A COMPREHENSIVE STUDY OF WEEE MANAGEMENT IMPLEMENTATION ISSUES IN INDIA

Ph.D. THESIS

by

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A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"A COMPREHENSIVE STUDY OF WEEE MANAGEMENT IMPLEMENTATION ISSUES IN INDIA"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Management Studies of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from December, 2015 to September, 2019 under the supervision of Dr. Gaurav Dixit, Assistant Professor, Department of Management Studies, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institution.

(ASHWANI KUMAR)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(Gaurav Dixit)
Supervisor

The Ph.D. Viva-Voce Examination of Ashwani Kumar, Research Scholar, has been held on ………………….

Chairperson, SRC **Signature of External Examiner**

This is to certify that the student has made all the corrections in the thesis.

(Gaurav Dixit) **Head of the Department**

Supervisor

Date:

ABSTRACT

Globally, increasing population, advanced industrialization and developing economies contribute to the rapid increase in waste, thereby amplifying the complexity and hazardous nature of waste. Developing nation has successfully gleaned the financial development, the production and consumption of its population extremely harms the standard of ecosystems and the respectability of its regular assets. With exponential expansion in electronic and electrical manufacturing sector, the waste and pollution generated due to this expansion have also increased rapidly causing deterioration of the environment. Compelled by deteriorating environmental condition due to rapid industrialization and market pressures, environmentalists, industrialists as well as academicians are concerned about incorporating environmentally sound waste management practices into the reverse and forward supply chain activities. Further, formal recycling sector being the backbone of any economy is the major contributor in terms of resource and energy recovery and also contribute significantly towards the environmental degradation. But existence of large informal recycling network can create negative impact on the environment because of their primitive approach towards WEEE treatment and recycling procedures. Consequently, to address the rising environmental concern, government and other stakeholders need to come up with stringent framework which helps to reduce environmental degradation. Thus keeping this in mind this study aims to analyze and develop a framework for WEEE management adoption and implementation issues in Indian context

This research work has four objectives and the whole thesis is divided into seven chapters. The first chapter is an introduction and presents the basic background and the need for the study. It highlights the importance of WEEE management in environmental as well as economic growth of the country. The second chapter deals with literature review and it provides an in-depth and exhaustive review of the literature on WEEE management. Detailed definitions of WEEE and various classification of WEEE are also discussed. An extensive review of the literature on enablers and barriers to WEEE management implementation/adoption is also presented in this chapter. Third chapter presents the research approach followed. It discusses about various methodologies adopted and their brief description. Fourth chapter deals with the development of a framework to identify barriers of WEEE management adoption and also determine the interrelationship among the barriers to WEEE management implementation. A total of seven main category barriers and forty-four sub category barriers are identified. Policy and regulatory barriers emerged as the most important barriers followed with technological barriers and socio-economic barriers. Fifth chapter deals with identifying enablers of sustainable WEEE management and selection of WEEE recycling partner based on green competencies. Forty-seven enablers are identified and recycling partners' selection using case of five recycling firms is done on the basis of these enablers. Resource and environmental capabilities and green core competencies found to be the most important enablers for the selection of WEEE recycling partner. Sixth chapter deals with the framework for identification and finalization and selection criteria by considering social, economic, environmental, technical and political aspects. A total of twenty nine criteria are categorized into five main dimensions for the selection of best and sustainable location for WEEE recycling plant. The results have indicated that environmental and natural criteria is the key criteria for the selection of sustainable location for WEEE recycling plant. Policy and legal criteria and economic criteria have occupied the second and third positions respectively. This framework can act as a benchmark for the selection of optimal location for siting WEEE recycling plant facilities.

Keywords: WEEE management, Recycling, Green competencies, DEMATEL, Grey theory, Fuzzy AHP, Best Worst method, VIKOR.

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I would also like to thank all the electronic and electrical equipment manufacturing firm and owners of recycling units surveyed for sparing their invaluable time by means of providing crucial data and information on their respective enterprises. It is due to their generous attitude and help that this thesis has seen the light of day. I am extremely grateful to them all. Last but not the least, I thank God Almighty and my beloved grandmother for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily.

(Ashwani Kumar)

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CHAPTER - I
INTRODUCTION

1.1 Background of the study

In view of constant depletion of earth's natural resources and increasing volume of waste of electrical and electronic equipment (WEEE) or e-waste, due to accelerated replacement rate of various types of electronic products corroborated with state of the art technology, weak environmental regulations and policies, WEEE recycling and disposal has become a challenging task for the electronics equipment companies (Kumar and Dixit, 2018a). The generation of sheer volume of WEEE containing various amount of hazardous and toxic substances cause a major threat to environmental and other social problems. According to the Solving the E-waste Problem (StEP, 2017), the world will generate further 33 percent more WEEE from 49 million metric tons to 65 million metric tons per year. In the year 2016, most of the WEEE was generated in emerging economies like India, China, Pakistan and other South Asian countries. It is noted that approximately 18.2 metric tonnes or 4.2 kg per inhabitant of WEEE was generated, of which, only 2.7 metric tonnes of WEEE was collected and recycled (Baldé et al., 2017). This special stream of waste not only contain valuable material but also consists of hazardous and toxic substances for e.g. brominated flame retardants (BFRs), heavy rare earth metals, etc. (Chen et al., 2016). As per the report of associated chamber of commerce (ASSOCHAM), India is an emerging world's fifth and second nation in Asia that generates e-waste with an annual growth of 25%; thus generated 18.5 lakh MT of electronic waste by 2016 as compared to the current level of 12.5 lakh MT annually. On the basis of research, some cities (see Table1.1) are found to be the leader of e-waste producer based on the yearly generation (Kumar and Dixit, 2018b). Moreover, India is having a tag of primary dumping site for WEEE from the developed nations. The reason behind it is the delay in law enforcement on producers or manufacturers, so as to come up with efficient management for handling returns and proper disposal of electronic products (Toxic Link, 2014). Figure 1 shows that almost 80% of WEEE is illegally exported from developed to developing nations like India, China, Nigeria, Pakistan, Philippines, Sri Lanka, Vietnam, Thailand and some part of West Africa, because of accessibility of inexpensive workmanship and lack of stringent regulation and norms (Sthiannopkao and Wong, 2013). Lack of strategies for recovery of resources and sanitary landfills has become prominent barriers behind un-segregating WEEE, thus challenging limited recycling and disposal option.

Figure1.1 Represents the export and suspected movement of WEEE from developed to developing countries (Kumar et al., 2017).

As per MAIT-GTZ (2007), almost 95% of total WEEE in India is assembled and recycled by unorganized subdivision that carry out operations like rare metal recovery and extraction of reused parts by environment unfriendly manner in the country. Informal sector is an entirely new profitable sector that involves WEEE trading, refurbishing, repairing, and extracting materials from obsolete electronic devices and provides a livelihood for poor and migrated people; however, it can cause many problems on aquatic system and human health (Awasthi et al., 2016). Merely 1.5 percent of WEEE recycled in India because of poor awareness about WEEE and its recycling methods, as well as the role of the rising informal sector are added challenges to the problem. For this reason, government and other environmental reformists all over the world need to critically think about the substitute consumption of these natural resources. Their other major concern is the WEEE and the way it is disposed-off in the environment due to rapid industrialization, causing destructive impact on the ecosystem (Bai and Sarkis, 2010). Recycling and the material recovery related issue of sustainable development are gaining importance around the world due to its social, environmental, and economic benefits by reducing the use of virgin materials and other resources like water and energy (de Oliveira et al., 2012). In addition, these processes play a vital role in minimizing the rising volume of waste dumped into the landfills and reducing the negative impact on the ecosystem (Bentaha et al., 2014). With the help of recycling, reuse and product recovery, aim is to retrieve valuable assets and rare earth material from the discarded electronic products. Apart from these, electronic manufacturers can gain economic benefits by using recycled materials instead of using the raw or virgin material in their production process (Kuo et al., 2010).

Further, UNEP (2016) in their meeting for sustainable development identified sustainable production and consumption of resources as a stand-alone goal for 2030. It also identified various fundamental areas to achieve sustainability goals viz. creating an enabling environment, adopting green competencies across the global supply chain, promoting sustainable production and consumption (SPC) practices across sectors by following sustainable consumption lifestyle in their livelihood, which has been indicated as the thrust areas to achieve the above-mentioned objective (Gupta and Barua, 2017). With increasing awareness amongst the consumer for environmental protection and surmounting concern of various agencies regarding climate change, global warming and the pressure from the legal institutions such as restriction of hazardous substances (RoHS), environmental protection (ErP), extended producer responsibility (EPR) and take-back legislation, etc. This enforced electronic companies to comply with environmental norms and regulations and paying more attention towards improving green competencies of entire supply chain which leads to minimize hazardous impact and sustain in the global market (Ho et al., 2010; Garlapati, 2016). Therefore, to maintain a leverage between social responsibilities and long-term economic benefit, the manufacturers need to select outsourcing recycling firms which are capable of innovative methods and equipped with state-of-art system using green and cleaner technologies (Kumar and Dixit, 2018a). For effective adoption of WEEE management activities, there are various reasons; but the presence of obstacles makes WEEE management challenging and the effect of these barriers cannot be overcome at the same time. Furthermore, the identical barrier requires different priorities of treatment depending on the variation in the characteristics of resources, strategies, and capabilities of the management of the organization. The mismanagement in handling WEEE can create tremendous negative impact on the ecological and economic performances of organizations (Robinson, 2009). By contrast, in developing nations WEEE management still to be an immature practice (Lau and Wang, 2009; Chakraborty et al., 2019). In the view of above statistics and information, there is an urgent need to have sufficient infrastructure, strong closed-loop and reverse logistic network, cleaner technologies, and inviolable legal policies for effective WEEE management in India. In developing countries, there are plenty of indications in respects of public willingness for recycling, consumer awareness, policies and regulation, and participation of stakeholders, however, some criticalities are observed while implementing effective WEEE management practices. It is well known that WEEE management is mandatory for maintaining economic, environmental and social norms in the developed and developing nations.

Table 1.1: Top E-waste producer cities in India.

Cities	**E-waste (Tons/Year)**
Mumbai	1.2 Lakh
Delhi-NCR	0.98 Lakh
Bangalore	0.92 Lakh
Chennai	0.67 Lakh
Kolkata	0.55 Lakh
Ahmedabad	0.36 Lakh

1.2 Definition and categories of WEEE

Technically, e-waste is only a subset of WEEE (waste electrical and electronic equipment). As per Organization for Economic Cooperation and Development (OECD), WEEE is defined that any gadget and appliance driven with electric circuit or electric power supply that has reached to end-of life (EoL) after consumers use (EU, 2002). Solving the e-waste problem (StEP) is an international initiative that works on developing solutions for the e-waste issue around the globe. According to Step Initiative (2014), "*E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its part that have been discarded by the owner as waste without intention of re-use.*"

Based on the European Union directives (EU directives, 2002), WEEE can be classified into ten different categories which have also included toys, sports and leisure equipment, medical devices, and automatic dispensers. However, these devices and equipment are no longer mentioned in the latest directives of the European Union commission (EU, 2012). A study by Balde et al. (2015) classified the WEEE into six distinct categories as presented in Table 1.2

Table 1.2 Represents the six different categories of WEEE.

S. No.	Waste Category	Equipment	Label code
1	Temperature exchange equipment	AC (air conditioners), heat pump, refrigerators and freezers.	TEE
2	Screens and monitors	TV (Television), laptops, monitors, notebook, tablets.	S&M
3	Large equipment	Electric stoves, printing and Xerox machines, photovoltaic (PV) panels, washing and dryers machines.	LE
4	Small equipment	Bread toasters, ventilation equipment, radio, electric calculators, scales, electric trimmers and shavers, toys, camera, medical devices, electric tools, vacuum cleaner, kettles, small monitoring and control devices, and microwave.	SE
5	Small IT and telecommunication equipment	Pocket calculator, routers, mobile phones, small printers, PCs (personal computers), and telephones.	IT&CE
6	Lamps	LED lamps, fluorescent lamps and high-intensity lamps.	L

(Balde et al., 2015)

1.3 Composition of WEEE and impacts on human health

WEEE or e-waste constituents with more than thousand diverse substances which falls under the categories of hazardous and non-hazardous substances. WEEE includes ferrous as well as non-ferrous metals along with glass, plastics, wood, PCB (printed circuit board), ceramics, plywood, rubber and other items. In non-hazardous substances category, iron and steel constitute more than fifty percent of the WEEE, followed by plastics (21%), non-ferrous elements (13%) and other metals. The non-ferrous metal presents in the WEEE includes rare and precious elements like aluminum (Al), copper (Cu), silver (Ag), gold (Au), platinum (Pt) and palladium (Pd). While in case of hazardous substances category, WEEE includes elements like mercury (Hg), lead (Pb), cadmium (Cd), arsenic (As), selenium (Se), chromium (Cr), and other flame retardants. Figure 1.2 depicts the detailed classification of hazardous substances of WEEE. Further, hazardous substances and components of WEEE classified into four different categories such as halogenated substances, radioactive substances, heavy metals, and some other hazardous substances.

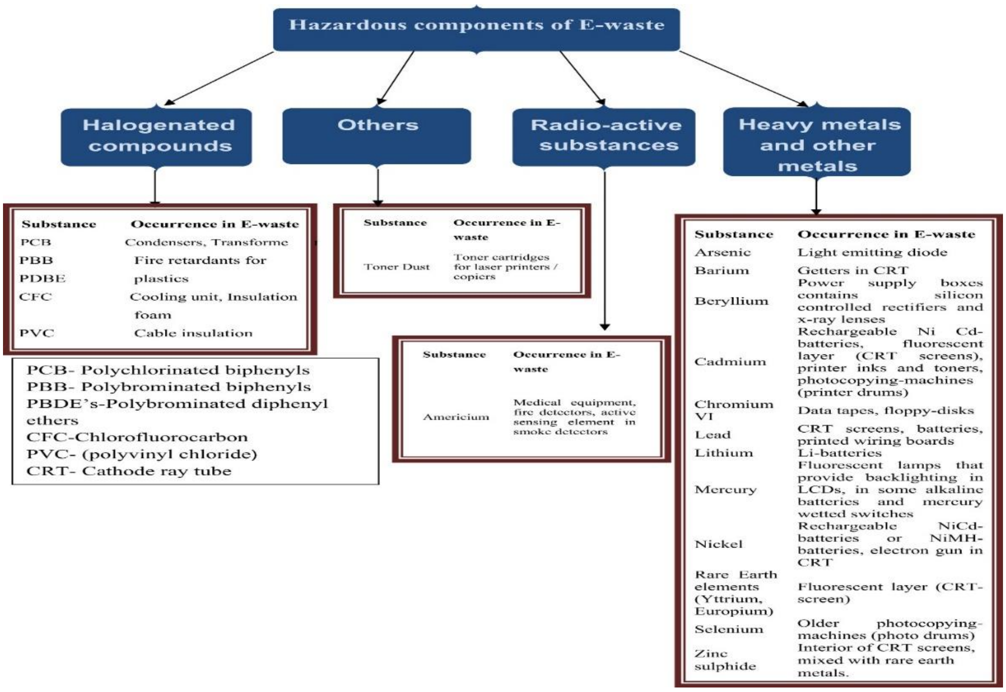

Figure 1.2 Represents the four different types of hazardous component of WEEE (Garlapti, 2016).

The presence of hazardous substances in WEEE can cause negative consequences such as waste exposure and health related issues (Grant et al., 2013. The physical and health related issues are mainly reported such as fertility issues (reproductive health), hormonal issues (thyroid function), bronchitis (lung function), and other cell functioning related issues. The presence of BFR (brominated flame retardants) in WEEE have adverse impact on human brain severely effects the nervous system and cause infertility in humans. Similarly, presence of lead and cadmium in CRTs (cathode ray tubes), batteries and PCBs (printed circuit board) can cause symptoms like chronic toxicity, flu, vomiting, diarrhea, coma and even death of workers involved in waste recycling.

Table 1.3 hazardous substances and their impacts.

WEEE components	**Toxic elements**	**Health issues caused by the exposure**
Printed circuit boards (PCBs), Poly vinyl chloride (PVC) cables	Bromide (Br)	Hormonal disorder issues, thyroid gland damage, loss of hearing, skin problems, DNA damages issues.
Capacitors, switches, batteries	Silver (Ag)	Skin pigmentation, effects brain, kidney, lungs and liver.
Arsenide embedded lamps and lights	Arsenic (As)	Cause lung cancer, skin disorder and impaired nervous system.
Battery, semiconductors, infrared (IR) detectors, printer ink and toner	Cadmium (Cd)	Pose serious risk of kidney damage.
Hard discs, computer housings	Cyanide (Cn)	Can cause to coma and death.
LCD, lamps, bulbs, batteries	Mercury (Hg)	Pose serious threat to kidney, brain and female foetuses.
LED, lead-acid battery, florescent tubes and lamps, transistors, solders	Lead (Pb)	Permanent damage to reproductive system, kidneys and nervous system.
Luminous component	Zinc (Zn)	Can pose serious risk to bone cancer.
CRT glass, computer housing, and solder alloy	Antimony (Sb)	Pose serious systems like, stomach ache and ulcer, vomiting and diarrhea.
Semiconductors, batteries, CRT, PCBs	Nickel (Ni)	Can cause body allergy, bronchitis, lungs disorder and cancer.

(Pathak et al., 2017)

1.4 WEEE management practices in India

According to MAIT-GTZ report, most of WEEE collected in India by informal sector with the help of waste pickers and scavengers and then handed over to dismantlers for further processes like segregating, dismantling, extracting valuable material and component for sold (Duan et al., 2011). The flow of WEEE in India is illustrated in figure 1.3. The ever-escalating prices of raw or virgin material have made informal or backyard recycling a one of the major reason for livelihood option and offers a great opportunity to the people to get attracted towards the informal recycling sectors. These informal and un-organized sector extracts all the material and reused part from the waste by employing primitive and backyard recycling practices. The residual material left out after backyard recycling is mixed with other solid waste and then dumped into open land which leads to deteriorating the environment and aquatic system (Zhang et al., 2014).

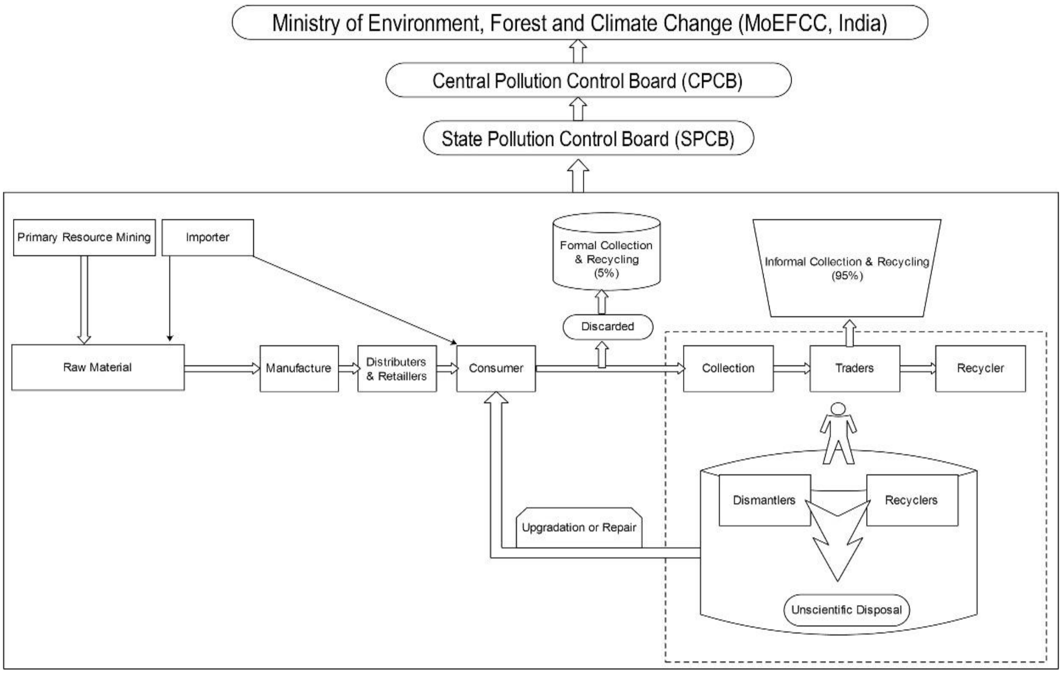

Figure 1.3 Represents the flow of WEEE in India (Awasthi and li, 2017).

The primitive and crude method used by informal recycling sector are; (i) manual dismantling using screw-driver, hammer, chisels and bare hands to separate various component presents in WEEE, (ii) open-pit acid baths for precious material recovery such as gold, silver, tin, etc., (iii) burning cables in open air for copper recovery, (iv) melting plastic in open air, (v) finally disposing unsalvageable material in open dumps or riversides. Table 1.4 shows the comparative gaps between informal and formal recycling practices in India.

Table 1.4 Comparative gaps between informal and formal recycling practices in India.

Informal recycling	**Formal recycling**
1. Manual dismantling and processing techniques of CRTs (cathode ray tubes) for segregation of glass and metal. *Remarks:* ▪ *The glass and other refractories recovered from the CRTs sold to the bangle makers.* ▪ *Release of phosphorous can be toxic if inhaled.* ▪ *Segregated CRTs are sold to the second hand market for local television makers.*	1. Segregation of glass and metal from CRTs in an air-closed chamber through heating and crushing machines. *Remarks:* ▪ *To minimize the impact of phosphorus, formal recycling units equipped with proper sucking system for takeout.* ▪ *Lead recovers from CRTs sold to the authorized companies for remanufacturing new batteries.*
2. Open-pit burning, acid baths methods are mainly used for precious metal recovery like gold (Au) and brass from PCBs, microchips and condensers. In this recycling sector, safety measures are avoided by workers. *Remarks:* ▪ *Workers are more prone to toxic fumes released from the waste.* ▪ *Acid bath methods can cause to toxicity hen residual disposed off into the open land.* ▪ *Lack of safety measures.* ▪ *Prone to health hazards.* ▪ *Low wages to workers.*	2. Electro-refining and smelting methods are used for separation in a closed chamber to recover metals such as nickel, gold, lead, copper, tin silver, palladium, etc. In formal recycling sector, proper safety and health hazards measure are taken for workers engaged in recycling and extraction activities. *Remark:* ▪ *Extraction is done under closed chamber.* ▪ *Dedicated funds invested for providing safety to workers.*
3. Low cost investment, weak infrastructure, primitive activities executed from home or through rented spaces. *Remark:* ▪ *Investment in illegal transboundary movement of WEEE from nation to nation or region to region.*	3. High capital investment for well- equipped infrastructure for environmentally sound WEEE recycling. *Remark:* ▪ *Recycling and disposal sites needs high capital investment for smooth functioning.*

Currently in India, more than 180 formal WEEE recycling units across the country authorized by central pollution control board (CPCB) which are operated by automated, semi-automated and manual operation for recycling and dismantling activities and their total capacity for WEEE recycling reported as 4.38 lakh tonnes per annum. To reduce the WEEE volume, recycling units should adopt best available technology (BAT) and best environmental practices (BEP) as a solution (Awasthi and Li, 2017). Recycling of WEEE should be beneficial to the environment when discarded. Environmentally sound WEEE management requires the establishment of collection centers, transportation, treatment, storage, recovery and disposal of WEEE, at national and/or regional levels. Regulatory authorities should have to provide these facilities and for the better performance there should be incentives. The government has to encourage the NGO's and manufacturers for establishing waste collection, exchange, recycling facilities at district, state and national levels (Cucchiella et al., 2015). The recycling and extraction facilities need to have proper air pollution control plans for the escape and point source emissions. Garlapati (2016) suggested that the use of biotechnological initiatives proved to be an eco-friendly approach for sustainable WEEE management. To achieve environmentally sound recycling of WEEE particular skill and training of operations should be required. Expert personnel are prerequisite for recycling step to screen the toxic and desirable substances from a complex WEEE then different environment friendly recycling processes have to adopt for toxic and desired substances separately. To minimize the adverse environmental impacts on the recycling personnel, obsolete gadgets have to provide by maintaining stringent environmental standards.

1.5 Need for environmental sound WEEE management

The UNEP in its annual meeting in 2016 has laid out an agenda for Sustainable development. Resource efficiency and sustainable consumption and production is the main goal for UNEP 2030 agenda for sustainable growth and development. This goal not only impacts the environmental improvement, but also involves sustained economic growth of the country through reduction in poverty, climate change and creating a sustained environment to live. A better understanding towards WEEE management is closely associated with sustainable development goals such as good health and well-being (Goal 3), clean water and sanitation (Goal 6), decent work and economic growth (Goal 8), Sustainable cities and communities (Goal 11), responsible consumption and production (Goal 12) and life below water (Goal 14). Inadequate treatment of WEEE can pose serious risks to human lives and contaminating soil, water and air due to the presence of various hazardous component in it. These issues are addressed in the above mentioned sustainable development goals (SDGs). The UNEP (2016) meeting came out with various focus areas for sustainable environmental and economic growth. These are:

Enabling Environment – It refers to giving support to participating countries in terms of creating an environment in which various policies are made that aims to reduce pollution, minimize landfill dumping and release of hazardous and toxic substances into environment to avoid air, soil and marine pollution. To achieve these goals, promotes the change towards sustainable WEEE management through better resource efficiency and sustainable production and consumption methods.

Shift towards sustainable cities and use of ICT – Most of WEEE will be generated in urban areas and it is important to manage WEEE adequately by increasing recycling rates through proper collection network which help to reduce the amount of WEEE ends up landfill sites. The shift towards smart cities and the use of information and communication technology (ICT) offers new and exciting opportunities to eastablish well equipped WEEE management in developing countries.

Responsible consumption and production – It refers to enhancing the lifestyle and awareness of the consumers in various developing countries and businesses so that they can make sustainable consumption and production as integral part of their day to day life through proper decision making which aims to substantially reduce WEEE generation through repair, reuse, and recycling.

1.6 Organization of the Thesis

The write-up of the thesis is divided into seven chapters as follows. The overall structure of the thesis is presented in Figure 1.4.

Chapter I presents the basic background and the need for the study. It highlights the importance of SMEs in economic growth of the country and also in innovation process. The basic definition of SMEs and various types of innovations are discussed at length. The need for green innovation in SMEs is also discussed and it also presents the basis structure of the whole thesis.

Chapter II provides an in-depth and exhaustive review of literature on WEEE management and recycling. This chapter through extensive review of literature attempts to record in various barriers to WEEE management implementation and adoption, various enablers of sustainable WEEE management based on green competencies which can act as criteria for selection of WEEE recycling partner. The gaps of previous studies and consequently the objectives of this study that emerged out of literature review have also been presented in this chapter.

Chapter III presents overall design of the study, which includes methodology adopted for carrying out the research work as well as various phases of the study. The details of various techniques/tools/methodologies employed for each phase of the study is presented in this chapter.

Chapter IV deals with the identification, finalization and prioritization of barriers to WEEE management implementation. This chapter proposes a framework using DEMATEL methodology. The framework helps to first rank barriers to WEEE management adoption and implementation and then determine the cause-effect relationship among the barriers of WEEE management.

Chapter V deals with the objectives 2 and 3 of the study i.e. Identifying, prioritizing and finding the relationship among the enablers of sustainable WEEE management adoption in Indian context and Selecting WEEE recycling partner for electronic manufacturing organization based on green competencies. The chapter is divided into two parts, in first part deals with the identifying the relationship among some selected enablers of sustainable WEEE management using Grey DEMATEL methodology. The second part involves in identification and prioritization of enablers of WEEE management and selecting best recycling partner on the basis of these enablers is done using an integrated fuzzy AHP and VIKOR methodology.

Chapter-VI provides a comprehensive framework to identify the criteria for the selection of sustainable WEEE recycling plant location. The framework was developed with the help of systematic literature review and discussion with domain experts. This chapter proposes a novel framework using integrated BWM-VIKOR methodology. The framework helps to first rank selection criteria based on STEEP consideration and then select the best location for the WEEE recycling plant.

Chapter VII provides a comprehensive overview of the research work conducted and the major findings along with the contribution of the present study in the existing set of literature. Besides, this chapter also provides the managerial implications of the present study. The last section of this chapter provides the limitation of the study. This chapter concludes by highlighting the suggestions related to scope of future work.

1.7 Chapter Summary

This chapter presents the basic background and the need for the study. The basic definition of WEEE or e-waste and various types of WEEE categories. Discussion on composition of WEEE including hazardous and non-hazardous components along with their impact on surrounding. After that the need for environmentally sound WEEE management is discussed. In the last section, the complete organization of the thesis is provided. Further in this, all sections mentioned in this chapter are discussed in detail in the subsequent chapters.

Review of the literature is the first logical step in a research effort and the next chapter is devoted to the same.

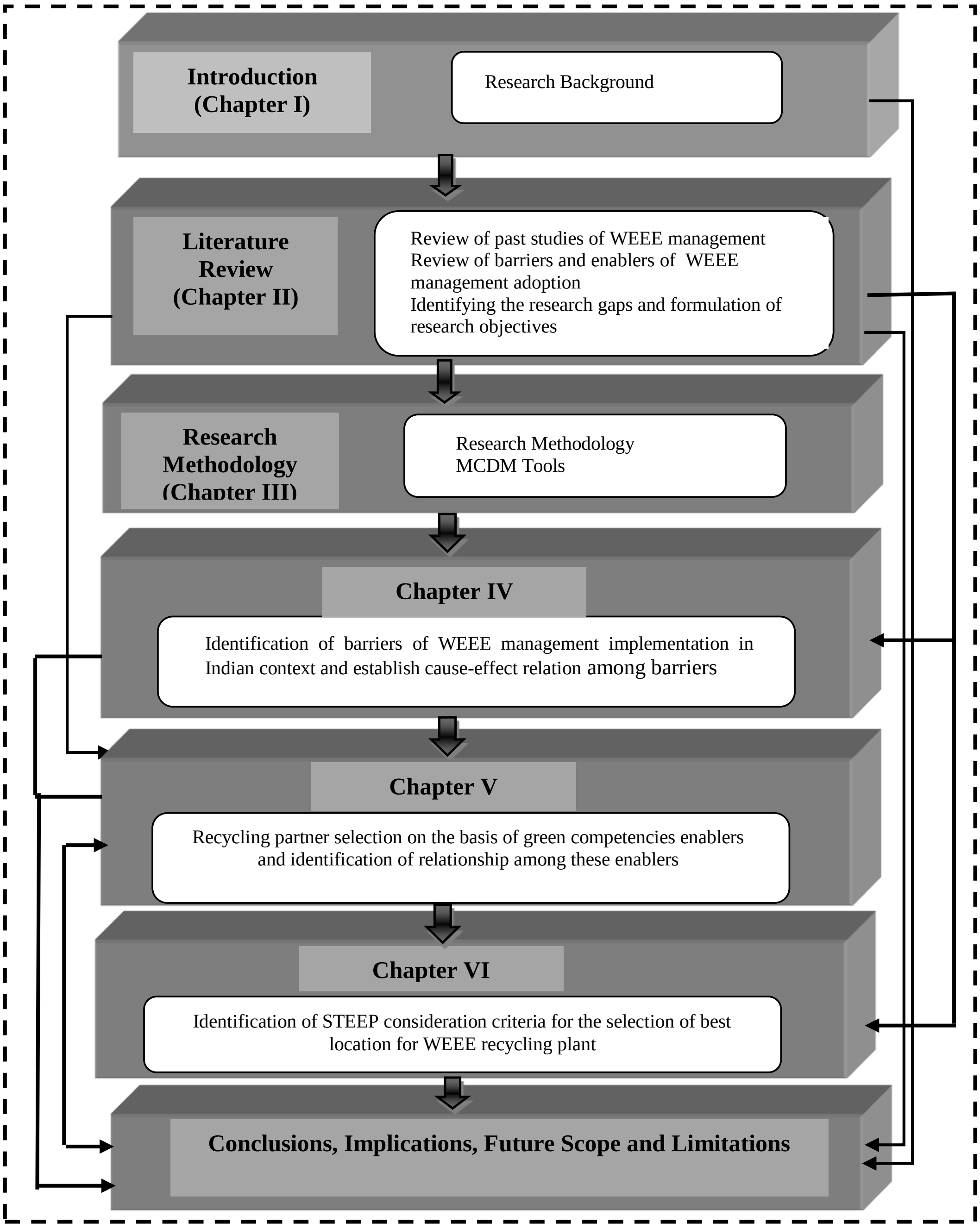

Figure 1.4 Thesis structure

CHAPTER - II
LITERATURE REVIEW

2.1 Introduction

This chapter provides an in-depth and exhaustive review of literature on WEEE management. Any research is incomplete without reviewing and analysing the past literature relevant to the research topic. This chapter through extensive review of literature attempts to record in brief the various barriers to WEEE management adoption/implementation, various enablers of sustainable WEEE management which can act as criteria for selection of WEEE recycling partner, and various evaluation criteria for the selection of sustainable WEEE recycling plant location based on STEEP consideration. The gaps of previous studies and consequently the objectives of this study that emerged out of literature review have also been presented in this chapter.

2.2 Literature Review at a Glance

According to Webster and Watson (2002) “A review of prior, relevant literature is an essential feature of any academic project. An effective review creates a firm foundation for advancing knowledge. It facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed”. On similar lines Fink (2005) defines literature review as “A literature review is a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners".

Through extensive literature review, this study tries to address following issues:

- Exploring the background and definitions of green innovation
- Identifying the various barriers and enablers of sustainable WEEE management adoption/implementation.
- Identifying the gaps in past literature and to formulate research objectives for this research

2.3 Literature Review Process

2.3.1 Units of Analysis and Delimiting

The primary criteria for selecting the papers were the papers published in English language in peer reviewed journals. It included papers from various journals, published book chapters, conference papers, few working papers, thesis related to the topic and case studies. The papers that were published in other languages were excluded from the literature review.

2.3.2 Method of Searching Literature

To search the relevant literature, we used popular keywords like WEEE or e-waste, recycling, WEEE management, recovery, closed loop supply chain of an electronic product, end of life management, enablers, etc. For the literature review, we considered the following sciences and social sciences databases such as ABI/Inform, EBSCO, ProQuest, Wiley. Emerald, Elsevier, Taylor and Francis, Science Direct, JSTOR, etc. Further, relevant papers and article were selected in the first phase. The article with relevance was still not clear were accessed after reading their abstract and keywords to further narrow down the article.

