak connections with the other factors of the system.

IInd quadrant comprises of the 'Dependent factors', these factors are said to have high dependence power and comparatively very low driving power.

IIIrd quadrant comprises of the 'Linkage factors' which are said to have a strong driving power and as well as strong dependence power. These factors are quite unstable in nature because of the fact that any single change striking them will have an effect on the other factors and furthermore will have a reaction on themselves.

IVth quadrant comprises of the 'Independent Factors' which are said to have very strong driving power and relatively very low dependence power.

The dependence and driving power of all the identified CSFs have been shown in Table 4.5. Within the table, a listing of '1' summed up across the rows & columns shows the driving power and dependence power respectively. Subsequently, the driving power-dependence power diagram is formulated, and has been appeared in figure 4.4. For instance, the element placed at second position (CSF2) in table 4.5 gets eleven as its driving power, two as its dependence power and it has been correspondingly placed at driving power of eleven and dependence of two in the driving power-dependence power diagram. In a similar manner all the various factors have been placed on different quadrants in the driving power-dependence power diagram in accordance with their respective driving power and dependence power.

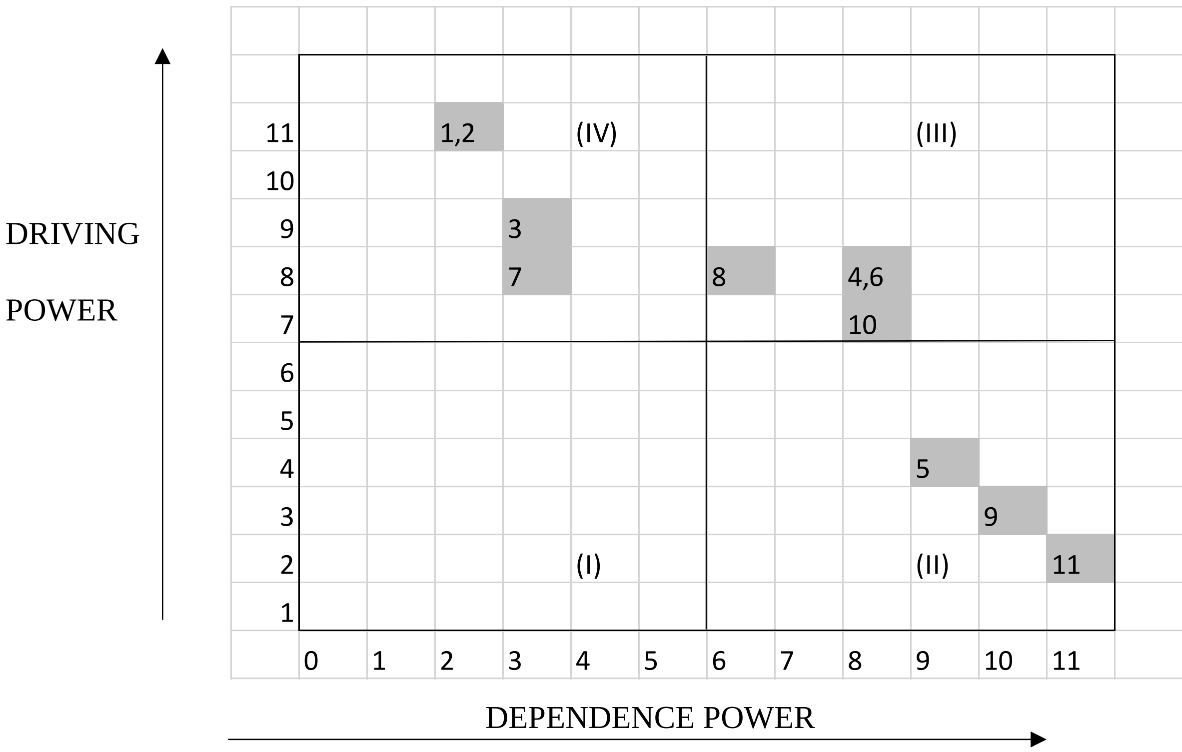

Fig 4.4 Driving power-dependence power diagram

4.6 Results and Discussions

ISM model of the critical success factors for effective implementation of e-waste management demonstrates the interrelationship among the various critical factors and furthermore provides us with the structural hierarchy of the factors through the level partition of factors as decided in various iterations from Table 4.6 to 4.12. The analysis of the factors is done through the Driving power-dependence power diagram which classifies the CSFs for effective implementation of e-waste management into four different categories namely Autonomous factors, Dependent factors, Independent factors, Linkage factors.

- Autonomous factors are the factors that have weak dependence as well as weak driving power and are said to be comparatively disconnected from the system. These factors cannot have much of influence on the other factors of the system. Figure 4.4 demonstrates that for this study there are no such factors that can be classified as autonomous factors.

- The driving power-Dependence power diagram indicates that there are four factors having strong dependence as well as strong driving power and are known as Linkage factors. Hence it can be gathered that among all the eleven factors identified in this study, Formal sector (CSF4), increasing collection centers (CSF6), increasing material availability (CSF10) have been classified as Linkage factors and are unstable in nature.

- Observation made From the ISM model (Figure 4.3) and from the driving power-dependence power diagram (Figure 4.4) is that the factors such as the Cost-effective recycling (CSF11), increased recovery and reuse (CSF9) and process technology (CSF5) occupies the first three levels of the model respectively, they possess a high dependence and comparatively very low driving power and have been classified as dependent variables.