2.4. Theoretical underpinnings

This research is explicitly grounded on the basis of the socio-economic theories which provide suitable platform to support the issue and add to understanding the validity of such arrangement with respect to barriers hindering the implementation of WEEE management in India.

Literature suggests that a single theoretical foundation is not sufficient to explain issues relating to the adoption of EoL product recovery management. For example, Boudier and Bensebaa (2011), suggest theories including transaction cost economic (TCE), institutional theory (INT) and stakeholder theory (ST) to explain how cost constraints on waste management and recycling activities in developed nation coupled with socially irresponsible behavior. Several studies have used theory of planned behavior (TPB) to investigate the relationship between attitude and willingness to support policy measures on household waste recycling (Tonglet et al., 2004; Omran et al., 2009; Nigbur et al., 2010; Mahmud and Osman, 2010; Pakpour et al., 2014; Wan et al., 2015). A study by Lau and Wang (2009) suggest that combination of complementary theories like transaction cost economic (TCE) and resource based theory (RBT) have been used to assist firms in choosing an end of life product recovery management system. Similarly, Sarkis et al. (2011) investigated similarities and differences derived from the nine theoretical perspective such as Stakeholder theory (ST); Ecological Modernization theory (EMT); Information theory; Complexity theory (CT); Resource Dependence theory (RDT); Institutional theory; Resource Based View (RBV); Social Network theory (SNT); and Transaction Cost Economics (TCE) theory in their adoption of green supply chain management (GSCM) practices. A recent study by Rahman et al. (2017) have used three theories such as TCE, RBT and neo-institutional theory (NIT) as theoretical underpinning to rationalize the challenges faced by multinational third-party logistics (MN3PL) operating in china. However, there is still lack of theoretically grounded research for waste management in India. Even though when there are some studies relying on certain theories but they solely rely on that particular theory to explain the phenomena (Hazra et al., 2013; Khan et al., 2015; Dubey et al., 2017; Venkatesan and Annamalai, 2017). Given the related complexity in India, using multiple theories may be helpful to obtain wider perspectives of barriers to WEEE management implementation. At last, we consider six theories such as transaction cost economics (TCE), resource-based theory (RBT), theory of planned behavior (TPB), institutional theory (INT), social network theory (SNT) and stakeholder theory (ST) as theoretical foundation of our study. An overview of the theoretical foundation and relevant barriers are shown in Table 2. In the following sub-sections we briefly discuss each of these theories and discuss the rationale for their application in the context of barriers to the implementation of WEEE management in India.

2.4.1. Transaction cost economics (TCE)

The theory of transaction cost economics (TCE) is generally accepted framework for analyzing return management and outsourcing decision making (Williamson, 1985; Hobbs, 1996; Andersson, 1997; Skjoett-Larsen, 2000). Here the underlying principle is that sourcing arrangement that minimizes costs associated with various firm transactions such as market based exchange, legal costs of establishing contracts, costs associated with return management of obsolete electronic goods, monitoring costs, sales taxes etc. (Coase, 1995; Gonzalez-Diaz et al., 2000; Rahman and Wu, 2011; Williamson, 1991; Zacharia et al. 2011). As the various costs inherent in the market structure continue to increase, it becomes more efficient to minimize these costs by adopting a firm structure which includes team work, collaboration with other firms and information disclosure among the supply chain (Barthelemy and Quelin, 2006; Cao and Zhang, 2011; Yang and Huang, 2000). Simultaneously, economic performance improvement can result from environmental performance improvement due to waste reduction and resources conservation (Zhu et al., 2005).

2.4.2. Resource based theory (RBT)

Resource based theory (RBT) stipulates that firms can generate above normal rates of return and achieve sustainable competitive advantage over its competitors if they are well supported by organization level core competencies and resources (Barney, 1991; Wernerfelt, 1995; Rugman and Verbeke, 2002; Barthelemy and Quelin, 2006; Finney et al., 2008). These core competencies and resources includes in the form of tangible assets, human resource, organizational capital, resources used to design, manufacture, and supply goods and equally provide service to the consumers (Morgan and Hunt, 1999). Thus, in this context resource based theory is very much relevant to product return and WEEE recovery management research in several ways. According to Walsh (2006), resource based theory explains how firms distribute resources by investing in waste return management. Other studies also suggests that developing environmental management system (EMS) strategies can generate organizational capabilities, such as flexibility to manage technological change from current system, and improve stakeholder integration in the entire supply chain (Hart, 1995; Russo and Fouts, 1997; Sharma and Vrendenburg, 1998). Nevertheless, above all this, inadequate allocation of resources is cited as one of the most identified obstacle in successful implementation of end of life (EoL) product return management (Shaharudin et al., 2015a,b).

2.4.3. Theory of planned behavior (TPB)

The theory of planned behavior (TPB) (Ajzen, 1991) provides a theoretical framework which helps to analyze how consumer's attitude and behavior influenced willingness to pay (WTP) for recycling their household e-waste. This theory is important to understand recycling behavior which requires considerable efforts on the part of consumers to segregate and take recyclables to waste collection centers. Each step requires a conscious and rational decision making, in which past behavior continue to influence intentions to perform specific behaviors (Carrus et al., 2008). A study of Boldero (1995) argues that the influence of situational factors such as the amount of effort involved, inconvenience, storage space and access to recycling schemes affects the recycling behavior. Thus, effective policy measures can change mindsets and behaviors of the consumer towards recycling of the household waste (Wan et al., 2014). In addition, various studies have confirmed its applicibality for analyzing the determinants which influence the recycling decision (Boldero, 1995; Chan and lau, 2002; Fielding et al., 2008; Davis et al., 2006; Ghani et al., 2013; Pakpour et al., 2014; Shelton and Medina, 2010; Taylor and Todd, 1995; Terry et al., 1999).

2.4.4. Institutional theory (INT)

Institutional theory (INT) provides an appropriate platform which can be used to examine how global pressure will influence manufacturers to adopt green or environmental practices in their organizational activities (Hirsh, 1975; Jennings and Zandbergen, 1995; Delmas and Toffel, 2004; Rivera, 2004; Zailani et al., 2012). This theory can be disseminate to organizations in a three forms of isomorphic drivers such as coercive isomorphism, normative isomorphism and mimetic isomorphism to improve green performance (DiMaggio and Powell, 2000; Sarkis et al., 2011; Scott, 2001; Wade-Benzoni et al., 2002). In addition, product return and recovery management can be associated with firm's social responsibilities. Oher studies also suggested that global environmental regulation, competitiveness and market forces are the key drivers that may motivate the firms manage environmental and waste return practices on a voluntary basis that meets social and legal expectation (Arora and Cason, 1995; Khanna and Damon, 1999; Kilbourne et al., 2002; Streck, 2004; Clemens and Douglas, 2006; Zailani et al., 2015).

2.4.5. Social network theory (SNT)

Social network theory (SNT) provides a suitable theoretical foundation to understand general sustainability developments (Connelly et al., 2010). In this theory, firms that have the ability to work with teams and collaborate with other firms are in the position to create competitive advantage in global market. Social network theory also examine the network structures and their role in the environmental oriented supply chain management practices. This theory helps firms to gain benefits by linking structural holes in a social network (Ahuja, 2000; Wuyts et al., 2004). Few studies suggested that social network theory has been explicitly focused, such as reverse logistics, green supply chain practices, environmental collaboration for developing recyclable products and cleaner technology (Ellram, 1990; Walton et al., 1998). In general words, social network theory provides an explanation for the alliance of different types of relationships based on the economic motivation, power trust and freedom (Uzzi, 1997).

2.4.6. Stakeholder theory (ST)

A stakeholder (actor) is any group or individual within the supply chain, especially when environmental strategies are introduced in an organizational objectives (Freeman, 1983; De Brito et al., 2008). Stakeholder theory (ST) provides theoretical foundation to explain the antecedent of implementing environmental or green practices in an organization like, product return and recovery management. Other studies also suggested that stakeholder theory has been used extensively in environmental management research, such as specific stakeholder influence on green purchasing, life cycle assessment in the supply chain, closed-loop supply chain, and green logistics practices (Björklund, 2010; Chien and Shih, 2007; Maignan and McAlister, 2003; Matos and Hall, 2007; Sarkis et al., 2010; Zhu et al., 2008). This theory also helps in investigating the defined role of various stakeholder with in the green supply chain practices and innovation diffusion (De Brito et al., 2008; Gonzalez-Torre et al., 2010; Gunther and Scheibe, 2005; Vachon and Klassen, 2008).

2.5. Review of Enablers of and Barriers to WEEE management adoption in developing and developed nations

As per the recent studies, it has been observed that the developing nations are much bigger producers of e-waste, and it will become twice that of the developed nations within the next six to eight years. It has been also 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 have been made through computer modeling that the developing countries will be more responsible for dumping computer systems rather than the developed countries by 2016 (Devi et al., 2004; Wath et al., 2010). Furthermore, the OECD nations export their e-waste to the non-OECD nations like China, Malaysia, Thailand, and India, and the dumping of the e-waste is raising severe concerns, even though the OECD countries are having the permission to export the unnecessary goods to poor nations for reuse or remanufacturing. This is leading to the erroneous classification of the non-functional goods as “used goods”. A substantial quantity of e-waste exports are administered outside European countries as well as Western African countries because of its hasty recycling processes in these regions, thereby leading to considerable environmental pollution and health hazards for the local people. Furthermore, the failure of recovering rare earth minerals has created problem related to the production of future electronic equipments (Duan et al., 2015).

According to Liu et al. (2006) studied the adverse impacts on human lives as well as the environment from backyard WEEE (waste electrical and electronic equipment) recycling due to the lack of stringent management practices. This study also reported that 60% of WEEE sold to the unorganized sector for informal recycling because 90% of resident have been reluctant to pay for formal recycling. Finding suggests that extended producer responsibilities have not fully implemented and the majority of formal facilities were not well equipped to tackle and compete with the informal sector. Streicher-Porte et al. (2007) studied that majority of WEEE generated in China is handled mostly by the informal recycling sector. The authors aimed to analyze the costs of logistics and storage of WEEE within both organized and un-organized recycling sector. Kahhat et al. (2008) conducted a study aimed to explores the challenges relating to future WEEE management policy and regulation in the context of United States.

Results of the study suggest that e-market refund deposit (e-MRF) scheme was designed to ensure a proper end of life (EoL) option and establish a competitive market for recycling, recovery and reuse services. Zaccai (2008), consumer's behavior plays an important role in environmental activities like purchasing green electronic products, keeping and employing electronic items to reduce hazardous impact on environment, and castigating disposal practices. Manomiavibool (2009) conducted a study to explore the feasibility of dealing with WEEE which resulted to the health and environmental hazards in non-OECD countries like India and China due to a poor WEEE management system and the existence of large informal recycling network. Authors used India as a case study for the identification of barriers and challenges for the implementation EPR mechanism. The study also suggested that timely implementation of extended producer responsibility (EPR) mechanism can be a driving force for the formal integration of the informal sector with the existing formal sector and strengthen voluntary take-back initiatives. Nnorom et al. (2009) explained the consumers' willingness to pay (WTP) initiative for greener product purchasing and developed a model depicting consumers' awareness and attitude toward environment protection. Solomon (2010) analyzed that environmental education, environmental laws and ethics are the three crucial disciplines in the enhancement and protection of environment; and out of these three disciplines, environmental ethics play as the role of an intermediate for the other two disciplines. Zoetman et al. (2010) analyzed the extrinsic factors such as extended producer responsibility (EPR), WEEE management regulation promoting closed-loop or reverse supply chain which helps to enhance high-level resource recovery and minimize degradation of an environment. Dwivedy and Mittal (2010) proposed a study to construct a model which helps to estimate the future generation of WEEE by considering their reuse and final disposal in the Indian context. Results of the estimation model will help in the organized recycling sector decision making in building an appropriate infrastructure for recycling activities in an environmentally sound way. Wath et al. (2010) presented an assessment of WEEE management system of developed as well as developing economies with a special reference of Switzerland, which is named as the first nation to adopted a formal WEEE management system. The authors also reported that it is difficult for a nation like India to completely replicate the WEEE management system that implemented in developed nations due to various reasons viz. poor infrastructure, socio-economic conditions, lack of stringent policies and regulation, lack of commitment and defined responsibilities of the concerned authorities. Yu et al. (2010) conducted a study to review the existing regulatory framework and pilot project for e-waste management in China. In this study, the authors reported that a deposit refund system which encourages consumers to return their e-waste and share financial benefits with authorities and electronic manufacturers plays a key success factor the successful of e-waste management project. Bereketli et al. (2011) conducted a study to identify and analyze the criteria for WEEE treatment strategies in the case of the Turkish telecommunication industry. A total of eight criteria were identified and analyzed using fuzzy LINMAP to rank the alternatives (linear programming technique for multidimensional analysis of preference). The identified criteria includes period of waste release, resource conservation ratio, initial investment cost, risk to damage natural habitat, capacity, convenience, stock and process cost. Wath et al. (2011) conducted a study which accounts e-waste generation, a composition based on recyclable and hazardous substance, categorization and best available practices available globally and in Indian scenarios such as recycling and resource recovery and reported their impact on the environment as well as on human lives. Wang et al. (2012) introduced the 'Best-of-2-Worlds' philosophy (Bo2W) which provides a theoretical recommendation and WEEE mitigation strategies to tackle the enormous rise in the waste in the emerging economies. The mitigation strategies integrating best WEEE recycling practices to treat hazardous and complex waste can serve as an eco-efficient than primitive recycling treatments. These mitigation strategies include formal take-back, adequate financing support to formal recycling sector and stringent WEEE management policies.Saphores et al. (2012) further evidenced that gender, marital status, awareness of toxic waste, recycling convenience, and previous e-waste recycling experience are the most important factors behind the explication of household willingness to pay for e-waste recycling in USA. Dwivedy and Mittal (2013) determined that consumer's attitude toward recycling, demographic, household income, and other economic profits substantially affect consumer's willingness to take part in recycling of e-waste in India. Agamuthu and Victor (2013) examined the WEEE polict trends includes WEEE regulatory framework, inventoties and data of WEEE generation, capacity and infrastructural building which indicates a positive roadmap towards sustainable WEEE managemement in Asian countries. Abdulrahman et al. (2014) investigated critical barriers in the implementation of electronic waste reverse logistics practices in Chinese electronic manufacturing industry. The finding suggested that lack of experts for reverse logistics, low commitement from the top management, lack of financial support for product return management, poor policy framework and lack of monitoring system for waste assessment affecting the implementation process. Sarkhel et al. (2015) examined the pre and post payment made by consumers for meliorated waste management in Bally Municipality in India. For managing the environmental concerns appropriately, the establishment of the following setups both at regional as well as national levels is essential. These steps are installation of adequate infrastructure such as transport facilities, storage centers, recycling plants, metal recovery, and disposal of electronic waste (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, development of suitable skill and proper training of recycling processes will be required to acquire environmentally sound recycling of e-waste (Yeh and Xu, 2013). As a prerequisite for recycling, professionals will be required to screen the noxious and wanted elements from the intricate electronic waste, and subsequently, the different eco-friendly recycling treatment can be adopted for both the noxious and wanted elements, separately (Zhang et al., 2012; Mukherjee et al., 2017). Therefore, the usage of obsolete gadgets should be prohibited and stringent environmental standards must be maintained for minimizing the negative effects of environment on the recycling personnel. The air pollution control strategies need to be adopted for the escape and point source emissions to facilitate the recycling process. In the current scenario, both private sectors as well as public sector are coming together to find a new way of recycling that is environment friendly, as it is the source of wealth for the private firms (Garlapati, 2016). Table 2.1 lists the past studies on waste management with application of multi-criteria decision making (MCDM).

Table 2.1 Past studies on waste management with application of MCDM

Author	**Methodology**	**Contribution**
Ravi et al. (2005)	ANP	They studied the challenges and enablers related to options in close-loop supply chain or reverse logistics for end of life (EOL) computers. Results indicates the four major perspective: customer, internal business practices, innovation and financial perspectives.
Rousis et al. (2008)	PROMETHEE	In this study authors examined and prioritized the alternative for WEEE management system by using MCDM approach based on their recycling performance and efficiency. The results showed that partial disassembly option and selling recycled material to the local market obtained most suitable option for WEEE management adoption in the case of Cyprus.
Queiruga et al. (2008)	PROMETHEE	In this study authors studied existing and future WEEE recycling plant facilities in order to treat the waste. The study came outwith three major objectives such as economic, infrastructural and legal fpr the optimal location of WEEE recycling plant site.
Tseng (2009)	ANP and DEMATEL	Author identified 17 critical decision making factors with 6 alternative solution to waste management and excessive landfilling

		issues. Finding of the study suggested human health is the main criteria nedd to be addressed and established thermal recycling technology for waste management for each city.
Sasikumar and Haq (2010)	ISM	They suggested that recycling is widely accepted for sustainable waste management option because of tendency to minimize logistics costs, disposal costs and the cost associated with landfill sites. Finding also suggested that critical barriers related to the WEEE recycling such as regulatory barriers, lack of policy support, lack of financial support, etc.
Ciocoiu et al. (2011)	AHP	Authors proposed a model based on the evaluation of social, economic, environmental, technical and political issues that affects the sustainable WEEE management implementation. Findings of the study suggested that environmental issues got the top ranking in the successful implementation of WEEE management system.
Sasikumar and Haq (2011)	Fuzzy VIKOR and Integer programming	They proposed a hybrid FMCDM-Multi-echelon network for the selection of WEEE recycling partner to recycle and recover lead from the used battery for the production of new battery. Findings also suggested 50%

		return rates is achieved in closed-loop supply chain activities.
Sharma et al. (2011)	ISM	They conducted a research to analyze the barriers of electronic waste reverse supply chain adoption in India. The study come out with 11 barriers that hinders the adoption of waste revese logistics out of which three barriers namely poor awareness about reverse supply chain, legal issues and financial constraint are categorized in independent group and studied more carefully than others in the successful adoption of WEEE reverse management.
Nouri et al. (2011)	ANP	They developed a decision making model for sustainable solid waste management practice.
Chiou et al. (2012)	Fuzzy AHP	In this study authors focuses on environmental, economic and social criteria for the implementation of reverse logistics practices in Taiwanese electronics industry. The outcome of the study revealed top three crucial criteria for successful implementation of reverse logistics activities such as envirormental regulation and directives, volume of WEEE recycled and cost assocated with recycling activities.
Rahman and Subramanian	DEMATEL	In this study, authors investigated the causal relationship among the factors for

(2012)		implementing end of life computer recycling operation. Results indicated that coordination among reverse logistics activities, resource availability and the volume and quality of recycled material are found crucial for recycling activities.
Shokohyar et al. (2013)	Mathematical optimization	They developed a simulation based optimization model which consider all the aspects of sustainability viz. social, economic and environmental aspect to evaluate the optimal site for WEEE collection and recycling in Iran. The developed model helps to maximize social benefits and reduce the environmental impact of the WEEE recycling activities.
Dou and Sarkis (2013)	Grey based DEMATEL	They analysed the internal and external barriers based on multiple stakeholders perspectives for implementation of restriction of hazardous substances(RoHS) in the Chinese electronics manufacturing company. Results of the study showed that lack of government supportive policies regarding RoHS implementation strongly influenced the funding support initiatives and lack of RoHS practices to manage the WEEE.
Yeh and Xu (2013)	Fuzzy MCDM optimal weight model	In this study authors developed a new model to evaluate the alternate WEEE recycling

		activities of WEEE recycling job in oorder to improve for corporate sustainability performance index by taking into account social , economic and environmental dimensions.
Herva and Roca (2013)	AHPand PROMETHEE	They analysed and ranking the recycling treatment alternatives in municipal solid waste management (MSWM). Results indicated that plasma gasification found to be most suitable treatment for solid waste management in order to energy recovery.
Ziout et al. (2014)	AHP	They proposed a PESTEL model which helps in stakeholders decision-making foe selecting end of life (EoL) product recovery options. Results suggested that remanufacturing proved to be the most profitable option whereas, cost-benefit analysis found suitable to addressed the economic details for the second level of recycling and recovery alternatives.
Ravi (2015)	ISM	In this study author investigated the interaction among the identified ten barriers of eco-efficiency in electronic packaging industry. The findings of the study suggested that lack of proper disposal of used product, lack of green product and lack of R&D found to be weak drivers and dependent on the other barriers.

Srivastava and Sharma (2015)	ISM	They develop the relationships among the identified e-waste management factors. Using ISM approach to evolve mutual relationships among these factors.
An et al. (2015)	AHP and VIKOR	In this study authors analysed the barriers that hinder the sustainable development of WEEE recycling industries.
Ahmed et al. (2016)	AHP and DEMATEL	They proposed an integrated model to select the dimensions and criteria for evaluating sustainable alternatives for the proper management of ELVs. MCDM method is used to select the most important dimensions and criteria for sustainable alternative selection. Next, a hierarchy has been constructed to develop a systematic technique to solve the alternatives selection problem.
Soltani et al. (2016)	AHP and Game Theory	They analysed the factors for sustainable waste to energy (WTE) technology selection in solid waste management.
Welfens et al. (2016)	ISM	In this study authors analysed drivers and barriers to returning and recycling mobile phones and their consideration. Results indicated that main factors that influence return and recycling behaviour focussing on mobile phones focused on poor awareness, lack of willingness to pay (WTP) and inadequate infrastructure for collection and

		recycling.
Xu and Yeh (2017)	Optimal weighting MCDM	In this study authors developed a novel approach for decision making in order to select a WEEE recycling activities and operations based on social, economic and environmental performances. The results outcomes suggested that job-oriented sustainability based approach significantly enhances the consistency, efficiency and sustainability of WEEE recycling jobs.
Milutinović et al. (2017)	LCA and AHP	In this study authors used LCA and AHP to rank the four scenarios according to the goal of environmental performance. The finding of the study suggested that anaerobic digestion for energy recovery found to be more appropriate scenario for achieving the desired goal of sustainable environmental performance.
Bhatia and Srivastava (2018)	Grey-DEMATEL	In this study authors analyzed the interrelationship among the external barriers to remanufacturing in Indian WEEE management sector. Finding of the study suggested that lack of collection channel for obsolete product is found to be crucial barriers for remanufacturing.
Chauhan et al. (2018)	ISM and DEMATEL	They analyzed 15 barriers for e-waste recycling in the Indian context to determine the hierarchical structure and causal relation

		among the barriers. The study finding suggested that lack of funds, subsidies and tax tariffs, waste availability are the most influential barriers for the development of WEEE management system.
Sahu et al. (2018)	Grey-DEMATEL	They investigated causal relationship among the key enablers which are responsible for replacing behavior existing working mobiles phones with with new ones by consumers.
Khoshand et al. (2019)	Fuzzy AHP	In this study authors developed a model by integrating fuzzy AHP method to evaluate the alternatives for e-waste collection and processing in Iran. The alternatives used for processing and collection are; recycling, landfilling, exporting, special event, drop-off and door to door collection. Results suggested that recycling and drop-off marked highest importance among other alternatives.

2.6. Review of recycling partner selection based on environmental and green competencies

Recyling partner selection is a strategic decision which requires a wide range of factors and techniques, which can be both qualitative and quantitative. Choosing right criteria is very important for undertaking the process of supplier selection to get the desired results, but choosing appropriate methodology is equally important to get the desired results. Wide range of techniques like AHP, Fuzzy AHP, TOPSIS, Fuzzy TOPSIS, DEMATEL, VIKOR, COPRAS, BWM, ELECTRE, MILP etc. are available in literature. Recycling of used electronic product or WEEE has emerged as a thrust research field since the last decade. A study by Murphy and Poist (2000) posited that recycling of WEEE, minimizing the consumption of renewable resources, and reusing the recycled material are the three key green strategies for handling the waste. Recycling can be defined as the collection, dismantle and de-manufacture in order to recover the valuable assets from the end of life (EoL) electronic product (Knemeyer et al., 2002). In order to meet the environmental regulation and norms, many researchers have studied the various criteria of green supplier selection (Bereketli et al., 2011; Chiou et al., 2008; Hsu et al., 2012; Kaya, 2012; Lee et al., 2009; Tseng and Chiu, 2013; Chakraborty et al., 2017). Besides environmental performance measures, the partner's selection literature is rich in terms of conceptual and decision models. The goal of partners' selection is a multi-criteria decision-making problem to evaluate partners for satisfying manufacturers' standards by using a set of organizational and operational criteria (Akarte et al., 2001; Huang and Keskar, 2007). Previous research studies suggested that widespread acceptance for MCDA approaches in the selection of green partners' selection (Chiou et al., 2008; Grisi et al., 2010; Hsu and Hsu, 2008; Noci 1997; Yan, 2009; Yeh and Chuang, 2011). For example, the study of Tam and Tummala (2001) identified 7 specific criteria for vendor selection including quality of service, solving capability, expertise, delivery lead time, cost of support services, experience and vendor reputation. By incorporating the environmental criteria into the supplier assessment, Handfield et al. (2002) utilized AHP method to construct an evaluation framework to assist managers in environmentally conscious purchasing decision making. Ravi et al. (2005) employed balanced scorecard (BSC) and analytical network process (ANP) model to evaluate the alternatives of reverse logistics operations for EoL computers. Lu et al. (2007) proposed AHP approach to evaluating the green supplier on the basis of environmental and economic aspects. Kannan et al. (2008) used ISM and AHP methodology to rank the supplier on the basis of green practices. Hsu and Hu (2009) identified 5 main criteria and 19 sub-criteria to select the best supplier on the basis of green practices by using analytical network process (ANP) model. Gumus (2009) used two-step FAHP and TOPSIS methodology to evaluate nine factors to evaluate the hazardous waste transportation firm. Lee et al. (2009) proposed a fuzzy analytical hierarchal process (AHP) model to evaluate the green suppliers with the consideration of various criteria such as technological upgradation, pollution production, environmental management system, green core competencies in the high tech industry. Awasthi et al. (2010) employed a fuzzy technique for order preference by similarity to ideal solution (TOPSIS) approach to select the best green supplier on the basis of environmental performance and mentioned that availability of cleaner technologies, green image, green products and compliance with environmental regulation are the key criteria in green supplier selection literature. Bai and Sarkis (2010) integrated grey system and rough set approach into supplier selection on the basis of sustainable practices like resource consumption, pollution control and mitigation practices and pollution production. Sasikumar and Haq (2010) used integrated VIKOR-MOOP approach to select the best recycling partners for the electronics industry. Büyüközkan and Çifçi (2012) proposed a hybrid MCDM approach in the evaluation of green supply chain partners' selection. Kabir (2015) proposed VIKOR approach to select hazardous waste transportation firm under fuzzy environment. Govindan et al. (2013) used multi-criteria approach to evaluate the supplier performance under fuzzy environment. He considered eco-design, pollution control, resource consumption and environmental management system as environmental criteria for measuring the sustainability of a supplier. Kannan et al. (2014) proposed fuzzy MCDM framework to select supplier on the basis of 17 green supply chain practices in the case of Brazilian electronics industries. In the recent review of Nielsen et al. (2014) and Govindan et al. (2015), they identified environmental management system (EMS) as the most important environmental criteria amongst other identified measures. Hashemi et al. (2015) employed the combined application of analytical network process (ANP) and grey relational analysis (GRA) to investigate economic as well as environmental aspects for the selection of a green supplier. Prakash and Barua (2016b) integrated MCDM to investigate the selection criteria for selection of best reverse logistics partners in the case of Indian electronic industries. This paper identified 7 main criteria namely firm performance, reverse logistics operation, resource capacity, service delivery, communication and IT systems, geographical location and reputation. Gupta and Barua (2017) utilized best worst method (BWM) and fuzzy TOPSIS to select supplier on the basis of various drivers of green innovation. Authors categorized the seven main criteria for green innovation. The author stated that resource availability and core competencies have been identified as the key criteria for supplier selection on the basis of green innovation ability. Use of these techniques vary depending upon the objectives of the study and the accuracy of these techniques in meeting those objectives. Just selecting the right criteria will not solve the purpose unless the correct methodology is applied. This section aims to review the important methodologies applied by various authors for supplier selection. Many authors have used single methodology for supplier selection like Liu et al., 2000 (DEA); Ghodsypour and O'Brien, 2001 (Mixed Integer Non Linear Programming); Sarkis and Talluri, 2002 (ANP); Rezaei et al., 2015, 2016 (BWM), but most of the authors have used hybrid of two methodologies for supplier selection, like, Ghodsypour and O'Brien, 1998 (AHP and Linear Programming); Thakkar et al., 2005 (ISM and ANP); Xia and Wu, 2007 (AHP and Rough Set Theory); Thongchattu and Siripokapiram, 2010 (AHP and ANN); Mohanty and Aouni, 2010; Kannan et al., 2013; Chaudhari et al., 2013; Gupta and Mohanty, 2016 (Fuzzy AHP, Fuzzy TOPSIS and MOLP); Prakash and Barua, 2016 (Fuzzy AHP and Fuzzy TOPSIS); Luthra et al., 2017 (AHP and VIKOR), this shows an emerging trend of use of hybrid methodologies for supplier selection. Also, some new methodologies have emerged like COPRAS and BWM which are used very recently and are widely accepted by the researchers due to their ease of applicability and consistency in results. Table 2.2 presents a brief overview of the methodologies applied for supplier selection by various authors.

Table 2.2 Review of past studies on partner/supplier selection based on green/environmental competencies

Authors	**Key area**	**Key criteria**	**Methodology used**
Lee et al. (2009)	Green Supplier selection	Quality, Finance, Organization, Technology Capability and Service	DELPHI and Fuzzy AHP
Bai and Sarkis (2010)	Sustainable supplier selection	Environmental management system, Pollution control, Resource consumption, Health and safety and Stakeholders influence	Grey systems and Rough set

Authors	Key area	Key criteria	Methodology used
Kuo et al. (2010)	Green partner Selection	Corporate Social Responsibility, Service, Delivery, Cost, Quality and Environment	ANN and MADA
Büyüközkan and Çifçi (2011)	Sustainable supplier selection	Organization, Financial performance, Service quality and Technology	Fuzzy ANP
Shaw et al. (2012)	Supplier selection for low carbon supply chain	Cost, Quality percentage, Greenhouse gas emission, Market demand	Fuzzy AHP and Fuzzy MOLP
Hsu et al. (2013)	Supplier selection in green supply chain management	Carbon governance, Training related to carbon management, Supplier collaboration, Carbon accounting and inventory	DEMATEL
Kannan et al. (2013)	Green supplier selection and order evaluation	Cost, Technology capability, Environmental competency	Fuzzy AHP, TOPSIS and MOLP
Dobos, and Vörösmarty (2014)	Green Supplier Selection	Reusability, CO_2 emission, Quality and Price	DEA type composite indicators
Kumar et al. (2014)	Green Supplier Selection	Price, Lead time and Carbon foot-print	DEA
Tsui and Wen (2014)	Green supplier selection in electronics industry	Environmental factor, R&D capability, current capability	AHP and ELECTRE III
Cao et al. (2015)	Green Supplier Selection	Environmental costs, Remanufacturing activities, Reverse logistics, Energy consumption and Waste management	Fuzzy TOPSIS
Freeman and Chen (2015)	Green Supplier Selection	Environmental management performance, Green competency, Cost, Quality and Delivery Schedule	AHP, Entropy and TOPSIS

Authors	Key area	Key criteria	Methodology used
Hashemi et al. (2015)	Green partner selection	Technology, Innovativeness, Eco-design, Environmental management system	ANP and Grey relational analysis
Kannan et al. (2015)	Green supplier selection	Quality, Price, Capability of suppliers, Environmental management, Green innovation	Fuzzy Axiomatic Design (FAD)
Awasthi and Kannan (2016)	Green supplier development	Resources, Emissions, Green Packaging, Green manufacturing, Green product design	Fuzzy NGT and VIKOR
Fallahpour et al. (2016)	Green supplier selection under fuzzy environment	Environmental management studies, Supplier's green image, Green competencies, Green product innovation, Eco design	DEA and Genetic programming
Govindan, and Sivakumar (2016)	Green Supplier Selection	Cost, Quality, Delivery, Recycle capability and GHS emissions	Fuzzy TOPSIS and MOLP
Rezaei et al. (2016)	Supplier selection life cycle approach	Resource consumption, Environmental costs, Green R&D, Green Design, Recycling	Best worst method
Bakeshlou et al. (2017)	Green Supplier Selection	Environment, Technology capability, Service, Quality and Cost	Fuzzy ANP, Fuzzy DEMATEL and Fuzzy MOLP
Luthra et al. (2017)	Sustainable supplier selection	Environmental costs, Quality of product, Price of product, Environmental competencies	AHP and VIKOR
Qin et al. (2017)	Green Supplier Selection	Green product innovation, Green image, Resource consumption, Green competencies and Staff environmental training	Fuzzy TODIM

Authors	Key area	Key criteria	Methodology used
Yazdani et al. (2017)	Green Supplier Selection	Financial stability, Management commitment, Facility, Reverse logistics, green design and environmental management system	QFD, DEMATEL, COPRAS and MOORA
Garg and Sharma (2018)	Sustainable outsourcing partner	Green purchasing, cleaner technologies, waste minimization, green certification, green packaging, green manufacturing and marketing	Best-worst method and VIKOR
Vahidi et al. (2018)	Sustainable supplier selection	Green technologies, energy consumption, amount of solid waste, pollution production and usage of toxic substances	SWOT and QFD
Guarnieri et al. (2019)	Sustainable supplier selection	Hazardous waste management, environmental management, green image, diversity, environmental costs	ELECTRE
Haeri and Razaei (2019)	Green supplier selection	Resource consumption, eco-design, green image, green product, green innovativeness, green technologies, environmental management system	Grey relational analysis and BWM

2.7. Review on WEEE recycling plant site selection and modelling techniques

Considering the evaluation system, the indicators of the WEEE recycling plant site selection are investigated from various aspects in the past studies. Chau (2005) proposed various risks criteria such as water mitigation, waste compositions, and objective risks in the selection of new landfill sites for solid waste recycling. Norese (2006) explored the sustainable dimensions and criteria for waste incinerator site, the criteria consist of technical aspects, local development, environmental aspects, social equity, and so on. Queiruga et al. (2008) suggested the economic, infrastructural, and legal objectives for the selection of WEEE recycling plant site in Spain. Ekmekcioglu et al. (2010) employed AHP and TOPSIS for the evaluation of best disposal alternative in Istanbul. In this study authors evaluated suitable criteria for to determine the combustion plant location such as land use, climate, road access, and, cost. Achillas et al. (2011) reported that special attention given to the infrastructural viability which is almost dependent on facilities' location Eskandari et al. (2012) investigated the issues associated with the socio-cultural, technical, environmental, hydrological, and geological issues. Ferreti and Pomarico (2012) integrated the sustainability assessments indicators for spatial evaluation of waste incinerator plant in the Torino city of Italy. Therefore, the identification of feasible land use for constructing and developing the waste recycling plant is very crucial (Wang et al., 2009; Kharat et al., 2016). Kumar and Hassan (2013) took various factors into consideration such as proximity to residential areas, water bodies, natural habitat, transport accessibility while planning for the selection of plant site. Banar et al. (2014) devised a set of indicator that helps in site selection by including acquisition costs, production and maintenance costs, compliance with laws, environmental grants and job creation. Fidelis et al. (2015) established an evaluation system for the site selection problem by considering environmental implication, health, and safety of local residents, and collaboration. Zhao et al. (2016) in their study investigated the influence of return of investment (ROI), net present value (NPV), and internal rate of return (IRR) while selecting the recycling plant site. Mohib-Ul-Haque khan et al. (2016) developed a framework integrating the techno-economic indicators (such as urban area, roads, transmission lines, slope, land use, waste supply, etc.) while finalizing the location of waste conversion facilities. Barakat et al. (2017) identified 10 selection criteria including lithology, faults, slope, distance between ground and surface water, proximity to urban areas, land use suitability, road proximity, elevation, wind and agglomerations while selecting the site for waste recycling facilities. From the perspective of sustainable development, Wu et al. (2018) established a sustainable evaluation index system, which covers all the dimensions of triple bottom line (TBL) such as social, environmental, economical as well as technological criteria for alternative selection.

To address issues related to the sustainable facility location problems, many researchers has recognized that majority of the problems regarding decision about site selection have been discussed through the multi-criteria decision making (MCDM) domain such as Analytical hierarchical process (AHP), Analytical network process (ANP), Decision making trial and evaluation laboratory (DEMATEL), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR), etc.. In addition, multi-objective decision making (MODM), fuzzy sets, analytic method, mixed integer/linear integer/goal programming, cluster analysis, and other soft computing methods have been employed (Azizi et al., 2014; Chauhan and Singh, 2016; Kheybari et al., 2019). Further, the facility location models have been widely utilized for locating waste recycling plant and disposal site to reduce negative impact on human lives and environment (Kharat et al., 2016). Eiselt and Marianov (2015) reviewed various hybrid techniques used in the literature for addressing the site selection problem. For example, Chang and Wei (2000) studied the model for solid waste collection network and landfill site by using f-MOLP (fuzzy multi-objective nonlinear integer programming). Eiselt (2006) used the mixed inter linear programming (MILP) for the selection of municipal solid waste (MSW) landfill sites by considering minimum logistics costs. He et al. (2012) integrated the fuzzy AHP and integer linear programming (FAHP-LP) to maximize customer service level by minimizing logistics costs in the case of transshipment problem. Kannan et al. (2013) proposed a hybrid framework utilizing the fuzzy MCDM and goal programming (GP) for order allocation problem in a green supply chain management. Eiselt and Marianov (2014) in their recent study minimized the operational cost and emissions by utilizing MILP approach for selecting landfill site. Parvaneh and El-Sayegh (2016) proposed a hybrid AHP-LP approach for the project selection. Zare et al. (2016) used the integrated FAHP-GP model for choosing the best industrial waste management system in the context of Iranian aluminum industry. Of the hybrid methods, the geographical information system (GIS) with AHP approach is the most popular method that has been employed for waste treatment and landfill site selection

(Natesan and Suresh, 2002; Kontos et al., 2005; Mahini and Gholamalifard, 2006; Melo et al., 2006; Chang et al., 2008; Sener et al., 2010; Eskandari et al., 2012; Yildirim, 2012; Alavi et al., 2013; ; Karsauliya, 2013; De Feo and De Gisi, 2014; Delivand et al., 2015; Al-Shahbeeb et al., 2016; Noorollahi et al., 2016; Sanchez-Lozano et al., 2017; Chabuk et al., 2017; Garni and Awasthi, 2017; Kabak and Keskin, 2018; Merrouni et al., 2018; Mohib-Ul-Haque Khan et al., 2018). In addition to the conventional MCDM approaches, the other approaches like Fuzzy MCDM such as F-AHP, FTOPSIS, F-ANP, F-DEMATEL, ELECTRE (Elimination and Choice Expressing Reality), PROMETHEE (Preference Ranking Organization method for enrichment of evaluations), VIKOR, etc., are also widely utilized by various researchers for selecting plant location to resolve issues like biased or vague judgment ratings (Melo et al, 2006; Gemitzi et al., 2007; Chang et al., 2008; Chou et al., 2008; Onut and Soner, 2008; Choudhary and Shankar, 2012; Cebi and Otay, 2015; Gupta et al., 2016; Kharat et al., 2016; Torabi et al., 2016; Aktas and kabak, 2018; Samanlioglu et al., 2017; Solangi et al., 2018; Buyukozkan et al., 2019; Feyzi et al., 2019).

2.8. Research Gaps, highlights and problem formulation

WEEE management is gaining magnificence in India because of majority of waste consuming landfill capacity and environmental degradation. Hence, in order to improve this issue, government of India (GOI) has implemented new WEEE management policy, addressing economic issues as assets recovery from used products, greening the supply chain and improving societal condition. In India, the Ministry of environment, forest and climate change (MoEF, 2016) report, has clearly provides a guidelines for identification of various source of WEEE and prescribed procedure for managing WEEE in an environmentally sound manner. Under these guidelines, government introduced a policy of extended producer responsibility (EPR) which states that the producer has to take the responsibility and liable to collect or dispose-off 30% to 70% (over seven years) of the WEEE after products end of life and to enable the recovery and/or reuse of useful material from WEEE by proper recycling methods, thereby reducing hazardous waste destined for disposal and to ensure the environmental sound management. However, it has so far been practiced in a very relaxed way by the enforcing agencies. These guidelines requires regular audit and monitoring to explore the fate of WEEE in various disposal routes, viz. landfill, second-hand market and recycling of WEEE. In spite of being a global manufacturing hub and waste dumping yard for developed nations, the developing countries like India are still at an infant stage of implementing WEEE management practices. And still struggling in finding best possible measure to minimize the waste generated by electronic manufacturing industry (Wang, 2005; Lau and Wang, 2009). However, Indian WEEE management system has deficient modern technologies, infrastructure and recycling framework for handling the WEEE (Wath et al., 2010; Luthra et al., 2011; Abdulrahman et al., 2014; Garlapati, 2016), but the extension of cognition and know-how through domain research may help in overcoming these barriers.

The review of the existing studies addresses the potential challenges related to WEEE management issues are concentrated on developed countries (Babu et al., 2007; Jindal and Sangwan, 2011; Lau and Wang, 2009; Skinner et al., 2008; Kahhat et al., 2008; Yang et al., 2008; Jang, 2010; González-Torre et al., 2010; Boeni et al., 2008). However, it is noted that very little research has investigated barriers to the implementation of WEEE management practices in the context of developing countries like India, China, Malaysia, Thailand, Vietnam and majority of these studies lacks theoretical foundation (Awasthi and li, 2017; Dou and Sarkis, 2013; Garlapati, 2016; Estrada-Ayub and Kahhat, 2014; Liu, 2014; Milovantseva and Fitzpatrick, 2015; Shumon et al., 2014; Sthiannopkao and Wong, 2013; Tong, 2004; Wath et al., 2010; Wath et al., 2011, Yu et al., 2010; Zhang et al., 2011; Zhang et al., 2012). This has been a topic of major concern for research scholar and practitioners directly involved in WEEE handling issues from all over the world. Thus, to fill this gap and promote the development of a sustainable WEEE management culture with the assistance of planned approach, the present study aims to assess the forty-four barriers of WEEE management in the Indian scenario and establisihing the relationship of one barrier over others.. Further, all the studies on WEEE management adoption are done taking few enablers and no study finding the relationship of the enablers of WEEE management. This study is first attempt taking a large number of factors (twenty-three) into consideration for finding the cause and effect relationship among the various enablers of sustainable WEEE management implementation.

Product take-back and environmentally sound recycling of WEEE is gaining importance in India due to the majority of WEEE disposed of in landfills. Hence, in order to protect the environment and landfills consumption, the government of India (GOI) has introduced new environmental regulation and electronic waste management policy, addressing economic as well as social issues (MoEF, 2016). As a part of the compliance with environmental guidelines and norms, many electronic manufacturers are enforced to educate their recycling partners to integrate green competencies (GC) in order to recover valuable assets and rare earth's material from the WEEE which leads to minimize the negative impact on the environment (Dwivedy et al., 2015; Garlaparti, 2016; Kumar and Dixit, 2018a; Wath et al, 2010; Wittstruck and Teuteberg, 2012). Based on past studies, the present study tries to explore these research gaps. The review of existing studies addresses the selection of green partners/suppliers based on the certain criteria was carried out in the context of developed countries and majority of the studies addresses environmental factors without considering management of hazardous and toxic substances in their closed supply chain activities (Amin and Zhang, 2012; Chien and Shih, 2007; Fu et al., 2012; Hsu and Hu, 2009; Jabbour and Jabbour, 2009; Kannan et al., 2014; Sarkis et al., 2011; Wang Chen et al, 2016). To date, no study has been reported in the previous literature considering green competencies (GC) including green core competencies, resource and environmental management capabilities, social responsibility benefits in the selection of recycling partner selection in case of Indian electronics manufacturers perspective (Garlapati, 2016; Govindan et al., 2015; Luthra et al., 2017). To the best of our knowledge, this study is the first attempt to fill this gap by employing natural resource based view theory to rationalize GC criteria for the selection of WEEE recycling partner. Further, many researchers have made a notable contribution by employing the application of various integrated or individual methodologies for supplier/partners selection (Awasthi and Kannan, 2016; Awasthi et al., 2010; Büyüközkan, 2012; Dalalah et al., 2011; Fu et al., 2012; Gumus, 2009; Hsu et al., 2012; Kannan et al., 2014; Lin et al., 2010, 2011; Kuo et al., 2015). Still, the literature lacks by utilizing the integrated FAHP-VIKOR method and explored robustness in case of Indian electronic industry context.

Previous studies addresses the selection of recycling plant location based on social, economic, and environmental was carried out in the context of various countries such as Alberta, China, Iran, Morocco, Taiwan, Turkey, United kingdom (Khadivi et al., 2012; Yildirim, 2012; Bahrani et al., 2016; Wu et al., 2016; Barakat et al., 2017; Karimi et al., 2018; Ming Liu et al., 2018; Wu et al., 2018; Feyzi et al., 2019; Sultan and Mativenga, 2019). Still, studies in the Indian context lacks in considering the technical, political and legal aspect along with sustainable dimensions such as social, economic and environment which highlights the major gap in the consideration of all the five dimensions for sustainable WEEE recycling plant location selection and evaluation. To best of knowledge, this study is the first attempt to offers a comprehensive STEEP framework based on extensive literature review and experts opinion, covering all the sustainability aspects-the economic, social and environment along and add policy and technical dimensions to enrich the existing literature. This study is one of the few studies to examine the location problem in a given country (India) by employing novel STEEP framework which can be seen another contribution of this study.

Therefore, after extensive literature review following gaps have been identified:

- Almost all of the studies on WEEE management are based in context of foreign countries and there is dearth of studies in context of developing nations especially India.
- It is evident from the literature that WEEE management practices in developed countries derived by enforce legislation on manufacturers to take extended responsibility for recovery, recycling and disposal of obsolete electronic products. There is a need of further research and consideration on policy as well as technical level to answer how to adopt and successfully combined the experience and know how the existing WEEE management model from abroad, with the current WEEE management system in India, in order to have formal and well-regulated WEEE management system for India (Srivastava and Sharma, 2015; Jafari et al., 2015).
- Several researchers have worked on identifying the conditions, norms and factors which facilitate the promotion and implementation of WEEE management. However, most of the academic writings focus only on few factors at a time. There is a lack of

studies providing holistic perspectives on managing WEEE comprehensively in Indian scenario (Wath et al., 2010; Garlapati, 2016).

- There are almost no study relating WEEE recycling partners selection, especially there is lack of studies on selection of WEEE recycling partners on the basis of environmental and green competencies (Lee et al., 2009).
- Finally there is no past study for selecting the WEEE recycling plant location by taken into STEEP consideration (Chauhan and Singh, 2016).
- Further, very few empirical studies and quantitative research have been reported to support the theoretical findings.

2.9 Objectives of the Research

The literature review shows that there are still large gaps in the literature of WEEE management which needs to be addressed. The extensive literature review and identification of the gaps have to lead to formulation of the research objectives. The primary objective of this research is to evaluate the interrelationship among barriers and enablers for the WEEE management implementation under the perspectives of the most important WEEE management stakeholders in the Indian context. The following research objectives have been formulated for this study and are listed below:

The study will be based on following research objectives:

Objective 1: Identifying and prioritize the barriers of WEEE management implementation and to explore cause and effect relationship in Indian context.

Research Question 1: How is the current state of the India with respect to WEEE management?

Research Question 2: What are the major barriers for the adoption of WEEE management in the Indian context and how do they relate to each others?

Objective 2: Identifying, prioritizing and finding the relationship among the enablers of sustainable WEEE management implementation in Indian context.

Research Question 3: How can managers evaluate the cause-effect relationship among enablers of the sustainable WEEE management in Indian context?

Objective 3: Selecting WEEE recycling partner for electronic manufacturing industry based on environmental and green competencies.

Research Question 4: What are the key evaluation criteria for the selection of recycling partner based on green competencies?

Research Question 5: Which approach for MCDM evaluation framework is appropriate in order to select recycling partners for electronic manufacturing industry?

Objective 4: Selecting the sustainable location for WEEE recycling location based on STEEP consideration.

Research Question 6: What are the prominent criteria and sub-criteria to select a WEEE recycling plant location and how STEEP framework is suitable for evaluating the best alternative location for establishing a WEEE recycling plant using selected criteria?

2.10 Chapter Summary

This chapter summarized the review of studies on WEEE management. To begin with, the concept of literature review was defined. The chapter summarizes the various studies on barriers and enablers of WEEE management implementation in context of various countries. The review of various MCDM techniques along with studies on partner selection based on green competencies is also presented. The extensive review indicates the various gaps in the literature. These gaps were analyzed and finally research objectives for the study were formulated and presented in this chapter. The next chapter presents the details of overall design of the study and present the various phases of methodologies employed to achieve the objectives formulated through literature review.

CHAPTER - III
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents overall design of the study, which includes methodology adopted for carrying out the research work as well as various phases of the study. The details of various techniques/tools/methodologies employed for each phase of the study is presented in this chapter.

3.2 Research Approach

According to Creswell (2003), the research approach (Qualitative, Quantitative, or Mixed Methods) is decided based on interrelated levels of decisions which when made dictate the approach and the research design process. These decisions are based on which knowledge claims, strategies of inquiry, and research method is used. The following Creswell definitions explain how these are combined:

"A quantitative approach is one in which the investigator primarily uses post positivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data" (Creswell, 2003).

"A qualitative approach is one in which the inquirer often makes knowledge claims based on constructivist perspectives (i.e. multiple meaning of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e. political, issue orientated, collaborative, or charge orientated) or both. It also uses strategies of inquiry such as narratives, phenomenology's, ethnography's, grounded theory studies, or case studies. The researcher collects open-ended, emerging data with the primary intent of developing themes from the data" (Creswell, 2003).

"A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g. consequence-orientated, problem-centered, and pluralistic). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g. on instruments) as well as text information (e.g. on interviews) so that the final database represents both quantitative and qualitative information" (Creswell, 2003). Based on these definitions and the work of O'Leary (2004) this can be summarised as shown in Figure 3.1.

Therefore, based on Figure 3.1, both Mixed Method Approach i.e. mixture of Quantitative Research Approach and Qualitative Research Approach would appear to be the approaches to be used in this thesis. First Quantitative Approach will be employed to collect the data and do analysis of the data using various tools like MCDM tools available for the study.

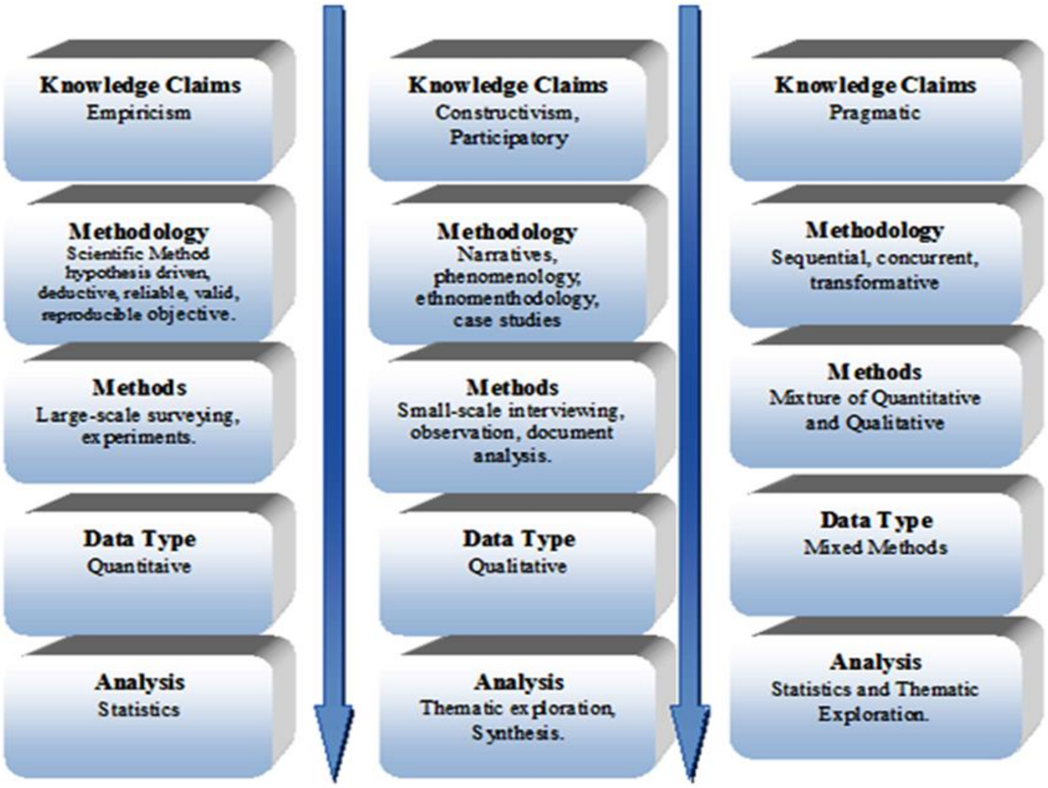

Fig. 3.1 Research Approach Flow Charts (O'Leary, 2004)

3.3 Phases of Research

The present study is divided into three main parts namely 'Review' and 'Analysis'. Review part includes extensive literature review regarding the topic of study. Analysis includes gathering information about current status of the implementation of research subject in the selected industry. It also includes quantitative analysis of the problems to give a solution for the various research problems. Based on this, the research work has been carried out in four phases:

Phase I: Clarifying the context by identifying the challenges and enablers to WEEE management adoption.

Phase II: Developing a cause-effect relationship among barriers.

Phase III: Developing a model for enablers and WEEE recycling partner selection.

Phase IV: Developing an integrated framework for selection of WEEE recycling plant location.

Figure 3.2 depicts the relevance and importance of each phase for meeting the objective of design of a generalized '*WEEE management Implementation and Adoption*' program.

3.3.1 Clarifying the Context

This phase reviews the literature on WEEE management practices in developing and developed nation. Various barriers that that affects the implementation of WEEE management have been explored from the existing literature and expert opinion. Fundamental issues and factors that can help to initiate and motivate practicing and adoption of WEEE management and recycling have also been explored. This phase also involves feedback from experts in industry and academia for finalizing the barriers, enablers and criteria of WEEE management adoption for further analysis and exploration to achieve the research objectives. The sampling method used is purposive sampling. The respondents selected are from electrical and electronics manufacturing, WEEE recycling units and central pollution control board (CPCB) executives of Delhi, Maharashtra, Hyderabad and Bangalore. The sample has been selected due to proximity and also because electrical and electronics component manufacturing are among top manufacturing in India having highest manufacturing output.

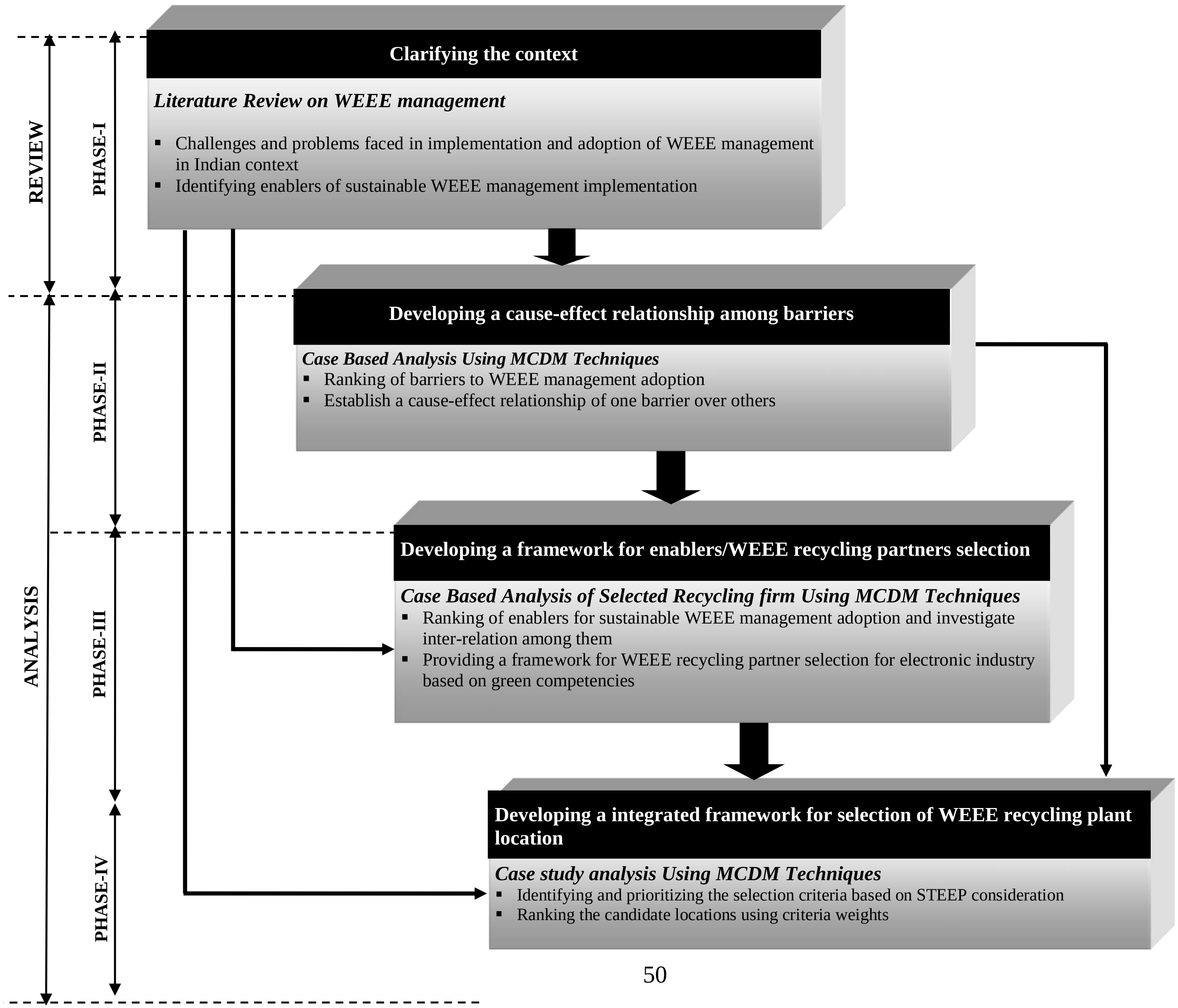

Figure 3.2 Design of the Study

3.3.2 Developing a framework for analysis of enablers/barriers to implementation of WEEE management, recycling partner selection and sustainable WEEE recycling plant location

This is the third phase of the study and it helps in achieving objective one, two, three and four of the study i.e. Prioritizing and evaluating the causal relation among the critical barriers of WEEE management (Objective 1), Identifying and finding the relationship among the enablers of sustainable WEEE management implementation (Objective 2), Selecting WEEE recycling partner based on green operation competencies (GOC) (Objective 3) and Selection of sustainable WEEE recycling plant location based on STEEP consideration (Objective 4). In this study, five methodologies have been used to achieve these objectives. These are:

- DEMATEL
- Grey-DEMATEL
- Fuzzy AHP
- VIKOR
- Best Worst Method (BWM)

The steps involved in each of these methodologies are discussed in following sections:

3.3.2.1 DEMATEL method

The DEMATEL is a mathematical method which can used to analyze the causal interdependence and association among the dimensions in a complex management problem for resolving the issue efficiently, and the end result of DEMATEL process is a visual representation that relies on graph theory (Tzeng et al., 2007). Between 1972 and 1976, the Science and Human Affairs of the Battelle Memorial Institute of Geneva developed this method. DEMATEL methodology recognizes the interaction among the barriers by categorizing them into cause and effect group and contributes to the identification of feasible solutions by a hierarchical structured manner (Hsu et al., 2013; Lin, 2013).. The detailed procedure of this methodology is summarized in several steps, which are given below:

Step 1: Defining the research problem: A substantial literature review is required to explore and compile relevant data for designing the research problem. The views of experts are very significant to understand and achieve the desired goal. The potential barriers related to successful adoption of WEEE management are listed; these barriers are to be assessed on the basis of the available literature and expert's responses.

Step 2: Establish a direct-relation matrix (A): In this step, each experts were asked to rate the barriers and to form a direct relationship matrix based on the scale. The scale designed has five levels: "0 (No influence), 1 (Very low influence), 2 (Low influence), 3 (High influence), 4 (Very high influence)". The initial data can be obtained as the direct relationship matrix, that is, (*n x n),* which is non-negative matrix that can be established as $X^k = [x_{ij}^k]$.To incorporate all the responses from *H* respondent, the average direct relation matrix 'a_{ij}' is developed by using the following equation (1):

$$a_{ij} = \frac{1}{H}\sum_{K=1}^{H} x_{ij}^{k} \tag{3.1}$$

Where, K= number of respondent with $1 \leq ik \leq H$

N= number of barriers criteria

Step 3: Normalizing the direct-relation matrix (D): On the basis of the direct-relation matrix or average matrix (M), the normalized matrix (D) can be obtained through equation (3.2):

$$D = M \times B,$$

$$\mathrm{B} = \mathrm{Min}\left[\frac{1}{Max\sum_{j=1}^{n} a_{ij}}, \frac{1}{Max\sum_{i=1}^{n} a_{ij}}\right] \tag{3.2}$$

Step 4: Attaining the total relation matrix (T): The total relation matrix (T) is developed by using equation (3.3).

$$T = N(I - N)^{-1} \tag{3.3}$$

Where, 'I' denotes the identity matrix.

Step 5: Developing a causal diagram: The sum of rows $[r_i]_{n \times 1}$ and sum of column $[c_j]_{1 \times n}$ represents the vectors of the total relation matrix respectively. Subsequently, the horizontal axis vector (r_i + c_j) named as "Prominence" exhibits the overall effect contributed and experienced by barrier 'i'. Similarly, the vertical axis vector (r_i - c_j) named as "Relation" may divide factors 'i' into cause group and effect group. Generally, if (r_i - c_j) is positive, then criteria is grouped into cause group, while if (r_i - c_j) is negative, then the criteria is grouped into effect group (Tseng, 2009).

3.3.2.2 Grey based DEMATEL methodology

The present study uses hybrid grey based DEMATEL approach as a solution methodology. Deng (1982) proposed the concepts of Grey theory from the grey numbers set. Grey theory provides an effective tool to deal with several ambiguities arises due to imprecise human decisions and also generates satisfactory results in presence of great variability in criteria (Xia et al., 2015). The major advantage of grey set theory is that it can be successfully integrated with any decision-making process in order to achieve decision accuracy (Liu et al., 2012). Grey theory is recognized as an efficient approach in both the conditions of fuzziness and resilience to deal with uncertainty, inconsistent or limited information, especially in case of group decision-making (Li et al., 2007). This theory is well-suited for small samples by converting the grey number into crisp numbers with the assistance of modified converting fuzzy values into crisp scores (CFCS) method involving a three-step procedure (Zhu et al., 2011; Liu and Qiao, 2014). Hence, this study employed a combination of Grey theory and DEMATEL in order to obtain the advantages of both methodologies by taking into consideration of vague information and imprecise human judgment to evaluate the causal relationships among the enablers of sustainable WEEE management. The detailed steps of Grey-DEMATEL are described as follows:

Step 1: Developing the initial relation matrices

Let ‘n’ be the number of enablers of sustainable WEEE management and ‘k’ be the number of experts chosen for the research problem. Each expert ‘p’ is given the task of assessing the direct impact of enabler *‘x’* over enabler *‘y’* on a six-point scale varying from 0-5 wherein ‘0’ indicates ‘no influence’ (N), ‘1’ indicates ‘very low influence’ (VL), ‘2’ indicates ‘low influence’ (L), ‘3’ indicates ‘medium influence’ (l), ‘4’ indicates ‘high influence’ (H) and ‘5’ indicates ‘very high influence’ (VH) among ‘n’ identified enablers. Table 3.1 represents the linguistics indicators and related grey numbers. In such a way, initial relation matrices were constructed for each expert according to the impact rating from the experts.

Table 3.1. Linguistics indicators and related grey numbers.

Linguistics assessment	**Related grey numbers**
No influence (N)	(0.0, 0.1)
Very low influence (VL)	(0.1, 0.3)
Low influence (L)	(0.2, 0.5)
Medium influence (M)	(0.4, 0.7)
High influence (H)	(0.6, 0.9)
Very high influence (VH)	(0.9, 1.0)

Step 2: Compute the corresponding grey relation matrices($\otimes A_{xy}^{l}$).

In this step, initial relation matrices are transposed into a corresponding grey number which specifying an upper($\bar{\otimes} A_{xy}^{p}$) and lower ($\underline{\otimes} A_{xy}^{p}$) range of values based on Table 4 (Deng, 1982).

$$\otimes A_{xy}^{p} = \left(\underline{\otimes} A_{xy,}^{p}\ \bar{\otimes} A_{xy}^{p}\right) \tag{3.4}$$

Where,

$1 \leq p \ \leq k; 1 \leq x \ \leq n; 1 \leq y \ \leq n$

Step 3: Evaluate the average grey relation matrix$\left(\otimes \check{A}_{xy}\right)$.

The average grey relation matrix is computed (Liu et al., 2012) from the 'k' grey relation matrices, $[\otimes A_{xy}^{p}]; p = 1 - k$ as,

$$\otimes \check{A}_{xy} = \left(\frac{\sum \underline{\otimes} A_{xy}^{p}}{k}, \frac{\sum \bar{\otimes} A_{xy}^{p}}{k}\right) \tag{3.5}$$

Step 4: Calculate the crisp matrix from the average grey matrix.

In this step, converting the average grey number into crisp numbers with the assistance of modified (CFCS) method involving a three-step procedure (Liu and Qiao, 2014);

(a) Normalization of the average grey numbers

$$\underline{\otimes}\, \dot{A}_{xy} = \left(\underline{\otimes} \check{A}_{xy} - {}^{min}_{\ \ y}\underline{\otimes} \check{A}_{xy}\right) / \triangle_{min}^{max} \tag{3.6}$$

where $\underline{\otimes}\, \dot{A}_{xy}$ denotes the normalized lower range value of the grey number $\otimes \check{A}_{xy}$

$$\bar{\otimes} \dot{A}_{xy} = \left(\bar{\otimes} \check{A}_{xy} - {}^{min}_{\ \ y}\bar{\otimes} \check{A}_{xy}\right) / \triangle_{min}^{max} \tag{3.7}$$

where $\bar{\otimes} \dot{A}_{xy}$ denotes the normalized upper range value of the grey number $\otimes \check{A}_{xy}$

$$\triangle_{min}^{max} = {}^{max}_{\ \ y}\bar{\otimes} \check{A}_{xy} - {}^{min}_{\ \ y}\underline{\otimes} \check{A}_{xy} \tag{3.8}$$

(b) Calculate total normalized crisp values

$$Z_{xy} = \left(\frac{\left(\underline{\otimes} \dot{A}_{xy}\left(1 - \underline{\otimes} \dot{A}_{xy}\right)\right) + \left(\bar{\otimes} \dot{A}_{xy} \times \bar{\otimes} \dot{A}_{xy}\right.}{\left(1 - \underline{\otimes} \dot{A}_{xy} + \bar{\otimes} \dot{A}_{xy}\right)}\right) \tag{3.9}$$

(c) Calculate final crisp values

$$Z_{xy}^{*} = (min\underline{\otimes}\check{A}_{xy} + (Z_{xy} \times \triangle_{min}^{max})) \tag{3.10}$$

And,

$$Z = [Z_{xy}^{*}] \tag{3.11}$$

Step 5: Determine normalized direct crisp relationship matrix (N).

In this step, the normalized direct relation matrix (N) is established by multiplying the average crisp relation matrix *Z* with normalization factor *R* and is given in Eqs. (9) and (10). Each element in this matrix N ranges from one to zero.

$$R = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} Z_{xy}^{*}}, \; x, y = 1,2,\ldots,n. \tag{3.12}$$

And,

$$N = Z \times R \tag{3.13}$$

Step 6: Establish total relation matrix (T)

In this step, total the relation matrix needs to be developed by processing normalized direct relation matrix (N) by using expression (11).

$$T = N(N - I)^{-1} \tag{3.14}$$

where 'I' represents the identity matrix.