- The ISM model indicates that variables such as public awareness (CSF1), rules and regulations (CSF2), stakeholder's participation (CSF3) are present at the base of the model possessing a very high driving power and have been classified as independent factors. The above indicated factors are also grouped as causal factors because they possess a very high driving power and a tendency to influence the overall system. These factors are the drivers of the system and will definitely help in accomplishing effective e-waste management.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

Presently, a complex issue of e-waste is being faced within the metropolitan urban communities especially of developing countries. The developing nature of the economy, increased availability of the options and ever-changing demands of the consumers is making it an important matter in question. To address this complex issue of e-waste a policy to handle and manage e-waste has to be considered and utilized. An immediate need is there for the effective e-waste management to comply with the norms of international environment regulations. Hence, eleven critical success factors have been determined in this study for the effective implementation of the e-waste management. Subsequently, the determined eleven CSFs were assessed and incorporated with the ISM methodology. The incorporation of the ISM methodology helped us in transforming the unsettled and weakly articulated CSFs of the system into a structured hierarchal model which can serve as the guiding tool for the management authorities for making policies about e-waste management.

The various leveled structural hierarchy of the factors that influences the effective implementation of e-waste management additionally helps in establishing the internal dependence among the factors by classifying them into the cause and effect group of factors. The vitality of the factors falling under cause group is that they possess a tendency to influence the overall system, on the other hand the factors falling under effect group possess a tendency to get influenced by the cause group of factors. This study and it's finding demonstrates that the public awareness (CSF1) about recycling of e-waste and rules and regulations (CSF2) addressing the e-waste issue are the most powerful and causal factors. Hence, there is the need to be more focused on increasing the public awareness and adopting befitting rules & regulations for the effective implementation of management of e-waste.

5.2 Future scope

Despite having the significance of the above stated outcomes, this present work has got much of future scope to offer. In the present work, an interrelationship model created and demonstrated with eleven critical success factors identified in relation to effective implementation of e-waste management through the utilization of ISM methodology. There can be various other factors related to the issue of managing e-waste, hence further in future more factors can be explored by learning and studying about other perspectives of managing e-waste. In the present work, also the statistical validation of the interrelationship model developed between the factors identified for effective e-waste management has not been done, henceforth it is proposed that future research might be focused on developing the preliminary model through ISM and afterward testing & validating the model statistically through the application of statistical validation techniques like Structural Equation Modelling (SEM).

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