Step 7: Calculate the sum of rows (*R*) and column (*C)* from the total relation matrix (T) and is given in Eqns. (12) and (13).

$$R = \left[\sum_{y=1}^{n} t_{xy} \,\forall x\right] \tag{3.15}$$

$$C = \left[\sum_{y=1}^{n} t_{xy} \,\forall y\right] \tag{3.16}$$

Step 8: Establish causal-prominence relationship diagram.

Finally, causal-prominence diagram is obtained in this step by evaluating the values of (R + C) and (R – C) by using Eqns. (3.15) and (3.16).

3.3.2.3 Fuzzy AHP methodology

In this study, fuzzy AHP is used to handles the uncertainty and fuzziness of the human decision making but also provide a robust approach for the stakeholders' to analyze the decision hierarchy. According to fuzzy AHP approach, synthetic extent analysis for each criteria and sub-criteria is done and explained by Chang's extent analysis (1996). In Chang's extent analysis for criteria, g_i

carried out. The value of each criterion and sub-criteria is obtained in extent analysis by using following notations:

$M_{gi}^1, M_{gi}^2, M_{gi}^3, \ldots\ldots\ldots\ldots, M_{gi}^m,$

Where i = 1, 2, 3, 4, 5, …., n and j = 1, 2, 3, 4, 5, …, m are TFN assigned in analysis given in Table 3.2-3.3.

Table 3.2 Triangular fuzzy number (TFN) for pair-wise comparisons.

Linguistic attributes	**Assigned TFN**
Equally importance	(1, 1, 1)
Very low importance	(1, 2, 3)
Low importance	(2, 3, 4)
Medium importance	(3, 4, 5)
High importance	(4, 5, 6)
Very high importance	(5, 6, 7)
Excellent importance	(7, 8, 9)

Table 3.3 Linguistics variable along with triangular fuzzy number (TFN) for pair-wise comparisons.

Linguistic attributes	**Assigned TFN**
Very low importance	(0.2, 0.25, 0.33)
Low importance	(0.25, 0.33, 0.5)
Medium importance	(0.33, 0.5, 1)
High importance	(1, 2, 3)
Very high importance	(2, 3, 4)
Excellent importance	(3, 4, 5)

Fuzzy AHP involved with several steps are depicted as follows:

Step-1: Calculate the value of fuzzy synthetic extent (E_i) with respect to the *i*th criteria by creating the inverse function is represented as,

$$E_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \quad (3.17)$$

Step-2: The possibility degree of $S_2 = (a_2, b_2, c_2) \geq S_1 = (a_1, b_1, c_1)$ is defined as below;

Where $a \leq b \leq c$

$V(S_2 \geq S_1) = \sup_{y \geq x}[\min(\mu_{s_1}(x), (y)]$, here *x* and *y* represents the membership function of each criteria. The above relationship can also be written as follows and given in Eq. (3.18):

$$V\ (S2\ \ \geq\ S1) = \begin{cases} 1 & if\ b_2 \geq\ b_1 \\ 0 & if\ a_1 \geq c_2 \\ \frac{a_1 - c_2}{(b_2 - c_2) - (b_1 - a_1)} & otherwise \end{cases} = \mu d \quad (3.18)$$

where µd is the ordinate of the highest intersection point between μ_{s_1} and μ_{s_2}, as represented in figure 3.1.

For comparison between S_2 and S_1, we need to determine both $V\ (S_1\ \geq S_2)$ and $V\ (S_2\ \geq S_1)$

Step-3: A convex fuzzy number S to be larger than *l* convex fuzzy number S_i (i = 1, 2,..., l) can be defined by:

$$V\ (S\ \ \geq\ S1,\ S2, S3, \ldots, Sl)\ =\ V\ [(S\ \ \geq\ S1), (S\ \ \geq\ S2), \ldots, (S\ \ \geq\ Sl)] \quad (3.19)$$
$$= min\ V\ (S\ \ \geq\ S1), i\ =\ 1, 2, \ldots, l$$

Consider that $d'\ (Ai\ = min\ V\ (Si\ \ \geq Sl)$

For l = 1,2,3,…, n, $l \neq i$, and then the vectors weight are given in equation (4)

$$W'\ =\ (d'\ (A1), d'\ (A2), \ldots\ , d'\ (Am)\ )T \quad (3.20)$$

Step-4: Finally, the normalized vectors weight are obtained by normalization method and it is given in Eq. (3.21)

$$W\ =\ (d\ (A1), d\ (A2), \ldots\ , d\ (Am)\ )T \quad (3.21)$$

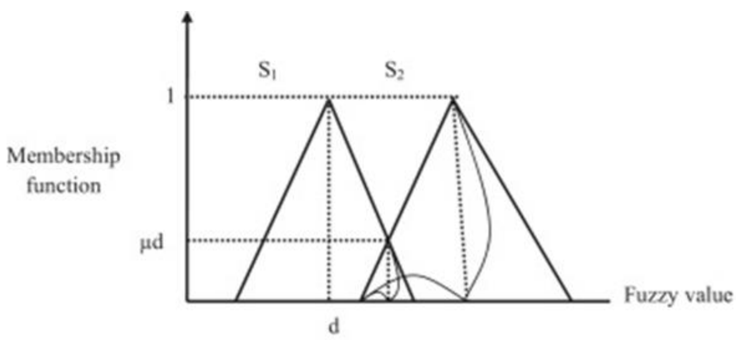

Figure 3.1. Representation of the intersection of fuzzy values

3.3.2.4 VIKOR method

VIKOR method is another effective MCDM tool was introduced as an applicable technique for optimizing multi-criteria problem of a complex system (Opricovic, 1998). This method is usually used for ranking and selecting the best from the set of alternatives in the presence of conflicting criteria, and establishes a compromise solution for the multi-criteria problem and assist the decision makers to reach the best possible decision. In contrast to other MCDM technique, VIKOR method introduces ranking index on the basis of closeness measure to the ideal solution (Opricovic and Tzeng, 2004). The various steps involved in compromise ranking algorithm is discussed as follows:

Step-1: Constructing pair-wise comparison for each recycling partner (RP) alternatives with respect to each GC criteria using prescribed linguistic scale (see Table 3.4).

Step-2: In this step, an aggregated decision matrix is computed using Eq. (3.22).

$$F = \frac{1}{k}\sum_{k=1}^{k} F_k \tag{3.22}$$

Step-3: Determine best f_j^* and the worst f_j^- values of each criteria respectively, *i= 1, 2, 3… n,* and given in Eq. (3.23) and (3.24).

$$f_i^* = Max\left(f_{ij}\right) \tag{3.23}$$

$$f_j^- = Min\left(f_{ij}\right) \tag{3.24}$$

Step-4: Compute the values of S_i and R_i by using the given relation in Eq. (3.25) and (3.26), where *i= 1, 2, 3… n.*

$$S_i = \sum_{j=1}^{m} W_j\left[\left(f_j^* - f_{ij}\right)/\left(f_j^* - f_j^-\right)\right] \tag{3.25}$$

$$R_i = Max_j\left[W_j\left(f_j^* - f_{ij}\right)/\left(f_j^* - f_j^-\right)\right] \tag{3.26}$$

Where W_j is the relative importance weight of 'j^{th}' criteria.

Step-5: Using Eq. (3.27), calculate the values for Q_i.

$$Q_i = v\left(\frac{S_i - S^*}{S^- - S^*}\right) + (1-v)\left(\frac{R_i - R^*}{R^- - R^*}\right) \tag{3.27}$$

Where,

$S^* = min_i\, S_i, S^- = max_i\, S_i$

$R^* = min_i\, R_i, R^- = max_i\, R_i$, and then v is representing as the maximum group utility weight and is taken as v = 0.5 in this study.

Step-6: Finally the alternatives are ranked by using the minimum value of Q_i.

Condition 1. Q (A (1)) is accepted if Q (A (2)) - Q (A (1)) ≥ 1/*n*-1,

Where A (2) has got the second rank in the analysis and *n* denotes the number of alternatives used in the study.

Condition 2. Q (A (1)) also attain top ranking according to both S and R values.

Table 3.4. Linguistic scale used to construct pair-wise comparison matrix for VIKOR analysis

Linguistic attributes	Importance rating
Equally importance (EI)	1
Medium importance (MI)	2
High importance (HI)	3
Very high importance (VHI)	4
Excellent importance (EXI)	5

3.3.2.5 Best-Worst method (BWM)

A new MCDM method known as Best Worst Method has been developed by Rezai (2015) is used to calculate the weights of the criteria. BWM is widely accepted by various researchers all over the world (Gupta and Barua, 2016; Gupta and Barua, 2017; Rezaei et al., 2017; Salimi and Rezaei, 2017; Ahmadi et al., 2017; Aboutorab et al., 2018; Kusi-Sarpong et al., 2019Rezaei et al., 2018; Kusi-Sarpong et al., 2019a,b; Zolfani et al., 2019). To determine the weights of the criteria using BWM, followed by detailed steps as given by Rezaei (2015; 2016) are explained below:

Step 1: Selection of attributes for analysis

Through literature review and expert opinion, the attributes are finalized for analysis.

Step 2: Among finalized attributes best and the worst attribute is finalized by each expert for both the main category and subcategory attributes.

Step 3: Next each expert is asked to give preference rating for the best attribute selected over all other attributes using a scale of 1 to 9.

Step 4: After this, the preference rating of all attributes with the worst attribute is taken by experts.

Step 5: Optimized weights (w_1^*, w_2^*, …….,w_n^*) for all the attributes is calculated next.

The objective is to obtain the weights of attributes so that the maximum absolute differences for all j can be minimized for $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$. This minimax model will be obtained:

$$\min \max \{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$$

$$\text{s.t.} \sum_j w_j = 1$$

$w_j \geq 0$, for all j (3.28)

Model (3.28) when transformed into a linear model gives better results, the model is shown below:

$\min \xi^L$

s.t.

$|w_B - a_{Bj} w_j| \leq \xi^L$, for all j

$|w_j - a_{jW} w_W| \leq \xi^L$, for all j

$$\sum_j w_j = 1$$

$w_j \geq 0$, for all j (3.29)

Model (3.29) can be solved to obtain optimal weights (w_1^*, $w_2^* \dots w_n^*$) and optimal value ξ^L.

Consistency (ξ^L) of attribute comparisons close to 0 is desired (Rezaei, 2016).

3.4 Chapter Summary

This chapter presented a step by step approach followed to accomplish each objective in various phase of the research. A mix of qualitative and quantitative methodologies have been used in research and discussed in this chapter. The quantitative techniques are aimed to assess the current situation, rank the various enablers and barriers and explore the relationship among enablers. The next chapter deals with first objective of the study, i.e. to identify, prioritize and evaluate the critical barriers to implementation of WEEE management.

CHAPTER - IV

ANALYSIS OF BARRIERS TO IMPLEMENTATION OF WEEE MANAGEMENT

4.1 Introduction

This chapter deals with the identification, finalization and prioritization of barriers to critical to WEEE management adoption in Indian context. It also identifies, and suggests some remediation's to overcome these barriers to adoption. This chapter proposes a framework using DEMATEL approach. The framework helps to prioritize the barriers and also establish a cause and effect relationship of one barrier over others.

4.2 Proposed framework for prioritization and determination of causal relationship of barriers

WEEE management is gaining magnificence in India because of majority of waste consuming landfill capacity and. Hence, in order to improve this issue, government of India (GOI) has implemented new WEEE management policy, addressing economic issues as assets recovery from used products, greening the supply chain and improving societal condition. In India, the Ministry of environment, forest and climate change (MoEF, 2016) report, has clearly provides a guidelines for identification of various source of WEEE and prescribed procedure for managing WEEE in an environmentally sound manner. Under these guidelines, government introduced a policy of extended producer responsibility (EPR) which states that the producer has to take the responsibility and liable to collect or dispose-off 30% to 70% (over seven years) of the WEEE after products end of life and to enable the recovery and/or reuse of useful material from WEEE by proper recycling methods, thereby reducing hazardous waste destined for disposal and to ensure the environmental sound management. However, it has so far been practiced in a very relaxed way by the enforcing agencies. These guidelines requires regular audit and monitoring to explore the fate of WEEE in various disposal routes, viz. landfill, second-hand market and recycling of WEEE. In spite of being a global manufacturing hub and waste dumping yard for developed nations, the developing countries like India are still at an infant stage of implementing WEEE management practices. And still struggling in finding best possible measure to minimize the waste generated by electronic manufacturing industry (Wang, 2005; Lau and Wang, 2009). However, Indian WEEE management system has deficient modern technologies, infrastructure and recycling framework for handling the WEEE (Wath et al., 2010; Luthra et al., 2011; Abdulrahman et al., 2014; Garlapati, 2016), but the extension of cognition and know-how through domain research may help in overcoming these barriers. Several barriers possibly hinder the adoption and implementation of WEEE management; these barriers are government policies, consumer attitude, technological gaps, stakeholders role, globalization and economic consideration between formal and informal sector (Qu et al., 2013; Estrada-Ayub and Kahhat, 2014; Milovantseva and Fitzpatrik, 2015). For effective adoption of WEEE management activities, there are various reasons; but the presence of obstacles makes WEEE management challenging and the effect of these barriers cannot be overcome at the same time. Furthermore, the identical barrier requires different priorities of treatment depending on the variation in the characteristics of resources, strategies, and capabilities of the management of the organization. The mismanagement in handling WEEE can create tremendous negative impact on the ecological and economic performances of organizations (Robinson, 2009). By contrast, in developing nations WEEE management still to be an immature practice (Lau and Wang, 2009). In the view of above statistics and information, there is an urgent need to have sufficient infrastructure, cleaner technologies, and inviolable legal policies for effective WEEE management in India. In developing countries, there are plenty of indications in respects of public willingness for recycling, consumer awareness, policies and regulation, and participation of stakeholders, however, some criticalities are observed while implementing effective WEEE management practices. It is well known that WEEE management is mandatory for maintaining economic, environmental and social norms in the developed and developing nations.

To rank and analyzing the critical barriers in the adoption and successful implementation of WEEE management practices, a three-phase methodology is proposed (Figure 4.1). **Phase-I** involves identification and listing the barriers on the basis of extensive literature review related to the adoption of WEEE management and supported with various socio-economic theories such as transaction cost economic (TCE), resource based theory (RBT), theory of planned behavior (TPB), institutional theory (INT), social network theory (SNT) and stakeholder theory (ST) (refer Table 4.1). Later, a semi structured questionnaire was formulated in the study to collect expert judgments for identifying the final barriers in the implementation of WEEE management in the Indian context. The experts rated the barriers on a five-point Likert scale (0= 'No influence'; 1= 'Very low influence'; 2= 'Low influence'; 3= 'High influence'; 4= Very high influence'), and the sole objective of the Likert scale was to rank the initially identified thirty-eight barriers that were selected after exhaustive discussion with the experts. It was decided that the barriers with the low rating and no significance will be eliminated from the list, but eventually none of the barriers were eliminated. In addition, a separate space was attached to the survey questionnaire, where the participant or respondent (Government, Corporate and Waste management experts) can suggest other significant barriers that can probably hinder the implementation of WEEE management. After the experts' responses, six more barriers were incorporated in addition to initially identified thirty-eight barriers related to the implementation of WEEE management. The six added barriers are given as lack of flexibility to change over to new practices from the current system, lack of consumer knowledge for green product, competition between formal and informal sectors, poor purchasing behavior of consumers, need to change the mindset and develop the habit for recycling WEEE and lack of financial support from government for WEEE recycling start-ups. Thus, we finalized forty-four barriers (Table 4.2) and categorized them into seven main barriers criteria. These seven criteria of the barriers are Policy and Regulatory barriers (PR), Infrastructural barriers (I), Knowledge barriers (K), Socio-economic barriers (SE), Socio-cultural barriers (SC), Technological barriers (T), and financial barriers (F). Additionally, the hierarchical structure of main barriers and sub barriers relating to WEEE management adoption is presented in figure 4.2. **Phase-II** utilizes DEMATEL which helps to prioritize and analyze the causal relation among the barriers for distinguishing the way of interlinking one barrier with the others and formulating the long standing flexible decision making policies to implement the WEEE management practices. Contrary to AHP, DEMATEL is one of the constructive modeling techniques that can be used to explore the interdependence among the barriers of a system through a causal diagram. The causal diagram based on digraphs presents the canonic understanding of the contextual relationships and the influence among the barriers (Wu, 2008). Finally, the findings are discussed with the authorities to assist them in framing institutional, infrastructural, core competencies and tactical schemes and policies which encourage the successful adoption of WEEE management practices in the Indian context. The various steps involved in the proposed research framework are illustrated in figure 4.1.

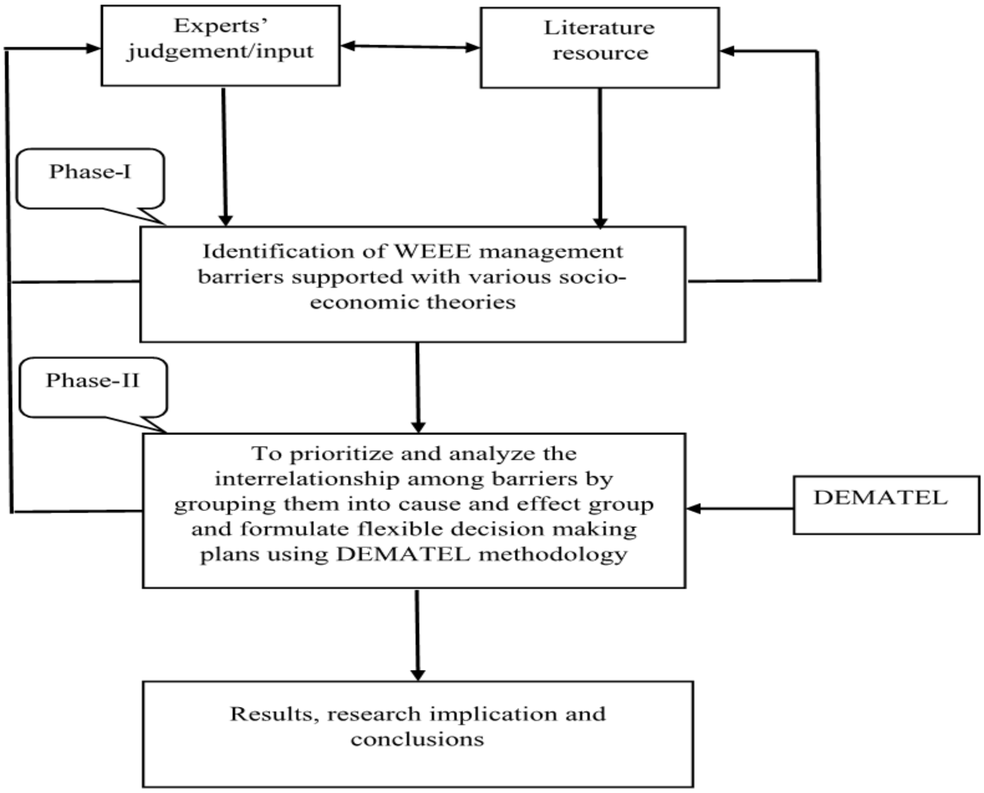

Figure 4.1 The various steps involved in proposed research framework.

4.2.1. Policy and Regulatory Barriers

Policy and regulatory barriers related to the implementation of WEEE management are delay in EPR (Extended producer responsibility) approaches and WEEE law enforcement, lack of systematic monitoring and auditing, un-defined role of stakeholders (actors), lack of restriction of hazardous substances (RoHS) practices, lack of policies and regulations addressing environmentally sound WEEE recycling, and violation of Basel Ban amendment (Wath et al., 2010; Rajesh, 2011; UNEP, 2009; Kojima and Michida, 2013; Yoon and Sim, 2015; Kiddee et al., 2013; Afroz et al., 2013; Dwivedy and Mittal, 2013; Toxic Link, 2014; Luthraet al., 2011; Abdulrahman et al., 2014; Garlapati, 2016; Robinson et al., 2009; Zhang et al., 2010). It is clearly seen that the regulatory and policy system are one of the most effective tools for the implementation of WEEE management but these policies are not entertained by informal sector

(Wath et al., 2010). The current Indian regulations and policies to tackle the harmless disposal of WEEE are ambiguous (Dutta et al., 2006; Dwivedy and Mittal, 2010). Moreover, the specific measures for managing WEEE are unclear in these policies and legislations, thereby weakening the effectiveness of WEEE management (Chaturvedi et al., 2007; Srinivasan and Bhambri, 2009; Rajesh, 2011).

4.2.2. Infrastructural Barriers

Infrastructural facilities play an essential part in the WEEE management issues. Infrastructural barriers include lack of infrastructural facility (storage, transportation), limited planning and forecasting of WEEE generation, and lack of coordination or collaboration between recycling partners (Lau and Wang, 2009; Rahimfard et al., 2009; Chung and Zhang, 2011). The management could handle WEEE collection, transportation, recycling, and disposal efficiently through an effective infrastructural facility (Dat et al., 2012). The absence of coordination among the recycling partners has hampered recycling ability of the recycling plant (Zhou et al., 2007). Chung and Zhang (2011) suggested that the absence of proper planning and forecasting of WEEE generation have hampered waste recycling ability to efficiently deal with issues related to WEEE generation.

4.2.3. Knowledge Barriers

The stakeholders consist of manufacturer, policymakers, and consumers of electronics goods and people involved in waste recovering industries; these stakeholders show little concern about the degrading condition of the environment and feeble consciousness about safeguarding the environment in the current scenario (Liu et al., 2006). The knowledge barriers that hinder WEEE management implementation are related to lack of awareness about take-back channel limited public awareness toward WEEE recycling, inadequate training program for less skilled labor, limited inter-industry knowledge exchange of WEEE recovery program, less awareness about the advanced recycling fee (ARF), lack of awareness about business opportunities for implementing WEEE recycling program, insufficient consumer knowledge about green product (Yu et al., 2010; Yoshida and Yoshida, 2010; Atasu and Subramanian, 2012; Dwivedy and Mittal, 2013; Nnorom et al., 2009; Ravi et al.,2005; Luthra et al., 2011; Khetriwal et al., 2009; Wang and Xu, 2014). This category refers to knowledge flow and WEEE management awareness in public and private domain. Poor knowledge about take-back channel of EOL products and poor public awareness towards WEEE recycling are the key issues related to successful implementation of WEEE management (Abdulrahman et al., 2014; Chi et al., 2011; Gutberlet, 2012).

4.2.4. Socio-economic Barriers

Socio-economic barriers refers to competition between formal and informal sector, insufficient subsidy and tax system for formal sector, deficient e-market deposit refund system, poor safety concern during informal recycling, lack of willingness to pay (WTP), inadequate harmonized system code, low recycling penetration and supply of domestic WEEE (Sharma et al., 2011; Baskaran and Muchie, 2006; Gregory and Kirchain, 2007; Grant et al. 2013; Cucchiella et al., 2015; Ojeda-Benıtez et al., 2008; Nnorom et al., 2009). Lau and Wang (2009) stated that in developing nations producers are still not able to recover rare and valuable material for recycling because of low recycling penetration and limited supply of domestic WEEE. Lack of willingness to pay for WEEE recycling is one of the key issues in WEEE management (Guerrero et al., 2013; Sarkhel et al., 2015). The appropriations and tax immunity can effectively inspire organized sector to contribute in the recycling of WEEE (Williams, 2005; Zhang et al., 2012).

4.2.5. Socio-cultural Barriers

Socio-cultural barriers include low public environmental consciousness, poor social condition of scavengers, waste pickers and sweepers, poor purchasing behavior of consumers, lack of willingness and pessimistic attitude of residents in WEEE recycling, backyard recycling operation, need for change in the mindset of people and to develop a habit of recycling WEEE (Min and Galle, 2001; Lau and Wang, 2009; Medina, 2000; World bank, 2010; Saphores et al., 2006; Williams et al., 2008; Chi et al., 2011). Carvalho et al. (2012) observed resident's unwillingness and pessimistic attitude toward WEEE recycling,as the issues behind the lck of WEEW management. The foremost challenge of WEEE handling is to take care of the safety measures of recycling workers (including women and children's). Workers continue to risk their health by working without taking any safety measure in backyard recycling sites (Wibowo and Deng, 2015). Kirakozian (2016) found that resident's environmental consciousness is an important causal factor and considerably affect WEEE recycling. Finally as per the literature, we found that cultural aspect has a pessimistic effect on WEEE recycling.

4.2.6. Technological Barriers

In this study, we identified the technological barriers, which are lack of green recycling practices for handling WEEE issue, limited skilled workforce, outdated technologies and processes of WEEE recycling, lack of establish standards and certification for WEEE recycling firms, lack of biological treatment of WEEE recycling, inadequate R&D assistance related to metal recovery, and lack of flexibility to change over to new practices from the current system (Mishra and Rhee, 2010; Kantarelis et al., 2011; Kapetanopoulou and Tagaras, 2011; Babu et al. 2007; Natarajan and Ting, 2014; Garlapati., 2016). The sustainability of WEEE management practices depends on the available technology and recycling techniques (Govindan et al., 2014). The key issues related to the implementation of WEEE management are lack of advanced technology and lack of standards and certification for recycling and disposal enterprises were key issues related to WEEE management implementation (Wath et al., 2010; Nnorom and Osibanjo, 2008).

4.2.7. Financial Barriers

Financial barriers are lack of financial support from government for WEEE recycling start-ups and inadequate availability of funds for RoHS practices, return monitoring, initial capital investment for recycling plants, collection centers, training and awareness program for WEEE recycling, and high cost involved in toxic waste disposal (Ravi and Shankar, 2005; Shi et al., 2008; Abdulrahman et al., 2014; Garlapati, 2016).Financial barriers are vital obstacle that assumes to comprehend instantaneous aids (Wath et al., 2010; Ravi et al., 2005). Table 4.1 listed the various socio-economic theories used to rationalize the identified barriers and Table 4.2 listed the main barriers and sub-barriers to WEEE management adoption used in the study.

***Table 4.1. Foundation of socio-economic theories relative to the barriers of WEEE management*.**

Theory	Basics of the theory	Support for WEEE Management	Barrier Category	Barriers
TCE	Companies exist to maximize their profits by minimizing their transaction cost incurred in all activities.	Minimization of transaction costs such as transportation cost, recycling cost and disposal cost and maximization other benefits like tax subsidies for formal recycling companies to make business more competitive.	Financial	High cost involved in toxic waste disposal
			Infrastructural	Lack of infrastructure facility (storage, transportation, treatment and disposal technology)
				Limited planning and forecasting of WEEE generation
			Socio-economic	Deficient e-market deposit refund system initiatives
				Low recycling penetration and supply of domestic WEEE
				Insufficient subsidy and tax system for formal sector
RBT	Companies are comprised with bundles of resources and competencies that represents the basis of their competitive advantage.	Maximize the recycling companies ability to access the wide range of resources; as recycling and disposal companies grows they can offer wide range of services such as collaboration with partners, knowledge and information and technical capabilities.	Financial	Lack of funds for RoHS practices
				Lack of funds for return monitoring systems
				Lack of funds for initial capital investment for recycling plants
				Lack of financial support from government for WEEE recycling start-ups
				Lack of funds for collection centers
				Lack of funds for training and awareness program for WEEE recycling
			Technological	Lack of green recycling practices for handling WEEE issue
				Limited skilled workforce
				Outdated technologies and processes of recycling
				Lack of biological treatment of WEEE
				Inadequate R&D assistance related to metal recovery
				Lack of flexibility to change over to new practices from current system
			Knowledge	Less awareness about the Advanced Recycling Fee (ARF)
				Inadequate training program for less skilled labor
				Limited public awareness toward WEEE recycling
				Lack of knowledge about

				take-back channel
				Lack of awareness about business opportunities for implementing WEEE recycling program
				Insufficient consumer knowledge about green product
			Socio-cultural	Low public environmental consciousness
			Socio-economic	Inadequate harmonized system code
TPB	Theory of planned behavior aims to explain the relationship between attitude willingness and behavior within human activity.	This theory is important to understand recycling behavior which requires considerable efforts on the part of consumers to segregate and take recyclables to waste collection centers.	Socio-economic	Lack of willingness to pay (WTP)
			Socio-cultural	Lack of willingness and pessimistic attitude of residents for WEEE recycling
				Poor purchasing behavior of consumers
				Need for change in the mindset and to develop a habit for recycling WEEE
				Lack of willingness and pessimistic attitude of residents for WEEE recycling
INT	Institutional theory provide a theoretical lens to examine legitimacy of green practices, including factors such as socio-cultural, social environment, tradition, socio-economic as well as legal environmental regulation.	According to Institutional theory, social, economic and political pressure influence organizational strategies leads to the adoption of WEEE management practices.	Policy and regulatory	Delay in WEEE Law enforcements
				Violation of Basel Ban amendment
				lack of systematic monitoring and auditing
				lack of RoHS practices
				Lack of policies and regulation addressing environmentally sound WEEE recycling
			Socio-cultural	Backyard recycling operation
NT	Network theory states that, organizations that have an intention to form alliances and coordinate well with other organization are capable to create competitive advantage.	Maximizes a firm's ability to leverage relationships; as 3PLs become responsible for a larger number of supply chain members their ability to offer greater network interactions increases.	Infrastructural	Lack of coordination or collaboration between partners
			Knowledge	Limited inter-Industry knowledge exchange of WEEE recovery program
ST	Stakeholder theory places shareholders (actors) as one of the multiple actors or group must consider in their decision making process	Stakeholder theory states that prioritization of social actors are required determine which stakeholder needs more attention form the	Policy and regulatory	Un-defined role of stakeholders (actors) Delay in EPR (Extended producer responsibility) approaches

		management and which do not. .	Socio-economic	Competition between formal and informal sector
				Poor safety concern during informal recycling
			Socio-cultural	Poor social conditions of scavengers, recycler and waste pickers

Note*: TCE= Transaction cost economics; RBT= Resource based theory; TPB= Theory of planned behavior; INT= Institutional theory; NT= Network theory; ST= Stakeholder theory

Table 4.2. Barriers of WEEE management implementation along with main criteria and sub-criteria.

Main Barriers Criteria	**Code**	**Sub Barriers Criteria**	**References**
Policy and Regulatory barriers (PR)	PR-1	Delay in EPR (Extended producer responsibility) approaches	Chaturvedi et al., 2007; Carisma, 2009; Mo et al., 2009; Wath et al., 2010
	PR-2	Delay in WEEE Law enforcements	Zhao et al., 2010; Kiddee et al., 2013; Abdulrahman et al., 2014; Garlapati, 2016
	PR-3	lack of systematic monitoring and auditing	Chisholm and Bu, 2007; Srinivasan and Bhambri, 2009; UNEP, 2009
	PR-4	Un-defined role of stakeholders (actors)	Kojima and Michida, 2013; Yoon and Sim, 2015; Shi et al., 2008; De Sousa Jabbour et al., 2014
	PR-5	lack of RoHS practices	Kiddee et al., 2013; Afroz et al., 2013; Dwivedy and Mittal, 2013; Menikpura et al., 2014; Trivedi et al., 2015
	PR-6	Lack of policies and regulation addressing environmentally sound WEEE recycling	Den Boer, 2007; Wang and Xu, 2014; Chauhan et al., 2018
	PR-7	Violation of Basel Ban Amendment	Luthra et al., 2011; Chung and Zhang, 2011; Robinson, 2009; Bisschop, 2012; Zhang et al., 2010
Infrastructural barriers (I)	I-1	Lack of infrastructure facility (storage, transportation, treatment and disposal technology)	Rahimfard et al., 2009; Dat et al., 2012; Prakash et al., 2015
	I-2	Limited planning and forecasting of WEEE generation	Lau and wang, 2009; Chung and Zhang, 2011
	I-3	Lack of coordination or collaboration between partners	Jindal and Sangwan, 2011; Chauhan and Singh, 2016
Knowledge Barriers (K)	K-1	Lack of knowledge about take-back channel	Yu et al., 2010; Yoshida and Yoshida, 2010; ETBC, 2011; Atasu and Subramanian, 2012; Dwivedy and Mittal, 2013; Abdulrahman et al., 2014
	K-2	Limited public awareness toward WEEE recycling	Liu et al. 2006; Pandya and Hon, 2008; Nnorom et al., 2009; Chi et al., 2011;

			Gutberlet, 2012
	K-3	Inadequate training program for less skilled labor	Post and Altman, 1994; Hillary, 2004; Ravi et al.,2005
	K-4	Limited inter-Industry knowledge exchange of WEEE recovery program	Luthra et al., 2011; Abdulrahman et al., 2014
	K-5	Less awareness about the Advanced Recycling Fee (ARF)	Terazono et al., 2006; Yoshida et al., 2007; Khetriwal et al., 2009; Saphores et al., 2012
	K-6	Lack of awareness about business opportunities for implementing WEEE recycling program	Den Boer, 2007; Wang and Xu, 2014
	K-7	Insufficient consumer knowledge about green product	Experts input
Socio-economic Barriers (SE)	SE-1	Competition between formal and informal sector	Experts input
	SE-2	Insufficient subsidy and tax system for formal sector	Williams, 2005; Sharma et al., 2011; Alvarez-Gil et al., 2007
	SE-3	Deficient e-market deposit refund system initiatives	Warschauer, 2004; Baskaran and Muchie, 2006; Gregory and Kirchain, 2007
	SE-4	Poor safety concern during informal recycling	Leung et al., 2008; Li et al., 2009; Driscoll and Shiheng, 2010; Grant et al. 2013; Cucchiella et al., 2015
	SE-5	Lack of willingness to pay (WTP)	Ojeda-Benıtez et al., 2008; Nnorom et al., 2009; Saphores et al., 2012; Guerrero et al., 2013; Sarkhel et al., 2015; Biswas and Roy, 2016; Kumar et al., 2016
	SE-6	Inadequate harmonized system code	Carisma, 2009
	SE-7	Low recycling penetration and supply of domestic WEEE	Lau and Wang, 2009
Socio-cultural barriers (SC)	SC-1	Low public environmental consciousness	Min and Galle, 2001; Lau and Wang, 2009; Nnorom et al., 2009; Carvalho et al., 2012; Godfrey et al., 2013
	SC-2	Poor social conditions of scavengers, recycler and waste pickers	Medina, 2000; World bank, 2010; Wibowo and Deng, 2015
	SC-3	Poor purchasing behavior of consumers	Experts input
	SC-4	Lack of willingness and pessimistic attitude of residents for WEEE recycling	Ravi et al., 2005; Saphore et al., 2006; Kirakozian, 2016
	SC-5	Backyard recycling operation	Williams et al., 2008; Chi et al., 2011
	SC-6	Need for change in the mindset and to develop a habit for recycling WEEE	Experts input
Technological Barriers (T)	T-1	Lack of green recycling practices for handling WEEE issue	Mishra and Rhee, 2010; Kantarelis et al., 2011
	T-2	Limited skilled workforce	Tojo, 2001; Gottberg et al., 2006; Lindhqvist et al., 2006 Kapetanopoulou and Tagaras, 2011

	T-3	Outdated technologies and processes of recycling	Babu et al. 2007; MPCB, 2007; Lau and Wang, 2009; Wath et al., 2010
	T-4	Lack of establish standards and certification for WEEE recycling firms	Nnorom and Osibanjo, 2008
	T-5	Lack of biological treatment of WEEE	Pant et al., 2012; Ilyas et al., 2013; Natarajan and Ting, 2014; Garlapati., 2016
	T-6	Inadequate R&D assistance related to metal recovery	Beamon, 1999; Rahimifard et al., 2009; Andiç et al.,2012; Govindan et al., 2014
	T-7	Lack of flexibility to change over to new practices from current system	Experts input
Financial barriers (F)	F-1	Lack of funds for RoHS practices	Ravi and Shankar, 2005; Shi et al., 2008
	F-2	Lack of funds for return monitoring systems	Abdulrahman et al., 2014
	F-3	Lack of funds for initial capital investment for recycling plants	Ravi and Shankar, 2005; Shi et al., 2008
	F-4	Lack of financial support from government for WEEE recycling start-ups	Experts input
	F-5	Lack of funds for collection centers	Ravi and Shankar, 2005; Shi et al., 2008
	F-6	Lack of funds for training and awareness program for WEEE recycling	Wath et al., 2010
	F-7	High cost involved in toxic waste disposal	Wath et al., 2010; Garlapati, 2016

4.3 An illustrative case study and application of proposed framework for WEEE management adoption in Indian Scenario

4.3.1 Data Collection

The cross functional decision/expert panel has been formed and it includes 18 experts that comprise five senior and middle manager executives or company experts from electric and electronic equipment (EEE) manufacturer, three electronic retailer, six WEEE recyclers, two policy makers (government expert), one academic expert, and one Non-Government Organization (NGO). These experts have been selected and targeted for interviews, so as to receive their responses to question specifically relevant to their respective roles and capacities. Experts selected have more than 10 years of experience and proficiency in their domain. A questionnaire was designed and circulated among the managers, waste management experts, field experts of EEE manufacturing companies, policy makers and WEEE recyclers to collect responses required for the research work. The EEE manufacturer, WEEE recyclers, and policy makers were primarily selected for data collection, because they are directly involved in the decision making process of implementation and adoption of WEEE management in Indian context. Finally, the responses were collected through personal interviews, group discussions with experts, and field visits on recycling sites, which were necessary owing to the small number of these subgroups and the concern of revealing proprietary information (Liang and Sharp, 2016). Table 4.3 depicted the detail summary of the respondent profile.

Table 4.3 A detailed summary of the respondents' profile.

Respondent	**No. of respondent**	**Position**	**Experience**
Electronic manufacturer	5	Senior and middle level manager	More than 10 years
WEEE Recycling	6	Owner	More than 12 years
Electronic retailer	3	Owner	More than 15 years
Central pollution control board (CPCB)	2	Government Executive	More than 12 years
Academic expert	1	Professor	More than 13 years
Non-government organization (NGO)	1	Social worker	More than 12 years

5.3.2 Finalization of selection criteria/barriers

In this phase, the barriers were identified and listed on the basis of extensive literature review and exhaustive discussion with domain experts related to the adoption of WEEE management. A panel of all the 18 experts rated the barriers on a five-point Likert scale. After three rounds of discussions among experts and additions of six barriers in the final list, a total of forty-four barriers were finalized which were categorized into seven categories as shown in Table 4.3 were taken for further analysis. Finally, we finalized forty-four barriers and categorized them into seven main barriers criteria. These seven criteria of the barriers are Policy and Regulatory barriers (PR), Infrastructural barriers (I), Knowledge barriers (K), Socio-economic barriers (SE), Socio-cultural barriers (SC), Technological barriers (T), and financial barriers (F) and represented in figure 4.2.

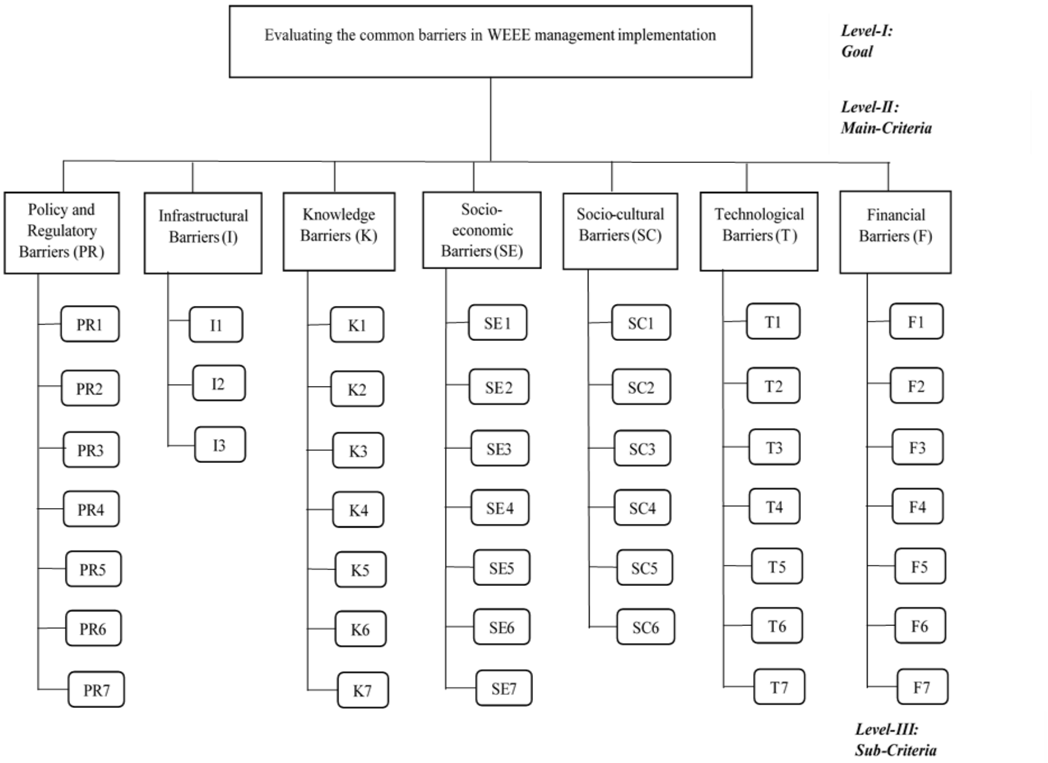

Figure 4.2 A decision hierarchical structure of barriers to WEEE management.

4.3.3. Evaluating the causal interaction among the WEEE management implementation barriers using DEMATEL application

In order to evaluate the interaction among the listed barriers pertinent to the adoption of the WEEE management from Indian perspective, the DEMATEL methodology is applied. This approach helps in scrutinizing the cause and effect relationship among the barriers and representing in causal relationship mapping. To start with the survey, we interacted with the experts and requested them to rate the barriers based on the prescribed likert scale depending upon the impact of one barrier over the other. The average direct relationship matrix (A) of the main criteria is constructed by taking the average of the responses of the experts (Table 4.4). Subsequently, with the help of equation (3.1), the normalized initial direct relation matrix (D) is calculated (Table 4.5).

Table 4.4 Average direct relation matrix (A) for main barriers criteria.

Main criteria	PR	I	K	SE	SC	T	F
PR	0	3	3.5	3.5	1.5	3.25	3.5
I	3.5	0	2	1.5	2.25	3	3.5
K	3.25	1	0	1.25	2.75	3	1.75
SE	3.25	3	2.75	0	2.5	3	3.5
SC	1.25	1.5	3.25	3.75	0	3.25	2.5
T	3	3	3	2	2	0	2.5
F	3	3.25	1.5	2	1.75	2.25	0

Table 4.5. Normalized direct relation matrix (D) for main barriers criteria.

Main criteria	PR	I	K	SE	SC	T	F
PR	0.0000	0.1644	0.1918	0.1918	0.0822	0.1781	0.1918
I	0.1918	0.0000	0.1096	0.0822	0.1233	0.1644	0.1918
K	0.1781	0.0548	0.0000	0.0685	0.1507	0.1644	0.0959
SE	0.1781	0.1644	0.1507	0.0000	0.1370	0.1644	0.1918
SC	0.0685	0.0822	0.1781	0.2055	0.0000	0.1781	0.1370
T	0.1644	0.1644	0.1644	0.1096	0.1096	0.0000	0.1370
F	0.1644	0.1781	0.0822	0.1096	0.0959	0.1233	0.0000

In the next step, based on Equation (3.3), the total relation matrix (T) is established by the following formula: $T = N (I - N)^{-1}$, and is represented in (Table 4.6). The total relationship matrix (T) and the values in the (r + c) column (i.e. prominence), demonstrate the overall effect of each barrier criteria throughout the system. Based on Table 4.6, the policy and regulatory barriers (PR) is considered to be the most important criteria, as it has acquired the maximum(r + c) value, i.e., 13.4797 whereas, the socio-cultural barriers (SC) have scored the least, i.e., 10.9071. Generally, the ranking of the main criteria can be done by (r + c) values. Similarly, the values in (r - c) column (i.e. relation) help to separate the criteria into cause and effect groups based on their obtained values. Following this, we calculated the threshold value of the main criteria with the help of the total relation matrix (T) that not only facilitates in making this structure distinct, but also helps in building the causal effect map. This interrelationship map helps to understand the influence of one barrier over the other barriers, and assists to filter out some negligible effects in the causal effect map. Based on the (r - c) values, the barrier under main criteria are categorized into cause and effect group. The causal effect map of the barriers under the main criteria is shown in Figure 4.3. Similarly, the analysis has been performed for the sub barriers too.

Table 4.6 Total relationship matrix (T) for main barrier criteria.

Main barriers	PR	I	K	SE	SC	T	F	r_i	r + c	r - c	Ranking
PR	0.949	0.9694	1.0317	0.9271	0.7885	1.1024	1.0962	6.8644	13.4797	0.2491	1
I	0.9934	0.7312	0.8668	0.7581	0.7317	0.9791	0.9861	6.0461	11.8316	0.2604	5
K	0.8519	0.6711	0.6565	0.6468	0.6597	0.8533	0.7826	5.1207	11.2391	-0.9977	6
SE	1.0877	0.9616	0.9942	0.7629	0.8228	1.0842	1.0884	6.8016	12.2055	1.3976	3
SC	0.8829	0.7885	0.9057	0.8363	0.6164	0.9735	0.9232	5.9266	10.9071	0.9461	7
T	0.9611	0.8562	0.8973	0.7648	0.7141	0.8256	0.9298	5.949	12.6296	-0.7316	2
F	0.8893	0.8089	0.7664	0.7083	0.6472	0.8625	0.7424	5.4247	11.9733	-1.1242	4
c_j	6.6153	5.7856	6.1184	5.4039	4.9805	6.6806	6.5487	Threshold value = 0.9933			

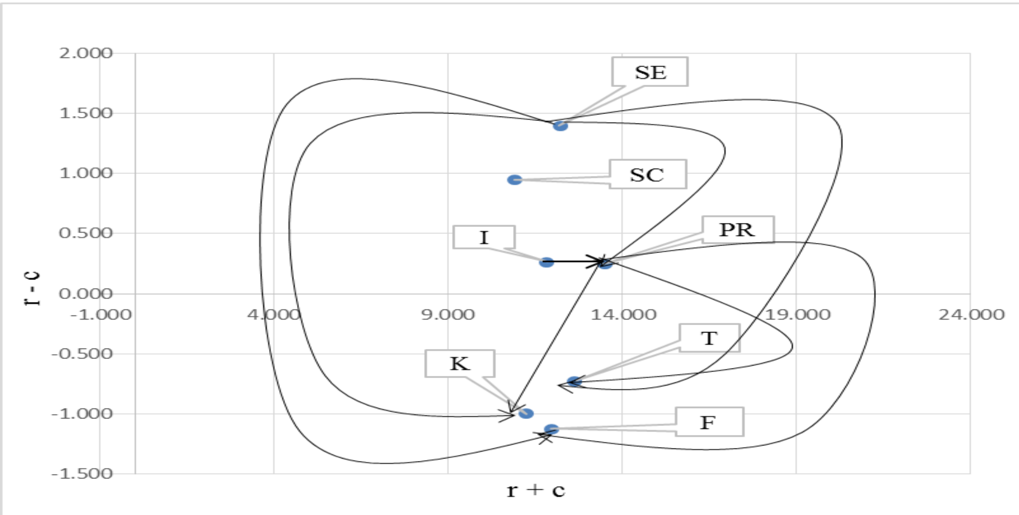

Figure 4.3. Causal digraph and relationship mapping (Main barriers criteria).

4.4. Results and discussions

This section discussed the result of the study, which represents an attempt to ameliorate the sustainable performance in the context of WEEE management from Indian perspective. In this study, each barrier and sub barrier under main criteria was ranked on the basis of the evaluation criteria, and the causal relationship among the barriers was visualized, based on the aggregated responses from the waste management experts that help in development of decision making approaches, which are useful in the operative execution of WEEE management.

Based on Table 4.6, the policy and regulatory barriers (PR) are considered to be the most important main barriers that play an important role in the implementation of WEEE management (Srinivasan and Bhambri, 2009; Wath et al., 2010; Rajesh, 2011). In addition, policy and regulatory barriers (PR) come under the cause group (figure 4.3), based on the (r - c) value that is equal to 0.2491 (positive). Correspondingly, the policy and regulatory barriers (PR) significantly affect on the barriers under main criteria. The seven sub barriers associated with policy and regulatory barriers are categorized as PR1 to PR7. These sub barriers are listed according to their relative weight and ranking in order of delay in extended producer responsibility (EPR) approach (PR1) > violation of Basel ban amendment (PR7) > lack of systematic monitoring and auditing (PR3) > lack of RoHS practices (PR5) > un-defined role of stakeholders (actors) (PR4) > delay in WEEE Law enforcement (PR2) > lack of policies and regulation addressing environmentally sound WEEE recycling (PR6) (Table 4.7).

Table 4.7 Total relationship matrix (T) for policy and regulatory barrier.

Sub-barrier	PR1	PR2	PR3	PR4	PR5	PR6	PR7	r_i	r + c	r - c	Ranking
PR1	0.6301	0.6789	0.7658	0.7812	0.7091	0.6341	0.8007	4.9999	9.3923	0.6074	1
PR2	0.6094	0.4410	0.6387	0.7011	0.5940	0.4500	0.6321	4.0663	7.8677	0.2648	6
PR3	0.7310	0.5743	0.5468	0.6731	0.6526	0.5781	0.7253	4.4811	8.7562	0.2060	3
PR4	0.5664	0.4925	0.6073	0.4753	0.4700	0.4302	0.6142	3.6560	8.1764	-0.8644	5
PR5	0.7296	0.5976	0.6452	0.6797	0.5095	0.5635	0.7645	4.4896	8.4275	0.5517	4
PR6	0.4391	0.3970	0.3936	0.4562	0.3633	0.2675	0.4554	2.7721	6.1822	-0.6380	7
PR7	0.6870	0.6202	0.6776	0.7538	0.6394	0.4868	0.5875	4.4522	9.0318	-0.1274	2
c_j	4.3925	3.8015	4.2751	4.5204	3.9379	3.4101	4.5796	Threshold value = 0.7133			

Delay in EPR approach (PR1) holds the top position and it is proved to be the most important barrier for the implementation of WEEE management in Indian scenario (Srinivasan and Bhambri, 2009). Further, according to the (r - c) values, the sub barriers (PR1), (PR2), (PR3) and (PR5) belong to cause group, which has significant influence over the sub barriers (PR4), (PR6) and (PR7) that belong to the effect group (Figure 4.4). Overcoming these barriers, there is an urgent need for the developing nation like India to introduce clear policies and regulatory instruments that deal specifically with issues like illegal import of WEEE, clear and defined role of the municipalities and Pollution Control Boards (PCBs) for implementation, ensuring effective compliance for final disposal and handling of WEEE, financial assistance of WEEE recycling and encouraging the establishment of the initiatives taken by waste disposal firms as well as special funds for the development of updated technology, extended producers responsibility (EPR) initiatives and development of a streamline national e-waste policy for WEEE management (Hick, 2005; Joseph, 2007; Osibanjo and Nonorom, 2007; Wath et al., 2010).

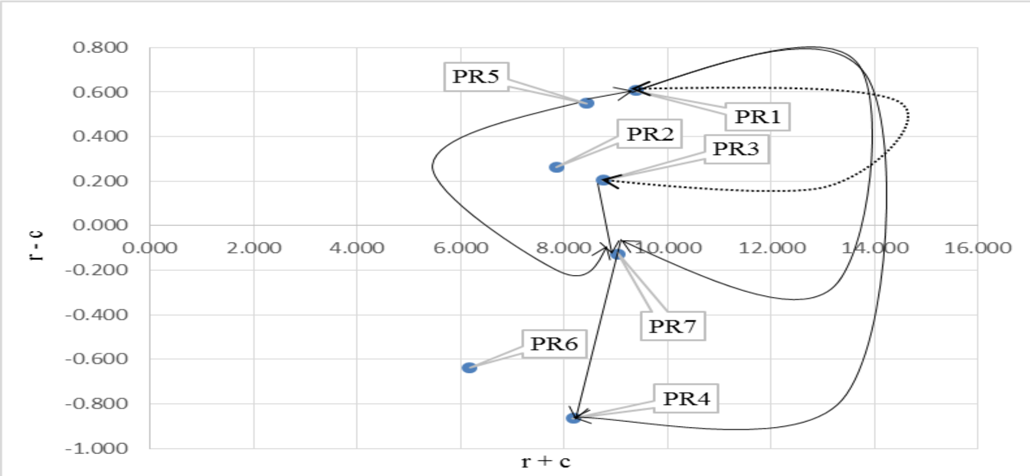

Figure 4.4 Causal digraph and relationship mapping of policy and regulatory barriers.

Technological barrier (T) holds the second position in the priority list and is considered as a key barrier in the adoption of WEEE management in Indian context (Table 4.6). Particularly, in emerging nations like India, there is deficiency of up to date recycling technologies and lack of skilled workforce for performing waste management activities (Lau and Wang, 2009; Wath et al., 2010; Gottberg et al., 2006; Kapetanopoulou and Tagaras, 2011). Further, considering the causal relationship mapping, technological barriers (T) belongs to effect group (Figure 4.3). Technological barriers (T) consists of seven sub barriers, and the ranking of these sub barriers are based on Table 4.8, limited skilled workforce (T2) > lack of green recycling practices for handling WEEE issues (T1) > lack of establish standards and certification for WEEE recycling firms (T4) > inadequate R&D assistance for metal recovery (T6) > outdated technologies and recycling processes (T3) > lack of biological treatment of WEEE (T5) > lack of flexibility to change over to new practices from the current system (T7). The sub barriers (T1), (T2) and (T5) come under the cause group, which implies that they have influential impact over the sub barriers come under the effect group, namely (T3), (T4), (T6) and (T7) (Figure 4.5). Advanced technological aid will help the developing nations in building competent infrastructure to handle the WEEE management problem. Developing nations should keep in mind their cultural, economic, social and environmental considerations while perusing the technology options (Khan et al., 2014).

Table 4.8 Total relationship matrix (T) for technological barriers.

Sub-barrier	T1	T2	T3	T4	T5	T6	T7	r_i	r + c	r - c	Ranking
T1	0.8376	1.1486	1.1700	1.0405	0.9329	1.0913	0.9207	7.1416	12.9925	1.2907	2
T2	0.9830	0.9986	1.1334	1.0412	0.9641	1.0903	0.9430	7.1536	14.1227	0.1844	1
T3	0.7372	0.8811	0.7678	0.8317	0.7074	0.8565	0.7147	5.4965	12.4731	-1.4802	5
T4	0.8261	1.0076	1.0252	0.7975	0.7937	0.9764	0.8406	6.2670	12.6154	-0.0814	3
T5	0.9166	1.0298	1.0624	0.9141	0.7246	0.9299	0.8631	6.4405	12.0372	0.8439	6
T6	0.8298	1.0001	0.9634	0.8683	0.7411	0.7837	0.7446	5.9310	12.4880	-0.6259	4
T7	0.7206	0.9033	0.8545	0.8551	0.7329	0.8289	0.6277	5.5229	11.1774	-0.1315	7
c_j	5.8509	6.9692	6.9766	6.3484	5.5967	6.5570	5.6544	Threshold value= 1.028			

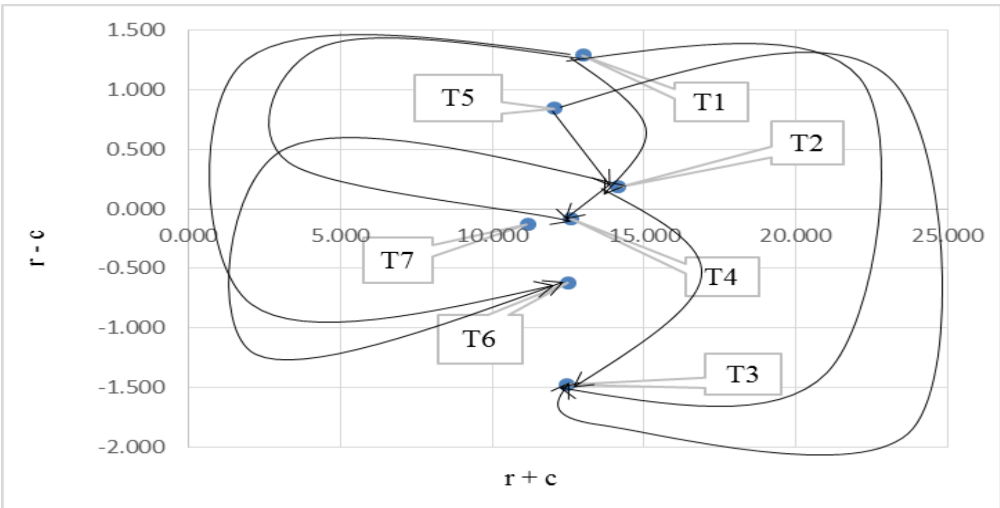

Figure 4.5 Causal digraph and relationship mapping of policy and technological barriers.

Socio-economic barrier (SE) acquires the third rank in the priority list and belongs to the cause group in the causal relationship map (Figure 4.3). The Socio-economic barrier (SE) consists of seven sub barriers and the ranking of these sub barriers are low recycling penetration and supply of domestic WEEE (SE7) > Competition between formal and informal sector (SE1) > lack of willingness to pay (WTP) (SE5) > deficient e-market deposit refund system initiatives (SE3) >

insufficient subsidy and tax system for formal sector (SE2) > poor safety concern during informal recycling (SE4) > inadequate harmonized system code (SE6). Of these barriers, low recycling penetration and supply of domestic WEEE (SE7) and Competition between formal and informal sector (SE1) hold first and second position (Table 4.9).

Table 4.9 Total relationship matrix (T) for socio-economic barriers.

Sub-barriers	**SE1**	**SE2**	**SE3**	**SE4**	**SE5**	**SE6**	**SE7**	**r_i**	**r + c**	**r - c**	**Ranking**
SE1	0.5193	0.5702	0.5208	0.5850	0.6165	0.5365	0.5984	3.9466	7.8802	0.0131	2
SE2	0.6061	0.3563	0.4294	0.5115	0.4867	0.4209	0.5079	3.3189	6.4528	0.1850	5
SE3	0.5312	0.4270	0.3682	0.4504	0.5648	0.4482	0.5758	3.3657	6.5793	0.1521	4
SE4	0.5693	0.4864	0.3966	0.3528	0.4922	0.4067	0.4929	3.1969	6.4402	-0.0464	6
SE5	0.5244	0.3949	0.5216	0.4494	0.4065	0.3918	0.5504	3.2389	6.9345	-0.4567	3
SE6	0.4455	0.3291	0.3658	0.3382	0.4295	0.2737	0.4510	2.6328	5.7099	-0.4444	7
SE7	0.7378	0.5700	0.6112	0.5561	0.6993	0.5994	0.5355	4.3093	8.0211	0.5975	1
c_j	3.9336	3.1339	3.2136	3.2433	3.6956	3.0772	3.7118	Threshold value= 0.5880			

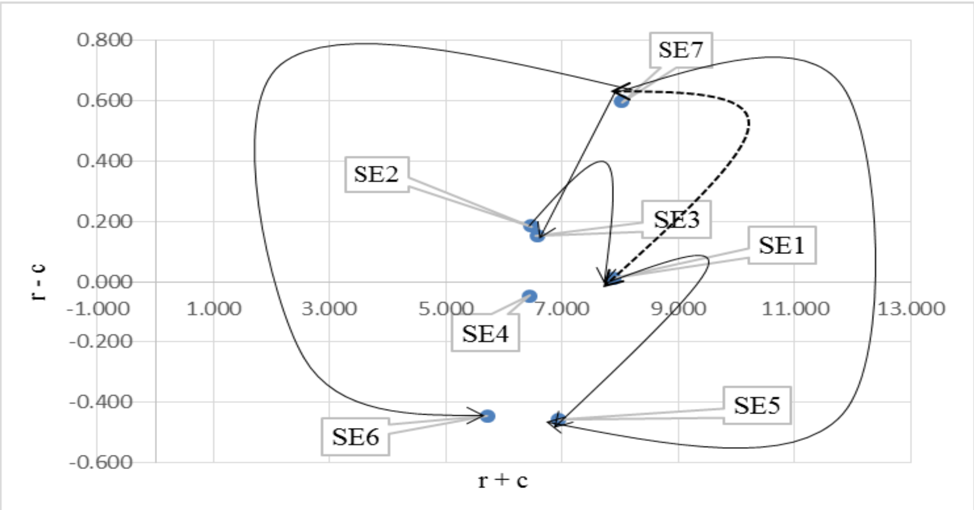

Figure 4.6 Causal digraph and relationship mapping of socio-economic barriers.

In addition, many authors (Sharma et al., 2011; Alvarez-Gil et al., 2007; Eric, 2005) have confirmed that a key barrier of WEEE management implementation is the lack of justified tax subsidies for organized sector. Finally, sub barriers (SE1), (SE2), (SE3) and (SE7) come under the cause group, and sub barriers (SE4), (SE5) and (SE6) come under the effect group (Figure 4.6). In this regard, a much needed tax subsidies and incentive plan policies is required for recycling sector. Encourage consumer towards willing to pay for the recycling activities. Therefore, the major goal is to identify the sustainable practices and to convey this knowledge to train practitioners for resolving issues related to WEEE management (Wath et al., 2010; Khan et al., 2014; Garlapati, 2016).

Financial barrier (F) holds the fourth position in the priority list (Table 4.6). The financial barrier (F) belongs to the effect group in the causal relationship map (Figure 3). According to the Table 4.10, the ranking of the reported financial sub barriers are lack of financial support from government for WEEE recycling start-ups (F4) > lack of funds for initial capital investment for recycling plants (F3) > lack of funds for collection centers (F5) > high cost involved in toxic waste disposal (F7) > lack of funds for training and awareness program for WEEE recycling (F6) > lack of funds for RoHS practices (F1) > lack of funds for return monitoring systems (F2). Of these sub barriers, lack of financial support from government for WEEE recycling start-ups (F4) holds the highest position among all the financial sub barriers for WEEE implementation (Ravi and Shankar, 2005; Shi et al., 2008). Besides, the sub barriers (F4), (F5) and (F7) are placed in the cause group, while the sub barriers (F1), (F2), (F3) and (F6) come under the effect group (Figure 4.7). Government and businesses would appreciate if they have intentional financial plans and vision connected with the approval and implementation of WEEE management practices in the Indian perspective (Wath et al., 2010).

Table 4.10 Total relationship matrix (T) for financial barriers.

Sub-barriers	F1	F2	F3	F4	F5	F6	F7	r_i	r + c	r - c	Ranking
F1	0.3220	0.4647	0.5030	0.4310	0.4104	0.4612	0.3645	2.9568	6.1613	-0.2476	6
F2	0.3970	0.2924	0.4812	0.3786	0.4139	0.4611	0.3778	2.8020	5.8864	-0.2824	7
F3	0.5057	0.4189	0.4387	0.5444	0.5651	0.5215	0.4982	3.4925	7.1701	-0.1850	2
F4	0.5917	0.5819	0.6781	0.4909	0.6165	0.6252	0.6198	4.2041	7.6175	0.7907	1
F5	0.4645	0.4184	0.5460	0.5199	0.3819	0.4994	0.4679	3.2979	6.6657	-0.0698	3
F6	0.4323	0.4621	0.4837	0.4921	0.4493	0.3669	0.4257	3.1120	6.5553	-0.3312	5
F7	0.4913	0.4460	0.5468	0.5565	0.5307	0.5080	0.3724	3.4518	6.5781	0.3254	4
c_j	3.2045	3.0844	3.6776	3.4134	3.3678	3.4433	3.1264	Threshold value=0.5671			

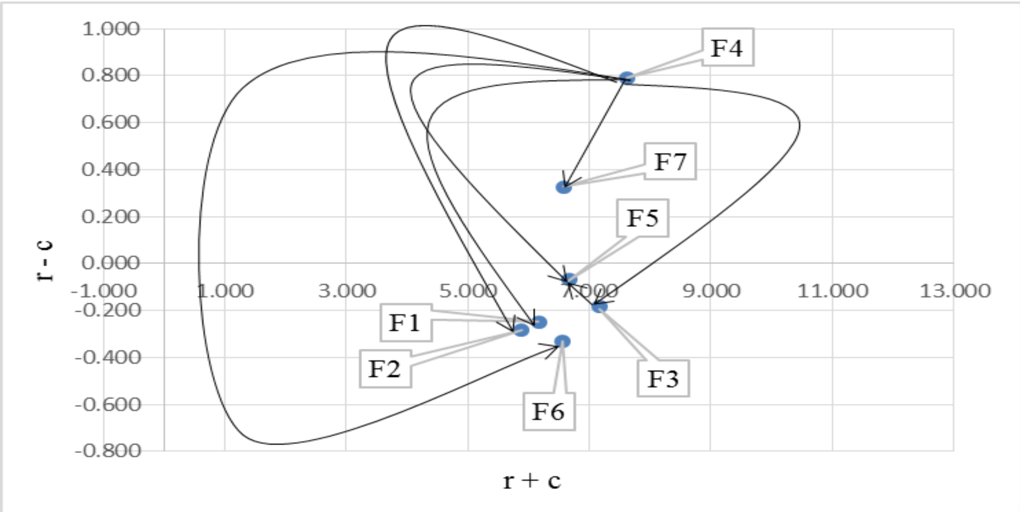

Figure 4.7. Causal digraph and relationship mapping of financial barriers.

Infrastructural barriers (I) acquire a fifth position among the other main barriers criteria and plays a crucial role in adopting effective WEEE Management practices (Rahimfard et al., 2009). Further, considering the causal mapping, the Infrastructural barrier (I) belongs to cause group (figure 3), which indicates that it is moderately vital among all other barriers under primary criteria. Under Infrastructural barriers (I), there are three sub barriers and their order of priority is highlighted as lack of infrastructural facilities (storage, transportation, treatment and disposal technology) (I1) > Lack of coordination/collaboration among supply chain partners (I3) > Limited planning and forecasting of WEEE generation (I2) (Table 4.11).

T***able 4.11 Total relationship matrix (T) for infrastructural barriers.***

Sub-barriers	I1	I2	I3	r_i	r + c	r - c	Ranking
I1	2.0019	1.8638	2.4493	6.3150	12.3197	0.3102	1
I2	2.0013	1.3462	2.0466	5.3942	10.1229	0.6654	3
I3	2.0015	1.5187	1.7364	5.2567	11.4890	-0.9757	2
c_j	6.0047	4.7287	6.2324	Threshold value= 2.046			

The sub barriers I1 and I2 fall under cause group, while I3 comes under effect group, which imply that barriers under cause group has a noteworthy influence over the barriers under effect group (Figure 4.8). A well-organized infrastructure such as proper storage and collection center, transportation amenities and better expertise in the disposal and recycling WEEE may resolve the difficulties relevant to the implementation of WEEE management and provide a chance to commence the receipt of WEEE management activities like repair, reuse, and recycling from business viewpoint (Abdulrahman et al., 2014).

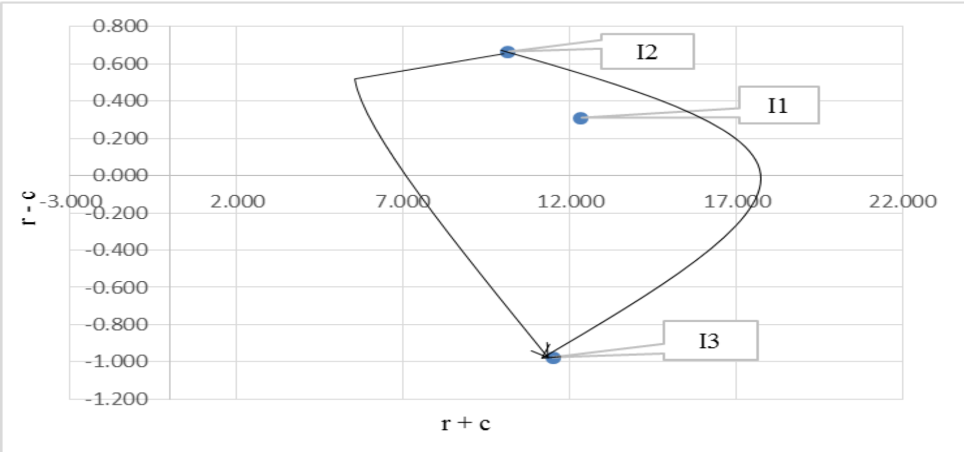

Figure 4.8 Causal digraph and relationship mapping of infrastructural barriers.

Knowledge barriers (K) obtain the sixth rank in the priority list, and are considered as a significant barrier to the adoption of WEEE management (Table 4.6). In addition, knowledge barrier (K) belongs to effect group in causal relationship map (Figure 3). There are seven sub barriers under Knowledge barriers (K) and their ranking order is given as limited public awareness towards WEEE recycling (K2) > less awareness about Advanced Recycling Fee (ARF) (K5) > lack of awareness about business opportunities for implementing WEEE recycling program (K6) > inadequate training for less skilled labor (K3) > lack of knowledge about take back channel (K1) > insufficient consumer knowledge for green product (K7) > limited inter-Industry knowledge exchange of WEEE recovery program (K4). According to the Table 4.12, limited public awareness towards WEEE recycling (K2) and less awareness about advanced recycling fee (ARF) (K5) are considered as the influential barriers to the adoption of WEEE management (Nnorom et al., 2009; Chi et al., 2011; Dwivedy and Mittal, 2013; Abdulrahman et al., 2014). According to the (r - c) values, the sub barriers (K1), (K5) and (K7) under cause group have significant influence over the sub barriers (K2), (K3), (K4) and (K6) that are in the effect group (Figure 4.9). Knowledge and awareness programs are vital for change and it should be adopted to control the menace of WEEE. With the help of consumers' awareness programs, the negative impact of WEEE on society and on the ecosystem can be highlighted. The awareness programs should be conducted on the basis of multi-actors involvement and collaboration among different sectors of society (Khan et al, 2014).

Table 4.12 Total relationship matrix (T) for knowledge barriers.

Sub-barriers	K1	K2	K3	K4	K5	K6	K7	r_i	r + c	r - c	Ranking
K1	0.6915	1.1155	0.9531	0.8763	0.8859	0.9301	0.7912	6.2436	11.6498	0.8373	5
K2	0.8712	1.0625	1.0770	0.9441	0.8927	1.0451	0.8976	6.7902	14.4700	-0.8896	1
K3	0.6877	1.0387	0.7793	0.9251	0.7068	0.8030	0.7964	5.7370	12.2809	-0.8069	4
K4	0.6147	0.9002	0.8441	0.6148	0.6293	0.7600	0.6405	5.0037	10.9210	-0.9136	7
K5	0.9299	1.3419	1.0604	0.9656	0.8185	1.1006	0.9232	7.1401	12.7153	1.5650	2
K6	0.8770	1.1383	0.9061	0.8191	0.8753	0.8179	0.8639	6.2978	12.6099	-0.0144	3
K7	0.7343	1.0825	0.9238	0.7723	0.7667	0.8555	0.6646	5.7998	11.3773	0.2223	6
c_j	5.4063	7.6798	6.5439	5.9173	5.5752	6.3121	5.5775	Threshold value= 1.0310			

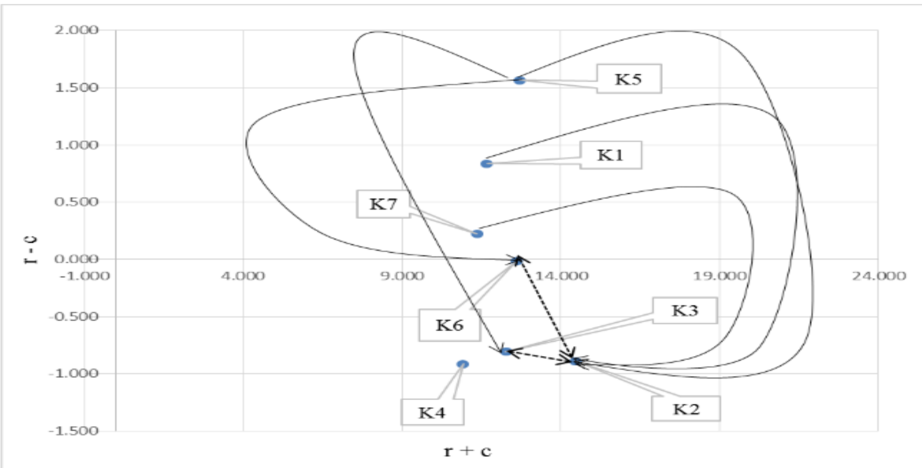

Figure 4.9 Causal digraph and relationship mapping of knowledge barriers.

Socio-cultural barrier (SC) holds the last position in the priority list and comes under the cause group in the causal mapping (Figure 3). The socio-cultural barrier (SC) consists of six sub barriers and the ranking of these sub barriers are low public environmental consciousness (SC1) > need to change in mindset and to develop a habit for recycling WEEE (SC6) > poor purchasing behavior of consumers (SC3) > lack of willingness and behavior of residents for WEEE recycling (SC4) > backyard recycling operation (SC5) > poor social conditions of scavengers, recycler and waste pickers (SC2). Of these barriers, low public environmental consciousness (SC1) and need to change in mindset and to develop a habit for recycling WEEE (SC6) are found to be most influential barriers to the WEEE management implementation (Table 4.13).

Table 4.13. Total relationship matrix (T) for socio-cultural barriers.

Sub-barriers	SC1	SC2	SC3	SC4	SC5	SC6	r_i	r + c	r - c	Ranking
SC1	0.5473	0.5777	0.5769	0.5964	0.5681	0.6437	3.5101	6.7993	0.2208	1
SC2	0.5176	0.2731	0.3756	0.3832	0.4295	0.3763	2.3553	4.7290	-0.0184	6
SC3	0.5825	0.3682	0.3172	0.4554	0.3640	0.5500	2.6373	5.1420	0.1326	3
SC4	0.5425	0.3439	0.4189	0.3187	0.3954	0.4979	2.5172	5.1366	-0.1022	4
SC5	0.5448	0.4248	0.3996	0.3767	0.2906	0.4248	2.4614	4.9048	0.0181	5
SC6	0.5545	0.3859	0.4166	0.4891	0.3957	0.3559	2.5977	5.4463	-0.2509	2
c_j	3.2893	2.3737	2.5047	2.6194	2.4433	2.8486	Threshold Value= 0.5454			

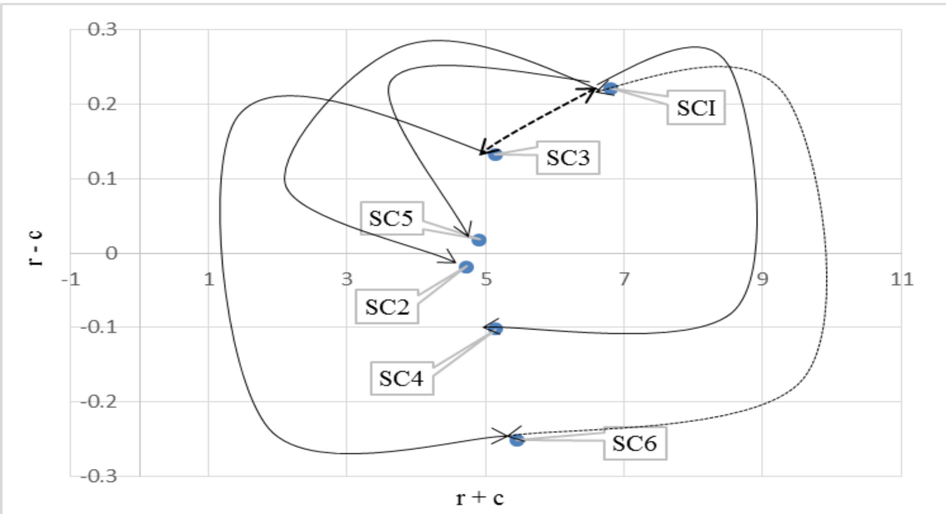

Figure 4.10 Causal digraph and relationship mapping of socio-cultural barriers.

With regard to these sub barriers, the barriers (SC1), (SC3) and (SC5) falls under cause group, while barriers (SC2), (SC4) and (SC6) come under the effect group (Figure 4.10). To overcome these barriers, government and other stakeholders must implement the social activities, which can generate income and employment for the waste pickers. The worker engaged in WEEE recycling activities must be properly trained, educated, and made aware about environmental protection. Poster environmental consciousness awareness program and workshops are effective methods for changing the mindset of consumers who are directly involved in the WEEE management issues (Mundada et al., 2004).

The results obtained through the application of DEMATEL methodology demonstrate that the ranking of main barrier criteria in the implementation of WEEE management practices depend on their (r + c) values that are given as PR-T-SE-F-I-K and SC. From this analysis, we observed that the policy and regulatory barriers (PR) and technological (T) barriers hold the first and second position in the priority list, and is considered as significant barrier to WEEE management implementation in the Indian context. This results will help practitioners to not only prioritize the WEEE management barriers, but also helps to determine inter-relationship among the barriers.

This present study brings out the following remediation for the effective implementation of WEEE management:

- Awareness campaign should be organized for electronic industries and consumers with regard to WEEE management.
- The implementation of EPR is vital and high emphasis is given on the take-back policies of the WEEE; this needs to be taken into consideration for an environmentally sound way to handle WEEE management issue.
- Government should provide a platform like skill development programmes (SDP) to enhance formal human resource training on the implementation of WEEE management.
- Collaboration and knowledge transfer should be developed particularly among the emerged and emerging economies so that the procurement of state of art of technologies can be made available at affordable costs.
- The formalization of unorganized recycling units and the need to bring an advanced recycling Fee (ARF) from consumers lead to the disposing of EoL electronic items.
- Door to door collection channel can be improved through formal integration between waste pickers and organized recycling units by providing assured.
- The government gives incentives for informal sector because livelihood of millions of people is engaged in this sector. The incentive includes tax reduction plans for WEEE recycling; government should give the status of WEEE recycling as home industries and

also provide training and awareness to the participants for the management of home recycling industry.

- The establishment of state-wise level governing bodies is helpful in controlling hazardous waste and illegitimate trans-boundary movement of WEEE among countries.

- The government should design and establish a framework for long term roadmap of environmental standards for various stream of WEEE to mitigate future uncertainty.

4.6 Chapter Summary

This chapter has developed a comprehensive framework to identify barriers of WEE management implementation. The framework was developed with the help of systematic literature review and discussion with domain experts. A total of forty-four barriers were identified for the study and categorized these barriers into seven main category, along with remediation to overcome these barriers. Finally, objective one of my research work is accomplished by establishing cause and effect relationship among the barriers to the implementation of WEEE management.

CHAPTER - V

ANALYSIS OF ENABLERS OF SUSTAINABLE WEEE MANAGEMENT AND WEEE RECYLING PARTNER SELECTION

5.1 Introduction

This chapter deals with objectives 2 and 3 of the study. Firstly, identifying and analyzing the relationship among the enablers of sustainable WEEE management using Grey theory and DEMATEL methodology. Secondly, selecting the WEEE recycling partner for electronics manufacturing organization based on green operational competencies using hybrid FAHP-VIKOR methodology.

5.2 Proposed framework for determining the causal relationship among enablers of sustainable WEEE management

Sustainable WEEE management is more complex to achieve as compared to traditional WEEE management. The enablers of sustainable WEEE management implementation have been broadly discussed in the previous literature. For the finalization of the identified enablers, this study has been employed Delphi method which was originally proposed by Dalkey and Helmer in 1963. In this method, all possible identified enablers related to the study were presented in front of the expert panel and then collecting opinion from each expert through various rounds of discussions until a unanimity is attained on the key enablers for the present study. Initially, 33 enablers were identified from the systematic literature review (SLR) and then put for evaluation by experts to seek their judgment regarding key enablers to be considered for the study. Thus, to explain the complexity of the problem, single theory is not adequate. With this in mind, the present study is subjected to three organizational theories including natural resource-based view (NRBV), stakeholder theory (ST) and institutional theory (INT) which helps to rationalize these enablers (Table 5.1). After various rounds of discussions, a team of experts finally conceded twenty-three (23) enablers which were further taken for analysis and are listed in Table 5.2. The finalized enablers of sustainable WEEE management were further evaluated by using a hybrid grey-based DEMATEL approach in order to analyze the relationship among the enablers through expert's rating judgment. Finally, the result findings and implications are discussed with stakeholders which provide insights into designing institutional and organizational policies which leads to sustainable WEEE management implementation. Figure 5.1 shows the step-wise proposed research framework of the study.

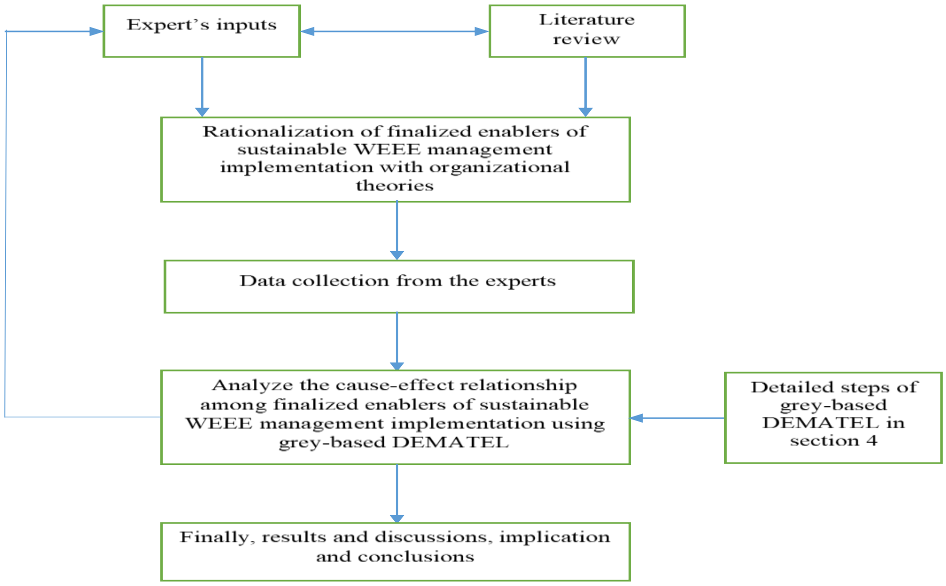

Figure 5.1. Proposed research framework of the study

Table 5.1 Rationale for the enablers of sustainable WEEE management with socio-economic theories.

Theory	Enablers
Natural Resource-Based View (NRBV)	Green training programs
	Clean development mechanism (CDM)
	Environmental management systems (EMS)
	Use of cleaner technologies for waste recycling
	Material and energy recovery
	R&D capabilities to improve WEEE management system
	Green packaging
	Green logistics and warehousing facilities
	Green information system (GIS)
Institutional Theory (INT)	Tax policies and subsidies benefits
	Advanced Recycling Fee (ARF)
	Avoid community landfills disposal
	Health and safety measures
	Reduction of hazardous and toxic substances in environment
	Environmental regulations and WEEE policies
	Monitoring of illegal import and dumping
Stakeholder Theory (ST)	Defined role of the stakeholders
	Joining informal sector with formal sector
	Extended producers responsibility (EPR)
	Collaboration with green partners
	Green image
	Financial institution offers loan to promote green practices
	Community awareness and involvement

5.2.1. Economic enablers

Economic instrument plays a vital role in sustainable WEEE management system implementation (Singh, 2017). To manage the quantum rise of WEEE, a huge amount of investment and skilled workforce is required to run the management effectively (Zaman, 2013). For environmental sound management of WEEE and minimize the financial burden of the producer, advanced recycling fee (ARF) should implement and explicitly mentioned in the price of the electronic product. Retailers are required to inform the consumer about ARF which is used for recycling and disposal activities at the end of product lifespan. On the other hand, deposit refund system provides an incentive plan for consumers who pay a fee at the time of purchase which is reimbursed when they returned the obsolete product to the formal recycler (Khetriwal et al., 2009; Wath et al., 2010; Garlapati, 2016). One of the main aims of sustainable WEEE management is the recovery of rare earth metal and the commercialization of recovered precious material. This precious material consists of gold, palladium, silver, copper, Aluminium, Zinc, Lead, Titanium, and so on (Coban et al., 2018; Pan et al., 2015; Wang et al., 2012). The recovery of precious material can reduce the use of the virgin material in production which leads to resource conservation and economic benefits (Arikan et al., 2017; Pan et al., 2015; Zhu et al., 2013). Subsidies benefits are distributed to consumers who returned their waste to formal recyclers for recycling which act as a motivating factor for the consumer, thus increasing the recycling rate of WEEE treated by formal sector (Wath et al., 2010). Subsidies benefits or providing zero-interest financial support for investors to establish formal WEEE recycling network (An et al., 2015). To promote cleaner production, financial institutions offers easy loans and government should design tax incentives policies to encourage electronic manufacturer to adapt eco-design, design for environment (DFE), green product development and implement green practices in their entire supply chain activities which leads to minimize hazardous emissions in the environment (Govindan et al., 2015; Sarkis, 2012; Yu et al., 2014; Zhu et al., 2016). Jamasb and Nepal (2010) pointed out that waste to energy (WTE) can serve as an effective practice in reducing landfill disposal while having economic as well as an environmental advantage. Modern “state of the art” waste incineration and gasification technologies transform WEEE into heat or energy and reduce the impact of total emissions of WTE plants on humans and environment (Arena and Di Gregorio, 2014). Hence, WTE has become an important option for waste recycling and energy conservation (Brunner and Rechberger, 2015).

5.2.2. Government policies and regulatory support enablers

Government policies and regulatory support plays a vital role in the implementation of WEEE management system and also act as a motivator for adopting green and sustainable recycling practices (Awasthi and Li, 2018; Heeks et al., 2015; Sthiannopkao and Wong, 2013; Wath et al., 2010). To manage the WEEE in an environmental sound manner, government should design a legal framework with clear and defined role which is essential for all stakeholders' i.e. Pollution control boards (PCBs), local municipal corporation, producers, retailers, consumers, waste recyclers, NGO's, etc. (Chi et al., 2011; Sinha-Khetriwal et al., 2005; Terazono et al., 2006). Khan et al. (2014) suggested that policymakers should revise existing policies and criteria to monitor and control the illegal trans-boundary movement of WEEE and dump from developed countries to developing countries. A study by Wath et al. (2010) stated that regulatory policies and WEEE directives issued by government authorities to ensure electronics manufacturers to take extend responsibility and manage the environmental impact of their obsolete products to avoid landfill disposals. The extended producer's responsibilities (EPR) considered as an instrumental policy which covered various activities like take-back of used products, recovery, recycling and the safe disposal (Garlapati, 2016; Kumar and Dixit, 2018a; ; Rahman and Subramanian, 2012; Wath et al., 2010). But managing the waste is a financial burden for the producer. To reduce the burden of electronics manufacturers' government should design liberal policies for informal sectors and encouraged them with financial incentives and tax subsidies to collaborate with formal sector for operational and logistics activities like collection, sorting, transportation and recycling which helps to achieve maximum collection and higher recycling rates (Abdulrahman et al., 2014; Chi et al., 2011; Chi et al., 2014; Gupta and Barua, 2017; Jafri et al., 2017; Yu et al., 2014). Velis et al. (2012) suggested that successful integration of informal sector with the formal sector in waste and resource recovery management developed a win-win strategic solution for improving livelihood, environmental protection, strengthen occupational health and safety, etc. in developing countries.

5.2.3. Social enablers

Due to climate change, ozone depletion and greenhouse gas emissions (GHGEs), consumers are more aware of environmental protection, green purchasing, and WEEE recycling and disposal (Lee and Lam, 2012). Consumer engagement and involvement have been recognized as a key element in WEEE recycling for e.g. willing to pay (WTP) for recycling their waste and voluntary participation in designing of WEEE management policy framework (Abba et al., 2013). Green purchasing behavior of consumers minimize the impact on the environment through product reuse, waste reduction and elimination of a toxic substance in the environment during recycling and disposal (Chan et al., 2012; Eltayab et al., 2011; Kwatra et al., 2014; Sarath et al., 2015; Zhu et al., 2016). A study by Vachon and Klaseen (2008) analyzed the concept of green collaboration among entire supply chain partners such as producers, suppliers, green partners, consumers. Such collaboration focused on waste minimization by setting a common environmental goal and provide all the required assistance in terms of technology sharing, information sharing, and providing training to the recycling workers in order to tackle the hazardous waste, thus contributing to economic as well as an environmental dimension (Gupta and Barua, 2016; Jabbour et al., 2015). Previous studies emphasize that high degree of collaboration among the supply chain partners led to environmental sound recycling and waste disposal (Dubey et al., 2015). The electronic manufacturers should integrate stringent occupational health and safety measures to recycling network in order to reduce the risks involved in waste processing (Mundada et. al., 2004). As per united nation, 2030 agenda for sustainable development goals, enhancing the quality of workplace safety is another important strategies of sustainable development to ensure that the workers can deliver their best for the nation economy (Gupta and Barua, 2017). Finally, a study by An et al. (2015) suggested that green training program foster worker skills and encourage them to adopt environmentally sound or cleaner technologies which can protect workers health as well as the ecosystem.

5.2.4. Environmental management enablers

Environmental management system (EMS) should be a prime vision and an integral part of the business administration and production system (Maruthi and Rashmi, 2015; Zhu et al., 2016). Heras and Arana (2010) stated that EMS works as an environmental policy tool that supports electronic manufacturers for setting up environmental goals, planning, responsibilities, as well as regular monitoring of its supply chain components. EMS certification such as ISO 14000 enhances the firm green image in the global market (Diabat and Govindan, 2011; Hsu and Hu, 2008; Manomaivibool, 2009; Wang Chen et al., 2016; Xu et al., 2013). Rousis et al. (2008) stated that the emission of hazardous and toxic substances originated from the WEEE treatment plants should be takin into prior consideration while implementing the WEEE management system. Hence, reducing resources utilization and harmful emissions is a primary concern for sustainable waste management (Yang et al., 2011). The clean development mechanism (CDM) provides a robust management approach which can be used in order to minimize their greenhouse gas emissions (GHGEs) by the WEEE recycling firms in the environment (Grant and Marshburn, 2014; Singh and Debnath, 2012; Wang Chen et al., 2016). Under the Kyoto convention, CDM is recognized as a key enabler for improving WEEE management system by which developed countries are willing to buy 'carbon credits' from developing countries (Wilson, 2007). With this environmental global concern, CDM has been actively encouraged by the World Bank particularly for landfill gas projects which helps in reduction of community landfills disposal (Arena and Di Gregorio, 2014; Wibowo and Deng, 2015).

5.2.5. Technology and infrastructure enablers

In recent years, organizations are forced to improve environmental quality by integrating green practices in their business process which also leads to enhance overall organizational economic performance in the global market (Lee et al., 2009). In order to achieve the corporate sustainable goals, it is mandatory for electronic manufacturers to well-equipped with green infrastructure and clean technologies to manage return as well as recycling of WEEE. The well-equipped infrastructures includes green logistics facilities, accessible collection centers, recycling and recovery plants, green packing etc. which helps the developing counties to tackle growing heap of WEEE into an economic opportunity (Kannan et al., 2014; Liu et al., 2017; Rostamzadeh et al., 2015; Zhu et al., 2016). Transportation of WEEE accounts a major source of hazardous emissions and environmental pollution in the environment (Jabbour et al., 2015). Green logistics and warehousing facilities can create an opportunity to minimize the environmental impact of the product lifecycle (Liu et al., 2017; Coban et al., 2018). Use of green packing material for WEEE can be easily recycled and disposed of in an environmentally friendly manner and also helps in carbon footprint reduction (Somsuk and Laosirihongthong, 2017). Green information system (GIS) serves as an intellectual medium which helps to disseminate information flow to improve supplier coordination and RFID labelled system is used for better tracking of return in order to accurate forecasting for inventory management (Diabat and Govindan, 2011; Hsu et al., 2013; Khan et al., 2015).

Table 5.2 Key enablers of sustainable implementation of WEEE management.

Enablers	Code	Explanation	References
Economic enablers			
Advanced recycling Fee (ARF)	EN1	Consumers have to pay a tax that covers future reverse logistics and disposal cost.	Nnorom and Osibanjo, 2008; Wath et al., 2010; Hong et al., 2014; Zeng et al., 2017; Zhou et al., 2017
Financial institution offers loan to promote green practices	EN2	Financial support provided by financial institutions which encourage to implement green practices and promote design for environmental initiatives like eco-design, green product development, remanufacturing, reuse.	Azapagic, 2004; Govindan et al., 2016; Gupta and Barua, 2017
Tax policies and subsidies benefits	EN3	Tax credit and subsidies benefits policies can encourage the consumer to return their discarded product to the formal recycling units for recycling and disposal.	Nnorom and Osibanjo, 2008; Shaik and Abdul Kader, 2012; Zhu et al., 2013; Abdulrahman et al., 2014; Mir et al., 2016; Gupta and Barua, 2017
Material and energy recovery	EN4	Assets recovery from the WEEE provides economic benefits to the focal firm as well as recycling firm through the sale of waste and extracting rare earth material and waste to energy (WTE) from the WEEE in an environmentally sound way. Assets recovery also helps in reducing the consumption of virgin material.	Arena and Di Gregorio, 2014; Lee et al., 2015; Brunner and Rechberger, 2015; Pan et al., 2015; Mir et al., 2016; Arikan et al., 2017; Coban et al., 2018
Social enablers			
Community awareness and involvement	EN5	Community awareness regarding environmental protection may encourage them for green purchasing and willing to pay for waste recycling activities.	Brandenburg et al., 2014; Govindan et al., 2016; Abba et al., 2013; Kwatra et al., 2014; Sarath et al., 2015; Borthakur and Govind, 2018; Xu et al., 2018
Collaboration with green partners	EN6	Establishing a green alliance involves any organized or un-organized collaboration between two or more firms which work on common solutions to achieve sustainability.	Vachon and Klassen, 2008; Hu and Hsu, 2010; Gunasekaran et al., 2015; Roehrich et al., 2017
Green training programs	EN7	Staff involved in recycling activities require technical as well as environmental training for recycling and disposal of the WEEE.	Hu and Hsu, 2010; Agamthu et al., 2011; Hsu et al., 2013; An et al., 2015; Zhu et al., 2016
Health and safety measures	EN8	The recycling firm should take health and safety measures and compliance with safety standards in practices for employees.	Mundada et al., 2004; An et al., 2015; Mani et al., 2015; Xu and Yeh, 2017; Xu et al., 2018
Environmental management enablers			
Green image of the firm	EN9	Green image of the firm defines the commitment of the firm towards green practices.	Grisi et al., 2010; Wen and Chi, 2010; Yeh and Chuang, 2011; Xu et al., 2018
Clean development mechanism (CDM)	EN10	The recycling firm should integrate with the focal firm for clean development mechanism projects	Wilson, 2007; Singh and Debnath, 2012; Grant and Marshburn, 2014

		which leads to sustainable development.	
Reduction of hazardous and toxic substances in environment	EN11	Recycling firm should take preventive measures to reduce and control the hazardous emission during WEEE recycling.	Yang et al., 2011; Grant and Marshburn, 2014; Xu et al., 2018
Environmental management systems (EMS)	EN12	The degree that it caters to the environmental certifications like ISO 14001, environmental regulations, planning to check whether the organization has its environmental issues controlled.	Hsu and Hu, 2009; Manomaivibool, 2009; Hu and Hsu, 2010; Diabat and Govindan, 2011; Xu et al., 2013; Govindan et al., 2015; Shaharudin et al., 2017
Avoid community landfills disposal	EN13	Reduce the amount of WEEE to be disposed-off in the community landfills with the help of product take-back initiatives.	Arena and Di Gregorio, 2014; Wibowo and Deng, 2015; Mir et al., 2016; Xu and Yeh, 2017; Xu et al., 2018
Technology and Infrastructure enablers			
Green packaging	EN14	Green packaging can help to reduce carbon footprints in the environment while recycling and disposal of WEEE.	Lee et al., 2009; Hsu et al., 2013; Somsuk and Laosirihongthong, 2016; Gupta and Barua, 2017; Kumar and Dixit, 2018a
Green information system (GIS)	EN15	Efficient green information system is required to improve the integration and coordination. GIS is needed to trace and track the returned product and to forecast for inventory management.	Bani et al., 2009; Hsu and Hu, 2009; Lee et al., 2009; Govindan and Diabat, 2011; Hsu et al., 2013; Khan et al., 2015
R&D capabilities	EN16	R&D investment and capability is required for developing eco-design and green manufacturing technologies which leads to waste management more sustainable.	Hsu et al, 2013; Lucas, 2010; Karunagaran et al., 2016; Gupta and Barua, 2016, 2017
Use of green or cleaner technologies for waste recycling	EN17	Use of green or innovative eco-friendly recycling practices to conserve the nature and natural resources and minimize the negative impact on human lives.	Chi et al., 20111; Jadhao et al., 2016; Zhang and Xu, 2016; Xu and Yeh, 2017; Xu et al., 2018
Green logistics and warehousing facilities	EN18	Green logistics and warehousing facilities of the firms can help in reduce environmental pollution and promote the optimum post-consumer collection and environmentally safe disposal.	Liu et al., 2012; Zhu et al., 2013; Kannan et al., 2014; Jabbour et al., 2015; Rostamzadeh et al., 2015; Liu et al., 2017; Coban et al., 2018
Government policies and regulatory support enablers			
Monitoring of illegal import and dumping	EN19	Regular monitoring and auditing of transboundary movement of hazardous waste and record of illegal of illegal dumping.	Wath et al., 2010; Anyango Tocho and Mwololo Waema, 2013; Khan et al., 2014; Garlapati, 2016
Integration of informal sector with formal sector	EN20	Firms should establish cooperation with informal recycling network for the collection and recycling of WEEE.	Tsoulfas and Pappis, 2006; Wilson, 2007; Hu and Hsu, 2010; Yu et al., 2010; Chi et al., 2011; Velis et al., 2012; Chi et al., 2014; Wilson et al., 2015; Wu and Chang, 2015; Garlapati, 2016

Defined role of the stakeholders	EN21	Role of stakeholders should be clear and formation of the taskforce for WEEE management is required for regulation and implementation.	Wath et al., 2010; Luthra et al., 2014; Mir et al., 2016; Garlapari, 2016; Kumar and Dixit, 2018a
Extended producers responsibility (EPR)	EN22	Producers should be responsible to manage the products entire life cycle such as take-back of an obsolete product, recycling, and the safe disposal.	Widmer et al., 2005; Manomaivibool, 2009; Wath et al., 2010; Kiddee et al., 2013; Garlapati, 2016; Zhou et al., 2017
Environmental regulations and WEEE policies	EN23	Regulations and policies encourage electronics firm to integrate environmental practices in their operational as well as business activities.	Lau and Wang, 2009; Wath et al., 2010; Diabat and Govindan, 2011; Ho et al., 2012; Garlapti, 2016; Govindan et al., 2016; Xu and Yeh, 2017; Kumar and Dixit, 2018a,b; Xu et al., 2018

5. 3 An illustrative case application of the proposed framework

The proposed research framework is used to analyze the enablers of sustainable WEEE management implementation from a multiple stakeholder's point of view. To conduct the study, we considered Bangalore and Mumbai as the case locations for the data collection. In this study, a team of four key WEEE management stakeholders were chosen strategically to evaluate the enablers of sustainable WEEE management implementation. These stakeholders comprises of one senior manager reverse logistics and supply chain from reputed electronic manufacturing company "ABC" (industry expert) which is leading electronic company in India and manufacturing wide range of electronic products, one recycling company owner (formal recycling expert) who has been working in WEEE recycling and has good relationship with electronic manufacturers, an official from the ministry of environment and forest, climate change (government expert) who is closely working for designing framework for the implementation of sustainable WEEE management and an academic expert who has great knowledge on waste management research problem. All the key stakeholders were selected on the basis of their experience of more than 15 years and their contribution to the domain of reverse logistics, waste management and supply chain of the electronics industry. Each expert was feeling enthusiastic to encourage and assist our research work. For the better application of grey-based DEMATEL approach, various authors suggested that four or less respondents/experts are well enough sample size to make meaningful judgement to the given problem (Fu et al., 2012; Bai and sarkis, 2013; Rajesh and Ravi, 2015; Govindan et al., 2016; Luthra et al., 2017; Gupta and Barua, 2018). Further, the process of data collection began by conducting interviews with respondents which lasted 2.5 to 3 hours and we have successfully conveyed our research problem with the clear definition of each listed enablers in order to obtain judgment ratings for the development of pair-wise comparison matrices. The two-way interaction facilitated the data collection process and helps to maximize the reliability. Finally, the collected pair-wise comparison matrices are further analyzed with the application of grey-based DEMATEL to visualize the cause-effect relationship among the enablers of sustainable WEEE management implementation.

5.3.1 Computational steps of the grey-based DEMATEL

Step 1: A team of four experts was formed to determine the direct influence among the twenty-three enablers of sustainable WEEE management implementation in the Indian context. The selected team of experts having more than 10 years of experience in the realm of supply chain management and asked them to rate the enablers of sustainable WEEE management implementation. Each expert investigated the direct influence of one enabler over other enabler and developed an initial relation matrices (23 x 23) with the help of defined linguistics scales. Further, in order to deal with human's subjective judgments, this study uses a grey number scale corresponding their linguistics variable as shown in Table 3.1.

Step 2: Using Eq. (3.4), four different initial grey relation matrix [$(\otimes A_{xy}^{1})$, $(\otimes A_{xy}^{2})$, $(\otimes A_{xy}^{3})$, $(\otimes A_{xy}^{4})$] were developed to assess the inter-relationship among the enablers. Table 5.3 depicts the initial grey matrix for expert 1 as grey number ($\underline{\otimes} A_{xy}^{p}$ / $\bar{\otimes} A_{xy}^{p}$).

Step 3: To ensure the congruity of experts' judgment, uniformity in ratings were given in all domain experts and average grey relation matrix is established by using Eqn. (3.5). The resultant grey relation matrix $(\otimes \check{A}_{xy})$ is presented in Table 5.4.

Step 4: In this step, crisp relation matrix (Z) is computed by converting the average grey number into crisp numbers with the assistance of modified (CFCS) method involving a three-step procedure. Finally, a crisp relation matrix is obtained by using Eqns. (3.6 – 3.11) and is presented in Table 5.5.

Step 5: Using Eqns. (3.12) and (3.13), Normalized direct relation matrix (N) is calculated and is presented in Table 5.6.

Step 6: In this step, the total relation matrix (T) is constructed by processing the normalized direct relation matrix (N) by using Eqn. (3.14) and is shown in Table 5.7.

Step 7: In this step, we calculate the sum of rows (23 x 1) and the sum of column (1 x 23) for each enablers using Eqns. (3.15) and (3.16). 'R' denotes the net effect given by enabler *x* towards other enablers and 'C' denotes the net effects received by enabler *y* from the other enablers and then prioritize the enablers on the basis of (R + C) and (R – C) values which are presented in Table 5.8.

Step 8: In this step, the cause-effect relationship diagram is constructed with the help of prominence (R + C) and relation (R – C) values and shown in Figure 5.2. Each enabler is categorized into cause and effect group on the basis of positive and negative (R – C) values (see Table 5.9). The relationship among enablers are represented with the help of arrows in cause-effect relationship diagraph (see Figure 5.2). Finally, the threshold value (θ) has been set to simplify various relationships among enablers which exceeds the value than θ. In this study, the threshold value (θ) is determined by adding one standard deviation to the mean of the total relation matrix (T) i.e. (0.2564 + 0.0315 = 0.2879).

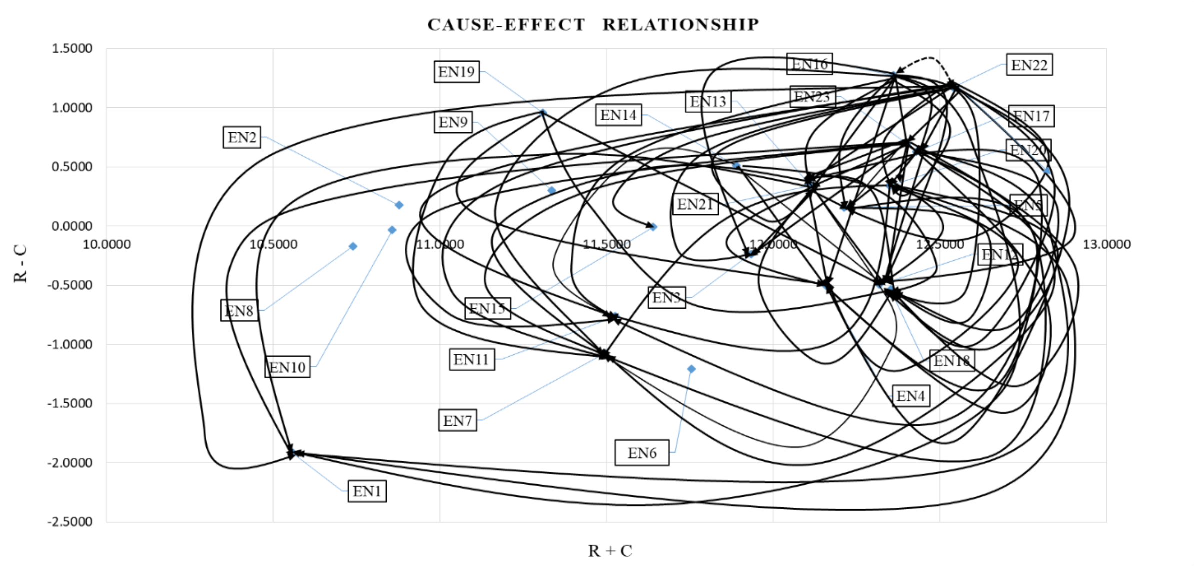

Figure 5.2 Cause-effect diagram for enablers of sustainable WEEE management implementation.

5.3.2 Results and discussions

The present study identifies twenty-three enablers of sustainable implementation of WEEE management from the exhaustive literature and discussions with an expert panel. But it is difficult to answer which of the enabler is very important than others, but prioritizing them by using a hybrid integrated approach made it more flexible, logical and tactical for decision-makers. To resolve the complexity of the decision problem, this study utilized integrated grey based DEMATEL to determine the cause and effect relationship among the enablers of sustainable

WEEE management implementation. To eliminate the insignificant effects among the enablers a threshold value of (0.2879) has been fixed in the study.

Based on (R + C) values, the enablers are listed according to their ranking in order as follows, EN22 > EN17 > EN23 > EN16 > EN18 > EN20 > EN12 > EN5 > EN4 > EN21 > EN13 > EN3 > EN14 > EN6 > EN15 > EN11 > EN7 > EN9 > EN19 > EN2 > EN10 > EN8 > EN1 (see Figure 5.3). According to the Table 5.8, extended producer responsibility (EN22) is found to be the most crucial enabler for sustainable implementation of WEEE management system in the Indian context. An extended producer responsibility (EPR) initiatives enables the policy package onto electronic manufacturers to take responsibility of physical as well as economic aspects of the end of life electronic products by downstream activities such as reverse logistics, disassembled for remanufacturing, recycling, resource recovery and disposal in an environmentally sound manner (Garlapati, 2016; Kiddee et al., 2013; Wang et al., 2016; Wath et al., 2010; Zhou et al., 2017). The successful implementation of the EPR system not only helps to improve organizational environmental performance but also maximize the economic benefits through proactive environmental strategy (Atasu and Subramanian, 2012; Barba-Sánchez and Atienza-Sahuquillo, 2016). Use of green or cleaner technologies for WEEE recycling (EN17) ranked second in the priority list according to the (R + C) values. A recent study by Kumar and Dixit (2018a) also suggested that the use of cleaner technologies for WEEE recycling and resource recovery leads to environmental sound management by minimizing the negative impact on the environment and human lives associated with recycling industry. Previous literature acknowledge the findings and states that recycling organizations can collaborate with research and development agencies and global leader in the same domain to promote better use of green or cleaner technologies and its transfer to support capacity building and contribute towards sustainable development (Chi et al., 2011; Seth et al., 2018; Xu et al., 2018). Environmental regulation and WEEE policies are considered to be the third most important enabler among the other enablers. To manage this special stream of waste, the government should introduce strong policies and environmental regulatory instruments that deal specifically with WEEE handling and management problems (Wath et al., 2010). Additionally, government should clearly define the role of multiple stakeholders for effective compliance of WEEE management policies (Garlpati, 2016). Integration of informal sector with the formal sector (EN23) holds the fourth rank among the other enablers of sustainable implementation of WEEE management. Informal recycling sector plays a vital role in Indian

WEEE recycling system and accounts for 95% of WEEE recycled by backyard operation practices which can create a serious impact on the environment as well as on human lives. A study by Majeed et al. (2017) clearly suggested that stringent policy framework should be designed in order to integrate dominant informal recyclers into the formal recycling sector. Integrated recycling network plays a key role in the effective collection which helps for the development of environmentally sustainable WEEE management system in Indian context (Wath et al., 2010; Garlapati, 2016; Kumar and Dixit, 2018a). Research and development (R&D) capabilities (EN16) ranked fifth in the priority based on the (R + C) values. Various researchers in the domain reverse logistics and waste management state that R&D investment and capabilities play a key role in technology advancement and process innovation which helps to resolve environmental and social issues (Hu and Hsu, 2010; Lucas, 2010; Gupta and Barua, 2016). To achieve the sustainable goals of 2030, Indian government should allocate adequate funds and force electronic manufacturers to invest some amount of profits in R&D initiatives which encourage strategies like eco-design for new product development (NPD), process innovation for resource recovery, innovative green material, etc. which can not only improve environmental performance of the product over the end of life cycle management but also sustenance the growth of nation economy by reducing the consumption of renewable resources (Gupta and Barua, 2017). Green logistics and warehouse facilities are the sixth most important enabler as per priority rating list. A well-equipped green logistics and warehousing infrastructure plays a vital role in reducing carbon footprints in the environment and minimizing resource consumption by utilizing green packaging materials that can be easily recycled for reuse and disposed of (Kannan et al., 2014). Apart of this six crucial enabler, advance recycling fee (ARF) is found to be the least important enabler among others.

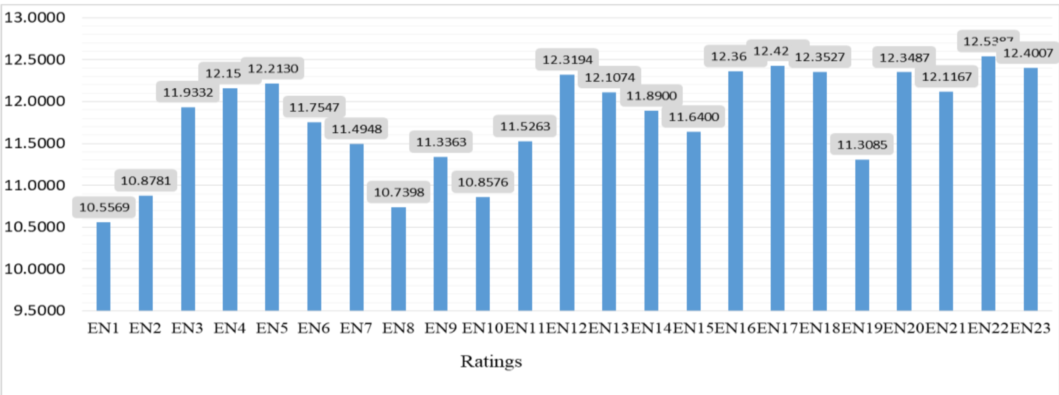

Figure 5.3. Priority ratings for enablers of sustainable implementation of WEEE management.

Further, the analysis is done to prioritize the enablers on the basis of (R – C) values. These causal enablers act as a driver which can significantly drive the overall system. The categorization and prioritizing the enablers helps policymakers to understand that causal group enabler should be given utmost attention and controlled accordingly because they can easily influence the enablers that fall under effect group (Lin et al., 2011). According to the data set (R – C) values, twelve enablers for sustainable implementation of WEEE management are ranked in accordance their relative positive relation values are as follows; EN16 > EN22 > EN19 > EN23 > EN17 > EN14 > EN13 > EN21 > EN20 > EN9 > EN2 > EN5 (refer Table 5.9). In the causal group enablers, R&D capabilities (EN16), extended producers responsibility (EN22), monitoring of illegal import and dumping (EN19), environmental regulations and WEEE policies (EN23) and use of green or cleaner technologies for waste recycling (EN17) are found top five key cause enablers. Thus, R&D capabilities and use of green or cleaner technologies are categorized as technology and infrastructure related enablers whereas extended producers responsibility, monitoring of illegal import and dumping and environmental regulations and WEEE policies are categorized as government regulatory and regulatory related enablers. From figure 5.2, it is observed that R&D investment capabilities significantly influence the material and energy recovery, collaboration with green partners, reduction of hazardous and toxic substances (RoHS), environmental management system and development of cleaner technologies. Similarly, extended producer responsibility ranked first according to the (R + C) values and also ranked second under cause group enablers. This causal enabler is significantly driving enabler for advanced recycling fee, tax policies and subsidies benefits, material and energy recovery, community awareness and involvement, green training program, avoiding landfills disposal, green logistics, and warehousing facilities and integration of informal and formal sector and defined the role of the stakeholders. Third key enabler among cause group enablers i.e. monitoring of illegal import and dumping is significantly influenced the material and energy recovery. Among all the causal enablers, extended producer responsibility (EN22) has gained the highest influential R index value (6.8553) in this study.

Similarly, the investigation can be done for effect enablers which are dependent or easily influenced by other enablers. These effected enablers can be prioritized according to their (R – C) values (see Table 5.9). According to figure 5.2, the most effected enablers is green logistics and warehousing facilities (EN18) followed by green training programs (EN7), environmental management system (EN12), material and energy recovery (EN4) and advanced recycling fee

(EN1). Developing green logistics and warehousing infrastructure by the electronic manufacturers can be influenced by other causal enablers such as community awareness and involvement (EN5), avoid community landfills disposal (EN13), green packaging (EN14), R&D investment capabilities (EN16), use of green or cleaner technologies for waste recycling (EN17), integration of informal sector with formal sector (EN20), defined role of the stakeholders (EN21), extended producers responsibility (EN22) and environmental regulations and WEEE policies (EN23). Additionally, R&D investment capabilities (EN16) and extended producers responsibility (EN22) shows a two-way relationship which is represented by a dotted arrow in figure 5.2. Both enablers EN16 and EN22 belongs to cause group and have a duple effect which signifies their inter-dependency on each other.

On a profound investigation of the results, the enablers for sustainable implementation of WEEE management can be categorized into four different zones which recognized that several pairs of enablers is mutually influenced by each other (see figure 5.4). The bunch of enablers situated above the x-axis is expressed as most influential or causal group enablers while enablers fall below x-axis are defined as an effect or dysfunctional group enablers due to which they can easily influence by causal group enablers. Zone 1 depicted the enablers with nominal relations and having least significance among other are expressed as independent enablers. The enablers belong to Zone 1 are advanced recycling (EN1), collaboration with green partners (EN6), green training programs (EN7), health and safety measures (EN8), clean development mechanism (EN10), reduction of hazardous and toxic substances (EN11) and green information system (EN15). Zone 2 comprises the causal enablers with the true driving effect but their influence on driven group enabler is superficial. Financial institution offers loan to promote green practices (EN2), green image of the firm (EN9), green packaging (EN14) and monitoring of illegal import and dumping (EN19) are associated with this zone. Next zone 3 represents the enablers falls under causal group having strong driving significance over other enablers. These enablers addressed as most crucial enablers and policy makers should provide more concentration on these enablers to solve the WEEE management implementation issue. The enablers belongs to this zone are community awareness and involvement (EN5), avoid community landfills disposal (EN13), R&D investment capabilities (EN16), use of green or cleaner technologies for waste recycling (EN17), integration of informal sector with formal sector (EN20), defined role of the stakeholders (EN21), extended producers responsibility (EN22) and environmental regulations and WEEE policies (EN23). Finally, zone 4, represents the enablers with high prominence index value but they fall under the dysfunctional group. These enablers are most influenced by other cause group enablers in the relationship mapping and they need to be looked upon and controlled immediately by the stakeholders to make an effective decision-making. The enablers belong to this zone are tax policies and subsidies benefits (EN3), material and energy recovery (EN4), environmental management systems (EN12) and green logistics and warehousing facilities (EN18).

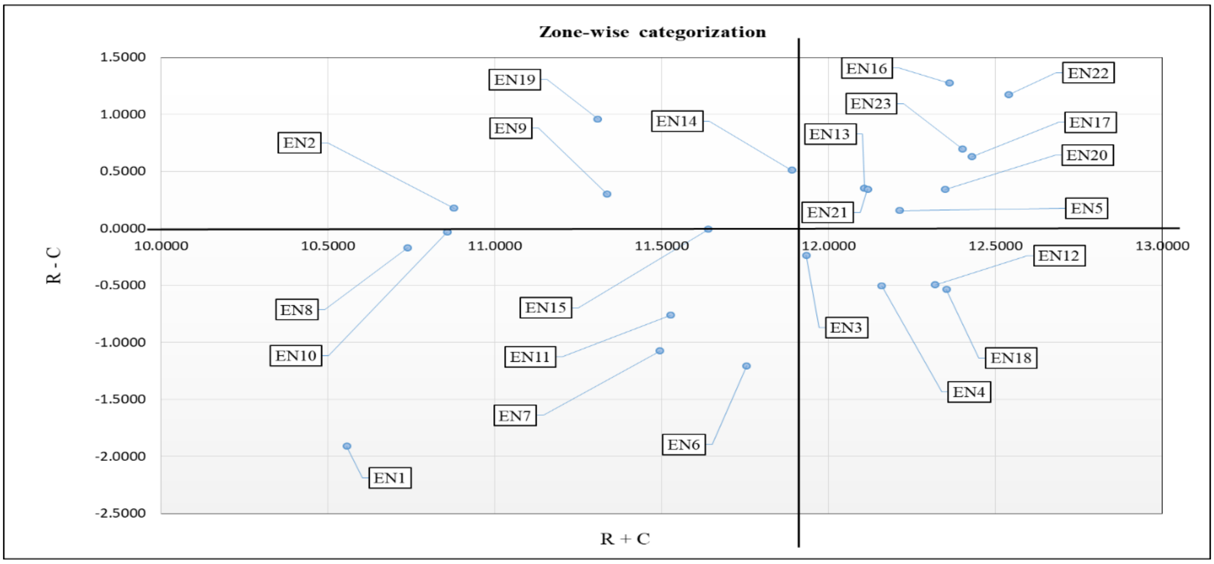

Figure 5.4 Zone-wise categorization of enablers for sustainable implementation of WEEE management.

Table 5.3 Grey relation matrix ($\otimes A_{xy}^{1}$) for enablers of sustainable WEEE management implementation given by Expert 1.

Enablers	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	EN13	EN14	EN15	EN16	EN17	EN18	EN19	EN20	EN21	EN22	EN23
EN1	0	0.1	0.1	0.2	0.4	0.2	0.6	0.1	0.4	0.6	0.4	0.2	0.2	0.2	0.4	0.4	0.2	0.6	0.2	0.4	0.2	0.1	0.2
	0.1	0.3	0.3	0.5	0.7	0.5	0.9	0.3	0.7	0.9	0.7	0.5	0.5	0.5	0.7	0.7	0.5	0.9	0.5	0.7	0.5	0.3	0.5
EN2	0.2	0	0.4	0.1	0.1	0.2	0.4	0.4	0.2	0.4	0.6	0.4	0.4	0.9	0.6	0.6	0.2	0.4	0.2	0.2	0.6	0.2	0.6
	0.5	0.1	0.7	0.3	0.3	0.5	0.7	0.7	0.5	0.7	0.9	0.7	0.7	1	0.9	0.9	0.5	0.7	0.5	0.5	0.9	0.5	0.9
EN3	0.6	0.1	0	0.2	0.4	0.4	0.6	0.4	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.2	0.2	0.4	0.2	0.2	0.6	0.2	0.6
	0.9	0.3	0.1	0.5	0.7	0.7	0.9	0.7	0.7	0.9	0.9	0.9	0.7	0.9	0.9	0.5	0.5	0.7	0.5	0.5	0.9	0.5	0.9
EN4	0.6	0.1	0.1	0	0.6	0.6	0.6	0.6	0.4	0.2	0.6	0.6	0.4	0.6	0.4	0.6	0.2	0.6	0.4	0.4	0.6	0.4	0.2
	0.9	0.3	0.3	0.1	0.9	0.9	0.9	0.9	0.7	0.5	0.9	0.9	0.7	0.9	0.7	0.9	0.5	0.9	0.7	0.7	0.9	0.7	0.5
EN5	0.4	0.2	0.2	0.4	0	0.2	0.6	0.6	0.4	0.6	0.1	0.1	0.4	0.4	0.6	0.2	0.2	0.6	0.2	0.2	0.6	0.2	0.4
	0.7	0.5	0.5	0.7	0.1	0.5	0.9	0.9	0.7	0.9	0.3	0.3	0.7	0.7	0.9	0.5	0.5	0.9	0.5	0.5	0.9	0.5	0.7
EN6	0.6	0.4	0.4	0.2	0.2	0	0.4	0.1	0.1	0.9	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.4	0.2	0.4
	0.9	0.7	0.7	0.5	0.5	0.1	0.7	0.3	0.3	1	0.9	0.7	0.7	0.7	0.5	0.5	0.5	0.7	0.5	0.5	0.7	0.5	0.7
EN7	0.4	0.6	0.6	0.2	0.1	0.1	0	0.4	0.4	0.4	0.6	0.6	0.4	0.4	0.6	0.4	0.2	0.4	0.2	0.2	0.6	0.2	0.4
	0.7	0.9	0.9	0.5	0.3	0.3	0.1	0.7	0.7	0.7	0.9	0.9	0.7	0.7	0.9	0.7	0.5	0.7	0.5	0.5	0.9	0.5	0.7
EN8	0.4	0.2	0.6	0.2	0.1	0.1	0.4	0	0.4	0.4	0.9	0.9	0.6	0.6	0.9	0.4	0.2	0.6	0.2	0.2	0.2	0.2	0.6
	0.7	0.5	0.9	0.5	0.3	0.3	0.7	0.1	0.7	0.7	1	1	0.9	0.9	1	0.7	0.5	0.9	0.5	0.5	0.5	0.5	0.9
EN9	0.4	0.6	0.4	0.4	0.6	0.1	0.1	0.6	0	0.4	0.6	0.4	0.4	0.6	0.6	0.4	0.2	0.6	0.2	0.2	0.4	0.2	0.4
	0.7	0.9	0.7	0.7	0.9	0.3	0.3	0.9	0.1	0.7	0.9	0.7	0.7	0.9	0.9	0.7	0.5	0.9	0.5	0.5	0.7	0.5	0.7
EN10	0.4	0.4	0.4	0.2	0.2	0.2	0.6	0.2	0.6	0	0.1	0.2	0.4	0.4	0.4	0.4	0.2	0.6	0.2	0.2	0.2	0.4	0.1
	0.7	0.7	0.7	0.5	0.5	0.5	0.9	0.5	0.9	0.1	0.3	0.5	0.7	0.7	0.7	0.7	0.5	0.9	0.5	0.5	0.5	0.7	0.3
EN11	0.2	0.2	0.2	0.2	0.6	0.2	0.4	0.1	0.1	0.6	0	0.2	0.1	0.6	0.4	0.2	0.4	0.9	0.2	0.4	0.6	0.2	0.6
	0.5	0.5	0.5	0.5	0.9	0.5	0.7	0.3	0.3	0.9	0.1	0.5	0.3	0.9	0.7	0.5	0.7	1	0.5	0.7	0.9	0.5	0.9
EN12	0.2	0.2	0.6	0.2	0.4	0.2	0.9	0.2	0.2	0.2	0.2	0	0.4	0.2	0.4	0.2	0.6	0.6	0.6	0.6	0.4	0.6	0.6
	0.5	0.5	0.9	0.5	0.7	0.5	1	0.5	0.5	0.5	0.5	0.1	0.7	0.5	0.7	0.5	0.9	0.9	0.9	0.9	0.7	0.9	0.9
EN13	0.2	0.2	0.4	0.2	0.4	0.2	0.9	0.9	0.6	0.4	0.4	0.4	0	0.4	0.4	0.2	0.4	0.2	0.6	0.6	0.4	0.6	0.4
	0.5	0.5	0.7	0.5	0.7	0.5	1	1	0.9	0.7	0.7	0.7	0.1	0.7	0.7	0.5	0.7	0.5	0.9	0.9	0.7	0.9	0.7
EN14	0.4	0.4	0.6	0.4	0.1	0.4	0.6	0.6	0.9	0.2	0.6	0.4	0.4	0	0.2	0.9	0.4	0.6	0.6	0.6	0.4	0.2	0.4
	0.7	0.7	0.9	0.7	0.3	0.7	0.9	0.9	1	0.5	0.9	0.7	0.7	0.1	0.5	1	0.7	0.9	0.9	0.9	0.7	0.5	0.7
EN15	0.2	0.4	0.6	0.2	0.4	0.2	0.6	0.2	0.4	0.4	0.2	0.4	0.1	0.4	0	0.4	0.6	0.9	0.6	0.4	0.4	0.2	0.4
	0.5	0.7	0.9	0.5	0.7	0.5	0.9	0.5	0.7	0.7	0.5	0.7	0.3	0.7	0.1	0.7	0.9	1	0.9	0.7	0.7	0.5	0.7
EN16	0.4	0.4	0.6	0.4	0.2	0.4	0.6	0.4	0.6	0.4	0.4	0.9	0.6	0.6	0.4	0	0.4	0.6	0.9	0.4	0.2	0.6	0.4
	0.7	0.7	0.9	0.7	0.5	0.7	0.9	0.7	0.9	0.7	0.7	1	0.9	0.9	0.7	0.1	0.7	0.9	1	0.7	0.5	0.9	0.7
EN17	0.4	0.2	0.4	0.2	0.4	0.2	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.2	0.4	0.6	0	0.6	0.6	0.4	0.2	0.6	0.2
	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.9	0.9	0.9	0.7	0.9	0.9	0.5	0.7	0.9	0.1	0.9	0.9	0.7	0.5	0.9	0.5
EN18	0.4	0.4	0.6	0.2	0.4	0.6	0.6	0.2	0.6	0.6	0.4	0.6	0.4	0.1	0.1	0.4	0.6	0	0.9	0.6	0.6	0.2	0.2
	0.7	0.7	0.9	0.5	0.7	0.9	0.9	0.5	0.9	0.9	0.7	0.9	0.7	0.3	0.3	0.7	0.9	0.1	1	0.9	0.9	0.5	0.5
EN19	0.4	0.6	0.4	0.2	0.2	0.6	0.9	0.6	0.6	0.6	0.4	0.4	0.6	0.6	0.2	0.1	0.6	0.2	0	0.1	0.1	0.9	0.1
	0.7	0.9	0.7	0.5	0.5	0.9	1	0.9	0.9	0.9	0.7	0.7	0.9	0.9	0.5	0.3	0.9	0.5	0.1	0.3	0.3	1	0.3
EN20	0.6	0.6	0.6	0.4	0.2	0.2	0.2	0.9	0.6	0.4	0.4	0.4	0.2	0.1	0.4	0.2	0.1	0.1	0.6	0	0.2	0.4	0.9
	0.9	0.9	0.9	0.7	0.5	0.5	0.5	1	0.9	0.7	0.7	0.7	0.5	0.3	0.7	0.5	0.3	0.3	0.9	0.1	0.5	0.7	1
EN21	0.9	0.6	0.4	0.4	0.6	0.4	0.2	0.4	0.6	0.6	0.4	0.4	0.6	0.2	0.2	0.2	0.4	0.4	0.2	0.2	0	0.2	0.6
	1	0.9	0.7	0.7	0.9	0.7	0.5	0.7	0.9	0.9	0.7	0.7	0.9	0.5	0.5	0.5	0.7	0.7	0.5	0.5	0.1	0.5	0.9
EN22	0.4	0.6	0.6	0.6	0.9	0.4	0.2	0.4	0.9	0.9	0.6	0.6	0.9	0.4	0.4	0.9	0.6	0.6	0.2	0.1	0.1	0	0.1
	0.7	0.9	0.9	0.9	1	0.7	0.5	0.7	1	1	0.9	0.9	1	0.7	0.7	1	0.9	0.9	0.5	0.3	0.3	0.1	0.3
EN23	0.4	0.9	0.9	0.4	0.6	0.4	0.2	0.2	0.6	0.4	0.4	0.6	0.6	0.9	0.2	0.6	0.4	0.4	0.6	0.2	0.9	0.6	0
	0.7	1	1	0.7	0.9	0.7	0.5	0.5	0.9	0.7	0.7	0.9	0.9	1	0.5	0.9	0.7	0.7	0.9	0.5	1	0.9	0.1

Table 5.4 Average Grey relation matrix ($\otimes\breve{A}_{xy}$) for enablers of sustainable WEEE management implementation.

Enablers	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	EN13	EN14	EN15	EN16	EN17	EN18	EN19	EN20	EN21	EN22	EN23
EN1	0	0.325	0.35	0.2	0.35	0.325	0.325	0.225	0.3	0.275	0.425	0.15	0.275	0.35	0.35	0.35	0.225	0.35	0.375	0.25	0.175	0.275	0.25
	0.1	0.6	0.6	0.45	0.65	0.6	0.6	0.5	0.6	0.55	0.7	0.4	0.55	0.65	0.65	0.65	0.5	0.65	0.65	0.5	0.45	0.55	0.55
EN2	0.4	0	0.4	0.425	0.375	0.325	0.35	0.4	0.225	0.275	0.575	0.5	0.4	0.4	0.325	0.4	0.325	0.3	0.4	0.525	0.5	0.3	0.375
	0.7	0.1	0.7	0.7	0.65	0.6	0.65	0.7	0.5	0.55	0.825	0.8	0.7	0.625	0.6	0.7	0.6	0.55	0.625	0.775	0.8	0.6	0.65
EN3	0.35	0.275	0	0.4	0.325	0.3	0.45	0.4	0.525	0.275	0.5	0.5	0.4	0.45	0.375	0.35	0.275	0.35	0.4	0.5	0.6	0.475	0.45
	0.65	0.55	0.1	0.7	0.6	0.6	0.75	0.7	0.775	0.55	0.8	0.8	0.7	0.75	0.65	0.65	0.55	0.65	0.7	0.8	0.9	0.725	0.75
EN4	0.5	0.375	0.225	0	0.45	0.475	0.325	0.5	0.35	0.35	0.4	0.475	0.35	0.6	0.375	0.45	0.4	0.4	0.4	0.5	0.5	0.325	0.275
	0.8	0.65	0.5	0.1	0.75	0.75	0.6	0.8	0.65	0.65	0.7	0.75	0.65	0.9	0.65	0.75	0.7	0.7	0.7	0.725	0.725	0.6	0.55
EN5	0.475	0.475	0.4	0.425	0	0.275	0.475	0.6	0.4	0.45	0.375	0.425	0.4	0.7	0.3	0.25	0.5	0.45	0.35	0.575	0.575	0.4	0.45
	0.725	0.725	0.7	0.675	0.1	0.55	0.75	0.9	0.7	0.75	0.65	0.7	0.7	0.9	0.55	0.5	0.8	0.75	0.65	0.825	0.825	0.7	0.75
EN6	0.5	0.35	0.4	0.4	0.35	0	0.4	0.425	0.275	0.375	0.3	0.55	0.35	0.35	0.225	0.4	0.25	0.575	0.4	0.225	0.275	0.35	0.35
	0.8	0.65	0.7	0.7	0.65	0.1	0.7	0.7	0.55	0.625	0.6	0.85	0.65	0.65	0.5	0.7	0.55	0.825	0.7	0.5	0.55	0.65	0.65
EN7	0.575	0.425	0.35	0.4	0.25	0.55	0	0.425	0.325	0.3	0.45	0.5	0.4	0.3	0.4	0.375	0.175	0.225	0.375	0.4	0.4	0.15	0.325
	0.825	0.7	0.65	0.7	0.5	0.775	0.1	0.7	0.6	0.6	0.75	0.8	0.7	0.6	0.7	0.65	0.45	0.5	0.65	0.7	0.7	0.4	0.6
EN8	0.45	0.2	0.4	0.4	0.175	0.275	0.325	0	0.4	0.35	0.475	0.7	0.4	0.4	0.625	0.35	0.275	0.35	0.175	0.25	0.3	0.4	0.425
	0.75	0.45	0.7	0.7	0.45	0.55	0.6	0.1	0.7	0.65	0.725	0.9	0.7	0.7	0.875	0.65	0.55	0.65	0.45	0.55	0.6	0.7	0.7
EN9	0.4	0.325	0.35	0.5	0.4	0.45	0.425	0.45	0	0.4	0.475	0.4	0.35	0.375	0.475	0.525	0.475	0.5	0.325	0.35	0.4	0.25	0.35
	0.7	0.6	0.65	0.8	0.7	0.675	0.7	0.75	0.1	0.7	0.725	0.7	0.65	0.65	0.725	0.775	0.725	0.8	0.6	0.65	0.7	0.55	0.65
EN10	0.4	0.3	0.35	0.3	0.3	0.325	0.475	0.225	0.45	0	0.275	0.45	0.35	0.35	0.475	0.5	0.175	0.625	0.375	0.35	0.45	0.4	0.375
	0.7	0.6	0.65	0.6	0.6	0.6	0.75	0.5	0.75	0.1	0.55	0.75	0.65	0.65	0.725	0.8	0.45	0.8	0.625	0.65	0.75	0.7	0.65
EN11	0.175	0.225	0.225	0.275	0.525	0.525	0.575	0.325	0.5	0.45	0	0.3	0.475	0.5	0.4	0.525	0.225	0.5	0.35	0.3	0.4	0.2	0.375
	0.45	0.5	0.5	0.55	0.775	0.775	0.825	0.6	0.725	0.75	0.1	0.6	0.75	0.8	0.7	0.775	0.5	0.725	0.65	0.6	0.7	0.45	0.65
EN12	0.375	0.35	0.4	0.35	0.3	0.4	0.625	0.3	0.275	0.4	0.225	0	0.3	0.475	0.5	0.4	0.5	0.45	0.4	0.5	0.45	0.475	0.5
	0.65	0.65	0.7	0.65	0.6	0.7	0.875	0.6	0.55	0.7	0.5	0.1	0.6	0.725	0.8	0.7	0.8	0.75	0.7	0.8	0.75	0.75	0.8
EN13	0.325	0.35	0.4	0.45	0.3	0.35	0.65	0.575	0.4	0.425	0.275	0.65	0	0.4	0.575	0.475	0.475	0.4	0.325	0.45	0.5	0.55	0.5
	0.6	0.65	0.7	0.675	0.6	0.575	0.85	0.825	0.7	0.675	0.55	0.85	0.1	0.7	0.825	0.725	0.725	0.7	0.6	0.75	0.8	0.85	0.8
EN14	0.375	0.325	0.45	0.575	0.425	0.45	0.425	0.275	0.525	0.4	0.575	0.575	0.45	0	0.4	0.5	0.35	0.55	0.375	0.55	0.35	0.35	0.35
	0.65	0.6	0.75	0.825	0.7	0.75	0.7	0.55	0.775	0.7	0.825	0.825	0.75	0.1	0.7	0.725	0.65	0.85	0.65	0.85	0.65	0.65	0.65
EN15	0.35	0.5	0.35	0.45	0.45	0.4	0.5	0.225	0.3	0.45	0.3	0.45	0.35	0.4	0	0.325	0.4	0.525	0.5	0.55	0.45	0.225	0.4
	0.65	0.8	0.65	0.75	0.75	0.7	0.8	0.5	0.6	0.75	0.6	0.75	0.6	0.7	0.1	0.6	0.7	0.775	0.8	0.85	0.75	0.5	0.7
EN16	0.45	0.5	0.425	0.575	0.475	0.525	0.275	0.3	0.35	0.45	0.35	0.675	0.6	0.45	0.35	0	0.575	0.375	0.65	0.7	0.475	0.6	0.625
	0.75	0.8	0.7	0.825	0.725	0.775	0.55	0.6	0.6	0.75	0.65	0.925	0.9	0.75	0.65	0.1	0.825	0.65	0.85	0.9	0.725	0.9	0.875
EN17	0.5	0.4	0.35	0.45	0.55	0.4	0.3	0.3	0.6	0.75	0.45	0.6	0.55	0.35	0.3	0.4	0	0.4	0.45	0.45	0.4	0.55	0.45
	0.8	0.7	0.65	0.75	0.85	0.7	0.6	0.6	0.9	0.95	0.75	0.9	0.85	0.65	0.6	0.7	0.1	0.7	0.75	0.75	0.7	0.85	0.75
EN18	0.35	0.575	0.525	0.4	0.45	0.475	0.5	0.25	0.45	0.45	0.4	0.35	0.475	0.225	0.425	0.3	0.575	0	0.75	0.425	0.3	0.5	0.2
	0.65	0.825	0.775	0.7	0.75	0.75	0.8	0.55	0.675	0.75	0.7	0.65	0.725	0.5	0.7	0.6	0.825	0.1	0.95	0.7	0.6	0.8	0.5
EN19	0.4	0.55	0.45	0.475	0.5	0.35	0.575	0.4	0.35	0.5	0.325	0.5	0.425	0.4	0.35	0.375	0.4	0.45	0	0.375	0.45	0.575	0.45
	0.7	0.85	0.75	0.725	0.8	0.65	0.825	0.7	0.65	0.8	0.6	0.8	0.7	0.7	0.65	0.65	0.7	0.75	0.1	0.65	0.675	0.825	0.675
EN20	0.575	0.625	0.4	0.5	0.475	0.375	0.575	0.65	0.4	0.4	0.525	0.575	0.525	0.275	0.35	0.4	0.425	0.375	0.3	0	0.375	0.625	0.475
	0.825	0.875	0.7	0.8	0.725	0.65	0.825	0.85	0.7	0.7	0.775	0.75	0.775	0.55	0.65	0.7	0.7	0.65	0.6	0.1	0.625	0.875	0.725
EN21	0.625	0.55	0.575	0.4	0.575	0.325	0.35	0.4	0.425	0.45	0.275	0.4	0.45	0.3	0.35	0.525	0.45	0.525	0.375	0.35	0	0.45	0.5
	0.875	0.85	0.825	0.7	0.825	0.6	0.65	0.7	0.7	0.75	0.55	0.7	0.75	0.6	0.65	0.775	0.675	0.775	0.65	0.65	0.1	0.75	0.8
EN22	0.55	0.625	0.575	0.55	0.45	0.375	0.35	0.4	0.475	0.525	0.55	0.5	0.675	0.4	0.575	0.75	0.5	0.5	0.25	0.575	0.375	0	0.5
	0.85	0.875	0.825	0.85	0.675	0.65	0.65	0.7	0.725	0.775	0.775	0.725	0.925	0.7	0.825	0.95	0.8	0.8	0.55	0.75	0.65	0.1	0.725
EN23	0.4	0.75	0.65	0.5	0.45	0.4	0.475	0.45	0.4	0.4	0.375	0.525	0.6	0.475	0.45	0.475	0.45	0.45	0.35	0.475	0.625	0.5	0
	0.7	0.95	0.85	0.8	0.75	0.7	0.725	0.75	0.7	0.7	0.575	0.775	0.9	0.725	0.675	0.75	0.75	0.75	0.65	0.725	0.875	0.8	0.1

Table 5.5. Crisp Grey relation matrix (Z) for enablers of sustainable WEEE management implementation.

Enablers	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	EN13	EN14	EN15	EN16	EN17	EN18	EN19	EN20	EN21	EN22	EN23
EN1	0.0000	0.4240	0.5000	0.2971	0.5350	0.5382	0.4667	0.3224	0.4343	0.3632	0.6424	0.2074	0.3747	0.5000	0.5169	0.4691	0.3576	0.5350	0.4848	0.3413	0.2578	0.3870	0.3814
EN2	0.5847	0.0000	0.6050	0.6205	0.5516	0.5382	0.5169	0.5657	0.3224	0.3632	0.8322	0.6751	0.5477	0.5156	0.4667	0.5309	0.5000	0.4324	0.4853	0.6905	0.6970	0.4343	0.5333
EN3	0.5169	0.3632	0.0000	0.6050	0.4828	0.5194	0.6525	0.5657	0.6905	0.3632	0.7716	0.6751	0.5477	0.6313	0.5333	0.4691	0.4288	0.5350	0.5309	0.6970	0.8283	0.6270	0.6525
EN4	0.7203	0.4848	0.3451	0.0000	0.6751	0.7674	0.4667	0.6970	0.5000	0.4691	0.6268	0.6253	0.4841	0.8283	0.5333	0.5927	0.6268	0.6050	0.5309	0.6402	0.6402	0.4516	0.4000
EN5	0.6474	0.5897	0.6050	0.6015	0.0000	0.4618	0.6667	0.8283	0.5657	0.5927	0.5712	0.5627	0.5477	0.8667	0.4181	0.3206	0.7716	0.6751	0.4691	0.7540	0.7540	0.5657	0.6525
EN6	0.7203	0.4691	0.6050	0.6050	0.5350	0.0000	0.5847	0.5807	0.3870	0.4701	0.4819	0.7387	0.4841	0.5000	0.3333	0.5309	0.4095	0.8044	0.5309	0.3224	0.3870	0.5000	0.5169
EN7	0.7784	0.5456	0.5350	0.6050	0.3647	0.8306	0.0000	0.5807	0.4516	0.4073	0.6992	0.6751	0.5477	0.4343	0.5847	0.4848	0.2864	0.3451	0.4848	0.5657	0.5657	0.2143	0.4667
EN8	0.6525	0.2608	0.6050	0.6050	0.2762	0.4618	0.4667	0.0000	0.5657	0.4691	0.6923	0.8411	0.5477	0.5657	0.8439	0.4691	0.4288	0.5350	0.2415	0.3687	0.4343	0.5657	0.6000
EN9	0.5847	0.4240	0.5350	0.7451	0.6050	0.6837	0.6000	0.6313	0.0000	0.5309	0.6923	0.5477	0.4841	0.5161	0.6474	0.6495	0.6923	0.7451	0.4240	0.5000	0.5657	0.3687	0.5169
EN10	0.5847	0.4073	0.5350	0.4650	0.4650	0.5382	0.6667	0.3224	0.6313	0.0000	0.4288	0.6114	0.4841	0.5000	0.6474	0.6545	0.2864	0.8021	0.4701	0.5000	0.6313	0.5657	0.5333
EN11	0.2667	0.3164	0.3451	0.4139	0.7368	0.8187	0.7784	0.4516	0.6402	0.5927	0.0000	0.4204	0.6253	0.6970	0.5847	0.6495	0.3576	0.6825	0.4691	0.4343	0.5657	0.2778	0.5333
EN12	0.5333	0.4691	0.6050	0.5350	0.4650	0.6749	0.8439	0.4343	0.3870	0.5309	0.3576	0.0000	0.4204	0.6270	0.7203	0.5309	0.7716	0.6751	0.5309	0.6970	0.6313	0.6453	0.7203
EN13	0.4667	0.4691	0.6050	0.6161	0.4650	0.5367	0.8308	0.7540	0.5657	0.5299	0.4288	0.7818	0.0000	0.5657	0.7784	0.5897	0.6923	0.6050	0.4240	0.6313	0.6970	0.7626	0.7203
EN14	0.5333	0.4240	0.6751	0.8044	0.6205	0.7527	0.6000	0.3870	0.6905	0.5309	0.8322	0.7310	0.6114	0.0000	0.5847	0.6028	0.5543	0.8151	0.4848	0.7626	0.5000	0.5000	0.5169
EN15	0.5169	0.6545	0.5350	0.6751	0.6751	0.6749	0.7203	0.3224	0.4343	0.5927	0.4819	0.6114	0.4538	0.5657	0.0000	0.4240	0.6268	0.7368	0.6545	0.7626	0.6313	0.3224	0.5847
EN16	0.6525	0.6545	0.6205	0.8044	0.6691	0.8187	0.4000	0.4343	0.4683	0.5927	0.5543	0.8542	0.8024	0.6313	0.5169	0.0000	0.8322	0.5516	0.7594	0.8667	0.6270	0.8283	0.8439
EN17	0.7203	0.7203	0.5350	0.6751	0.8151	0.6749	0.4492	0.4343	0.8283	0.8747	0.6992	0.8024	0.7387	0.5000	0.4492	0.5309	0.0000	0.6050	0.5927	0.6313	0.5657	0.7626	0.6525
EN18	0.5169	0.5169	0.7368	0.6050	0.6751	0.7674	0.7203	0.3687	0.5779	0.5927	0.6268	0.4841	0.6078	0.3224	0.6000	0.4073	0.8322	0.0000	0.8747	0.5807	0.4343	0.6970	0.3136
EN19	0.5847	0.5309	0.6751	0.6691	0.7451	0.5972	0.7784	0.5657	0.5000	0.6545	0.5000	0.6751	0.5627	0.5657	0.5169	0.4848	0.6268	0.6751	0.0000	0.5161	0.5779	0.7540	0.5964
EN20	0.7784	0.7093	0.6050	0.7451	0.6691	0.6146	0.7784	0.8056	0.5657	0.5309	0.7622	0.6743	0.6694	0.3870	0.5169	0.5309	0.6424	0.5516	0.4073	0.0000	0.5000	0.8175	0.6474
EN21	0.8439	0.8439	0.8044	0.6050	0.8044	0.5382	0.5169	0.5657	0.5807	0.5927	0.4288	0.5477	0.6114	0.4343	0.5169	0.6495	0.6372	0.7368	0.4848	0.5000	0.0000	0.6313	0.7203
EN22	0.7880	0.7880	0.8044	0.8151	0.6161	0.6146	0.5169	0.5657	0.6270	0.6495	0.7743	0.6210	0.8542	0.5657	0.7784	0.8747	0.7716	0.7451	0.3455	0.6944	0.5161	0.0000	0.6607
EN23	0.5847	0.5309	0.8576	0.7451	0.6751	0.6749	0.6474	0.6313	0.5657	0.5309	0.5168	0.6694	0.8024	0.6270	0.5964	0.6064	0.6992	0.6751	0.4691	0.6270	0.8175	0.6970	0.0000

Table 5.6 Normalized Crisp relation matrix (N) for enablers of sustainable WEEE management implementation.

Enablers	**EN1**	**EN2**	**EN3**	**EN4**	**EN5**	**EN6**	**EN7**	**EN8**	**EN9**	**EN10**	**EN11**	**EN12**	**EN13**	**EN14**	**EN15**	**EN16**	**EN17**	**EN18**	**EN19**	**EN20**	**EN21**	**EN22**	**EN23**
EN1	0.0000	0.0283	0.0334	0.0198	0.0357	0.0359	0.0311	0.0215	0.0290	0.0242	0.0428	0.0138	0.0250	0.0334	0.0345	0.0313	0.0239	0.0357	0.0323	0.0228	0.0172	0.0258	0.0254
EN2	0.0390	0.0000	0.0404	0.0414	0.0368	0.0359	0.0345	0.0377	0.0215	0.0242	0.0555	0.0450	0.0365	0.0344	0.0311	0.0354	0.0334	0.0288	0.0324	0.0461	0.0465	0.0290	0.0356
EN3	0.0345	0.0242	0.0000	0.0404	0.0322	0.0346	0.0435	0.0377	0.0461	0.0242	0.0515	0.0450	0.0365	0.0421	0.0356	0.0313	0.0286	0.0357	0.0354	0.0465	0.0552	0.0418	0.0435
EN4	0.0480	0.0323	0.0230	0.0000	0.0450	0.0512	0.0311	0.0465	0.0334	0.0313	0.0418	0.0417	0.0323	0.0552	0.0356	0.0395	0.0418	0.0404	0.0354	0.0427	0.0427	0.0301	0.0267
EN5	0.0432	0.0393	0.0404	0.0401	0.0000	0.0308	0.0445	0.0552	0.0377	0.0395	0.0381	0.0375	0.0365	0.0578	0.0279	0.0214	0.0515	0.0450	0.0313	0.0503	0.0503	0.0377	0.0435
EN6	0.0480	0.0313	0.0404	0.0404	0.0357	0.0000	0.0390	0.0387	0.0258	0.0314	0.0321	0.0493	0.0323	0.0334	0.0222	0.0354	0.0273	0.0537	0.0354	0.0215	0.0258	0.0334	0.0345
EN7	0.0519	0.0364	0.0357	0.0404	0.0243	0.0554	0.0000	0.0387	0.0301	0.0272	0.0466	0.0450	0.0365	0.0290	0.0390	0.0323	0.0191	0.0230	0.0323	0.0377	0.0377	0.0143	0.0311
EN8	0.0435	0.0174	0.0404	0.0404	0.0184	0.0308	0.0311	0.0000	0.0377	0.0313	0.0462	0.0561	0.0365	0.0377	0.0563	0.0313	0.0286	0.0357	0.0161	0.0246	0.0290	0.0377	0.0400
EN9	0.0390	0.0283	0.0357	0.0497	0.0404	0.0456	0.0400	0.0421	0.0000	0.0354	0.0462	0.0365	0.0323	0.0344	0.0432	0.0433	0.0462	0.0497	0.0283	0.0334	0.0377	0.0246	0.0345
EN10	0.0390	0.0272	0.0357	0.0310	0.0310	0.0359	0.0445	0.0215	0.0421	0.0000	0.0286	0.0408	0.0323	0.0334	0.0432	0.0437	0.0191	0.0535	0.0314	0.0334	0.0421	0.0377	0.0356
EN11	0.0178	0.0211	0.0230	0.0276	0.0491	0.0546	0.0519	0.0301	0.0427	0.0395	0.0000	0.0280	0.0417	0.0465	0.0390	0.0433	0.0239	0.0455	0.0313	0.0290	0.0377	0.0185	0.0356
EN12	0.0356	0.0313	0.0404	0.0357	0.0310	0.0450	0.0563	0.0290	0.0258	0.0354	0.0239	0.0000	0.0280	0.0418	0.0480	0.0354	0.0515	0.0450	0.0354	0.0465	0.0421	0.0430	0.0480
EN13	0.0311	0.0313	0.0404	0.0411	0.0310	0.0358	0.0554	0.0503	0.0377	0.0353	0.0286	0.0521	0.0000	0.0377	0.0519	0.0393	0.0462	0.0404	0.0283	0.0421	0.0465	0.0509	0.0480
EN14	0.0356	0.0283	0.0450	0.0537	0.0414	0.0502	0.0400	0.0258	0.0461	0.0354	0.0555	0.0488	0.0408	0.0000	0.0390	0.0402	0.0370	0.0544	0.0323	0.0509	0.0334	0.0334	0.0345
EN15	0.0345	0.0437	0.0357	0.0450	0.0450	0.0450	0.0480	0.0215	0.0290	0.0395	0.0321	0.0408	0.0303	0.0377	0.0000	0.0283	0.0418	0.0491	0.0437	0.0509	0.0421	0.0215	0.0390
EN16	0.0435	0.0437	0.0414	0.0537	0.0446	0.0546	0.0267	0.0290	0.0312	0.0395	0.0370	0.0570	0.0535	0.0421	0.0345	0.0000	0.0555	0.0368	0.0507	0.0578	0.0418	0.0552	0.0563
EN17	0.0480	0.0480	0.0357	0.0450	0.0544	0.0450	0.0300	0.0290	0.0552	0.0583	0.0466	0.0535	0.0493	0.0334	0.0300	0.0354	0.0000	0.0404	0.0395	0.0421	0.0377	0.0509	0.0435
EN18	0.0345	0.0345	0.0491	0.0404	0.0450	0.0512	0.0480	0.0246	0.0385	0.0395	0.0418	0.0323	0.0405	0.0215	0.0400	0.0272	0.0555	0.0000	0.0583	0.0387	0.0290	0.0465	0.0209
EN19	0.0390	0.0354	0.0450	0.0446	0.0497	0.0398	0.0519	0.0377	0.0334	0.0437	0.0334	0.0450	0.0375	0.0377	0.0345	0.0323	0.0418	0.0450	0.0000	0.0344	0.0385	0.0503	0.0398
EN20	0.0519	0.0473	0.0404	0.0497	0.0446	0.0410	0.0519	0.0537	0.0377	0.0354	0.0508	0.0450	0.0446	0.0258	0.0345	0.0354	0.0428	0.0368	0.0272	0.0000	0.0334	0.0545	0.0432
EN21	0.0563	0.0563	0.0537	0.0404	0.0537	0.0359	0.0345	0.0377	0.0387	0.0395	0.0286	0.0365	0.0408	0.0290	0.0345	0.0433	0.0425	0.0491	0.0323	0.0334	0.0000	0.0421	0.0480
EN22	0.0526	0.0526	0.0537	0.0544	0.0411	0.0410	0.0345	0.0377	0.0418	0.0433	0.0516	0.0414	0.0570	0.0377	0.0519	0.0583	0.0515	0.0497	0.0230	0.0463	0.0344	0.0000	0.0441
EN23	0.0390	0.0354	0.0572	0.0497	0.0450	0.0450	0.0432	0.0421	0.0377	0.0354	0.0345	0.0446	0.0535	0.0418	0.0398	0.0404	0.0466	0.0450	0.0313	0.0418	0.0545	0.0465	0.0000

Table 5.7 Total relation matrix (T) for enablers of sustainable WEEE management implementation.

Enablers	EN1	EN2	EN3	EN4	EN5	EN6	EN7	EN8	EN9	EN10	EN11	EN12	EN13	EN14	EN15	EN16	EN17	EN18	EN19	EN20	EN21	EN22	EN23
EN1	0.1704	0.1739	0.1989	0.1932	0.2000	0.2127	0.2028	0.1706	0.1796	0.1730	0.2099	0.1895	0.1856	0.1884	0.1926	0.1821	0.1849	0.2113	0.1736	0.1870	0.1785	0.1805	0.1850
EN2	0.2559	0.1876	0.2518	0.2614	0.2471	0.2619	0.2539	0.2279	0.2147	0.2145	0.2682	0.2676	0.2413	0.2331	0.2343	0.2285	0.2389	0.2538	0.2126	0.2544	0.2509	0.2275	0.2398
EN3	0.2647	0.2225	0.2259	0.2739	0.2552	0.2743	0.2752	0.2391	0.2490	0.2258	0.2770	0.2805	0.2535	0.2515	0.2507	0.2364	0.2470	0.2738	0.2259	0.2670	0.2709	0.2508	0.2590
EN4	0.2764	0.2290	0.2475	0.2339	0.2661	0.2884	0.2623	0.2458	0.2362	0.2318	0.2673	0.2768	0.2483	0.2629	0.2493	0.2427	0.2582	0.2773	0.2255	0.2625	0.2576	0.2393	0.2422
EN5	0.2862	0.2476	0.2777	0.2869	0.2364	0.2840	0.2889	0.2667	0.2535	0.2516	0.2784	0.2875	0.2659	0.2778	0.2560	0.2387	0.2801	0.2958	0.2328	0.2831	0.2786	0.2593	0.2710
EN6	0.2542	0.2087	0.2424	0.2501	0.2357	0.2170	0.2478	0.2194	0.2096	0.2122	0.2366	0.2610	0.2276	0.2227	0.2170	0.2193	0.2241	0.2664	0.2078	0.2220	0.2219	0.2225	0.2286
EN7	0.2552	0.2112	0.2349	0.2472	0.2227	0.2669	0.2079	0.2174	0.2108	0.2057	0.2472	0.2545	0.2285	0.2163	0.2297	0.2142	0.2131	0.2355	0.2022	0.2339	0.2304	0.2016	0.2234
EN8	0.2500	0.1963	0.2424	0.2508	0.2204	0.2478	0.2413	0.1820	0.2213	0.2128	0.2498	0.2677	0.2319	0.2273	0.2496	0.2164	0.2257	0.2509	0.1899	0.2256	0.2255	0.2262	0.2345
EN9	0.2675	0.2248	0.2585	0.2808	0.2615	0.2832	0.2702	0.2414	0.2037	0.2353	0.2707	0.2716	0.2480	0.2434	0.2560	0.2457	0.2618	0.2853	0.2191	0.2536	0.2533	0.2336	0.2489
EN10	0.2516	0.2106	0.2437	0.2476	0.2372	0.2576	0.2586	0.2081	0.2295	0.1868	0.2385	0.2587	0.2330	0.2272	0.2414	0.2322	0.2221	0.2723	0.2088	0.2386	0.2424	0.2314	0.2351
EN11	0.2306	0.2034	0.2305	0.2434	0.2526	0.2738	0.2645	0.2157	0.2293	0.2240	0.2092	0.2465	0.2406	0.2386	0.2361	0.2304	0.2250	0.2640	0.2075	0.2332	0.2373	0.2122	0.2340
EN12	0.2688	0.2319	0.2674	0.2723	0.2565	0.2865	0.2891	0.2325	0.2323	0.2386	0.2541	0.2406	0.2481	0.2529	0.2640	0.2420	0.2703	0.2846	0.2287	0.2699	0.2611	0.2546	0.2653
EN13	0.2772	0.2424	0.2796	0.2902	0.2681	0.2909	0.3010	0.2635	0.2545	0.2495	0.2707	0.3034	0.2326	0.2609	0.2802	0.2571	0.2777	0.2933	0.2320	0.2780	0.2772	0.2732	0.2775
EN14	0.2792	0.2378	0.2819	0.3000	0.2772	0.3035	0.2863	0.2400	0.2612	0.2484	0.2944	0.2982	0.2701	0.2239	0.2663	0.2566	0.2680	0.3054	0.2355	0.2847	0.2637	0.2557	0.2632
EN15	0.2637	0.2397	0.2589	0.2766	0.2659	0.2824	0.2782	0.2228	0.2316	0.2389	0.2578	0.2754	0.2460	0.2460	0.2140	0.2315	0.2577	0.2845	0.2333	0.2701	0.2577	0.2311	0.2530
EN16	0.3117	0.2740	0.3033	0.3253	0.3041	0.3320	0.2982	0.2648	0.2691	0.2739	0.3011	0.3316	0.3056	0.2868	0.2850	0.2401	0.3088	0.3145	0.2721	0.3149	0.2950	0.2997	0.3071
EN17	0.3039	0.2674	0.2863	0.3050	0.3015	0.3112	0.2898	0.2544	0.2811	0.2811	0.2987	0.3158	0.2903	0.2682	0.2704	0.2642	0.2446	0.3061	0.2521	0.2889	0.2803	0.2840	0.2841
EN18	0.2672	0.2342	0.2745	0.2759	0.2693	0.2916	0.2818	0.2289	0.2442	0.2425	0.2705	0.2715	0.2591	0.2345	0.2562	0.2342	0.2736	0.2415	0.2497	0.2621	0.2489	0.2574	0.2400
EN19	0.2804	0.2425	0.2800	0.2890	0.2817	0.2904	0.2940	0.2487	0.2471	0.2537	0.2714	0.2923	0.2648	0.2578	0.2600	0.2470	0.2697	0.2937	0.2013	0.2670	0.2663	0.2691	0.2658
EN20	0.3005	0.2603	0.2833	0.3018	0.2848	0.3001	0.3021	0.2711	0.2583	0.2530	0.2961	0.3007	0.2793	0.2546	0.2681	0.2575	0.2781	0.2943	0.2343	0.2413	0.2691	0.2800	0.2768
EN21	0.3000	0.2651	0.2918	0.2888	0.2893	0.2903	0.2813	0.2520	0.2553	0.2529	0.2711	0.2881	0.2715	0.2532	0.2633	0.2603	0.2742	0.3011	0.2361	0.2698	0.2330	0.2653	0.2771
EN22	0.3207	0.2827	0.3151	0.3269	0.3018	0.3214	0.3065	0.2734	0.2802	0.2782	0.3166	0.3183	0.3098	0.2840	0.3026	0.2964	0.3058	0.3273	0.2483	0.3059	0.2895	0.2473	0.2967
EN23	0.2968	0.2568	0.3073	0.3106	0.2935	0.3121	0.3024	0.2674	0.2659	0.2604	0.2886	0.3092	0.2952	0.2766	0.2803	0.2692	0.2900	0.3107	0.2454	0.2898	0.2967	0.2810	0.2434

Table 5.8 Cause-effect parameters for enablers of sustainable WEEE management implementation.

Enablers	R	C	R + C	R - C	Ranking	Relation Category
EN1	4.3241	6.2328	10.5569	-1.9087	23	Effect
EN2	5.5277	5.3504	10.8781	0.1773	20	Cause
EN3	5.8496	6.0836	11.9332	-0.2340	12	Effect
EN4	5.8275	6.3318	12.1593	-0.5044	9	Effect
EN5	6.1846	6.0284	12.2130	0.1562	8	Cause
EN6	5.2747	6.4800	11.7547	-1.2053	14	Effect
EN7	5.2105	6.2843	11.4948	-1.0738	17	Effect
EN8	5.2862	5.4535	10.7398	-0.1673	22	Effect
EN9	5.8182	5.5181	11.3363	0.3001	18	Cause
EN10	5.4129	5.4447	10.8576	-0.0318	21	Effect
EN11	5.3826	6.1437	11.5263	-0.7612	16	Effect
EN12	5.9123	6.4071	12.3194	-0.4948	7	Effect
EN13	6.2307	5.8766	12.1074	0.3541	11	Cause
EN14	6.2012	5.6888	11.8900	0.5124	13	Cause
EN15	5.8168	5.8232	11.6400	-0.0064	15	Effect
EN16	6.8185	5.5427	12.3612	1.2758	4	Cause
EN17	6.5296	5.8995	12.4291	0.6300	2	Cause
EN18	5.9092	6.4435	12.3527	-0.5343	5	Effect
EN19	6.1337	5.1748	11.3085	0.9590	19	Cause
EN20	6.3455	6.0032	12.3487	0.3423	6	Cause
EN21	6.2308	5.8859	12.1167	0.3449	10	Cause
EN22	6.8553	5.6834	12.5387	1.1718	1	Cause
EN23	6.5494	5.8513	12.4007	0.6980	3	Cause

Table 5.9 Ranking of relation vector

Rank	Cause enabler	R – C	Rank	Effect enabler	R – C
1	EN16	1.2758	1	EN1	-1.9087
2	EN22	1.1718	2	EN6	-1.2053
3	EN19	0.9590	3	EN7	-1.0738
4	EN23	0.6980	4	EN11	-0.7612
5	EN17	0.6300	5	EN18	-0.5343
6	EN14	0.5124	6	EN4	-0.5044
7	EN13	0.3541	7	EN12	-0.4948
8	EN21	0.3449	8	EN3	-0.2340
9	EN20	0.3423	9	EN8	-0.1673
10	EN9	0.3001	10	EN10	-0.0318
11	EN2	0.1773	11	EN15	-0.0064
12	EN5	0.1562			

5.3.3 Sensitivity analysis

Sensitivity analysis can be performed to test the reliability and robustness of the solution methodology as well as the results obtained from the analysis. Sensitivity analysis also helps to determine whether the possible human biases of an individual expert may have influenced on the outcomes of the study. To perform the sensitivity analysis, we alter the weight of an individual expert to investigate the effect on the overall system (Rajesh and Ravi, 2015; Kumar and Dixit, 2018b). For the smooth conduct of the analysis, equal weight can be assigned to each expert and after that weights can be altered for each scenario as shown in Table 5.10.

Table 5.10 Weight allocation for each expert analyst.

	Expert 1	Expert 2	Expert 3	Expert 4
Scenario1	0.4	0.2	0.2	0.2
Scenario 2	0.2	0.4	0.2	0.2
Scenario 3	0.2	0.2	0.4	0.2
Scenario 4	0.2	0.2	0.2	0.4

Table 5.11 Sensitivity analysis of cause/effect enablers for each scenario

Ranking order	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Enabler	R - C	Enabler	R - C	Enabler	R - C	Enabler	R - C
1	EN16	1.4074	EN16	1.172	EN16	1.10703	EN16	1.2301
2	EN22	1.2855	EN22	0.95071	EN22	1.0879	EN22	1.1151
3	EN19	0.9873	EN19	0.81976	EN19	1.06115	EN19	1.0876
4	EN17	0.6653	EN23	0.8134	EN23	0.9024	EN23	0.8247
5	EN23	0.6005	EN14	0.72492	EN17	0.726	EN14	0.4529
6	EN14	0.4735	EN17	0.69003	EN20	0.6339	EN17	0.4442
7	EN13	0.4139	EN9	0.58638	EN14	0.53993	EN9	0.2758
8	EN21	0.2222	EN20	0.48425	EN21	0.27543	EN13	0.2458
9	EN2	0.1034	EN13	0.47963	EN9	0.16703	EN21	0.1798
10	EN20	0.0991	EN5	0.46811	EN13	0.14043	EN10	0.1678
11	EN15	0.0952	EN15	0.41247	EN5	0.11999	EN5	0.1428
12	EN9	0.0418	EN21	0.32308	EN10	-0.00807	EN20	0.0632
13	EN4	0.0207	EN10	0.05763	EN2	-0.08901	EN3	-0.0390
14	EN5	-0.0611	EN2	-0.19019	EN3	-0.18245	EN2	-0.0529
15	EN8	-0.1307	EN8	-0.32606	EN8	-0.26271	EN8	-0.0996
16	EN3	-0.1485	EN3	-0.43454	EN15	-0.31304	EN18	-0.1111
17	EN12	-0.3904	EN12	-0.4902	EN18	-0.37211	EN15	-0.3303
18	EN10	-0.4662	EN11	-0.54967	EN12	-0.61132	EN4	-0.4551
19	EN18	-0.5914	EN6	-0.71375	EN11	-0.61591	EN12	-0.6211
20	EN11	-0.8854	EN4	-0.75078	EN4	-0.6813	EN11	-0.6414
21	EN7	-1.0015	EN18	-0.76651	EN7	-0.9594	EN7	-0.8621
22	EN6	-1.0219	EN7	-1.49042	EN6	-1.0982	EN6	-0.9583
23	EN1	-1.7189	EN1	-2.27026	EN1	-1.56769	EN1	-2.0590

To check the variation for the scenario 1, higher weight was given to expert 1 and rest of the experts were given equal weight for computation. Similarly, a sensitivity analysis was also performed for other experts by allocating higher weight to each of the individual experts. Four independent total relationship matrix was computed on the basis of sensitivity analysis. From the total relationship matrix, relation and prominence values were obtained and four separate ranking on the basis of their (R – C) index values are shown in Table 5.11. The results of the sensitivity analysis shows no serious variation in the ranking of the enablers of sustainable WEEE management in each scenario. Finally, it is concluded that the proposed model for this study is free from any biases and the obtained results are robust in nature.

5.4 Proposed framework for WEEE recycling partner selection based on green competencies using fuzzy AHP and VIKOR

India is one of the largest emerging economies in the world and it is likely to produce 5.2 million MT of WEEE annually by the year 2020 with respect to the current level of 1.85 million MT which exhibit CAGR (compound annual growth rate) of about 30% which is quite higher than the volume of waste generated globally (ASSOCHAM-ckinetics, 2016). Still, an alarming 95% of WEEE is handled by informal sector for recovery activities in India (Verma and Agrawal, 2014; Kumar et al., 2016; Kumar and Dixit, 2018a). Despite this, acceptability of product return and recovery management or WEEE recycling is yet not widely recognized in the Indian context (Dwivedy and Mittal, 2012; Kumar and Dixit, 2018a). According to the national WEEE management policy introduced by the government of India (GOI) addressed that all electronics producer are now required to take extended responsibility for their obsolete electronics product take-back and environmental damage (MoEF, 2016). Because of this policy, electronics industry acknowledges that offering green products not only meet the environmental and customer demand but is also important to integrate green recycling partners in their supply chain to achieve a sustainable environmental as well as economic advantage. Moreover, Indian electronic manufacturers face many challenges in the development and selection of such a desirable recycling network because most of the electronic manufacturers in India rely on importing electronic parts due to the underdeveloped domestic component manufacturing sector. Hence, the challenge lies while selecting those recycling partners who can comply with environmental regulation and sustainable need of the manufacturer (Borthakur and Sinha, 2013). Therefore, many important decisions need to be reviewed in order to select the best recycling partner on the basis of green competencies (GC).

In the light of the above, selection of WEEE recycling partners plays a vital role in improving environmental performance as well as socio-economic benefits which leads to achieve sustainable development (Büyüközkan and Çifçi, 2012; Gunasekaran et al., 2001; Hsu et al., 2013; Luthra et al., 2015). A green recycling partner is one that can contribute resources and green core competencies that the focal electronic manufacturer's company wants to outsource. But selection of recycling partners according to the manufacturers' multiple requirements and environmental demands is the challenge to be addressed in the present context. Previous studies have indicated that the selection of recycling partners is a complex decision-making process due to the presence of various alternatives (Berns et al., 2009; Gupta and Barua, 2017; Lee et al., 2015; Marufuzzaman et al., 2009). A study by Sarkis et al. (2011), indicated that the organizational theory is one among all social science theories to explain the complex organizational phenomena. Thus, the present study is grounded on natural resource-based view (NRBV). This theoretical perspective will help to explore most significant green criteria or practices in the context of recycling partner selection (refer Table 5.12). In view of the above, this study has following goals and objectives:

- To explore and finalize the criteria of green competencies from the literature and rationalize with theoretical underpinning.
- To prioritize and evaluate the criteria of green competencies (GC) for recycling partners in the Indian context.
- To select the best recycling partner among all the alternative based on the green competencies.

A novel three phase methodology (see Figure 5.5) is proposed for WEEE recycling partner selection problem in this study. In the first phase, identification and finalization of criteria for recycling partners' selection through a rigorous literature review and discuss with experts with in a Delphi study. The second phase involves FAHP technique for prioritizing the criteria in a taxonomical way according to their importance based on the skilled expert judgment (Saaty, 1980). Finally, the third phase involves selecting the best recycling partner among the other alternatives by using VIKOR ranking techniques. VIKOR also recognized as an effective decision tool to evaluate the alternatives, especially when experts are not competent to express their ratings in the decision-making process.

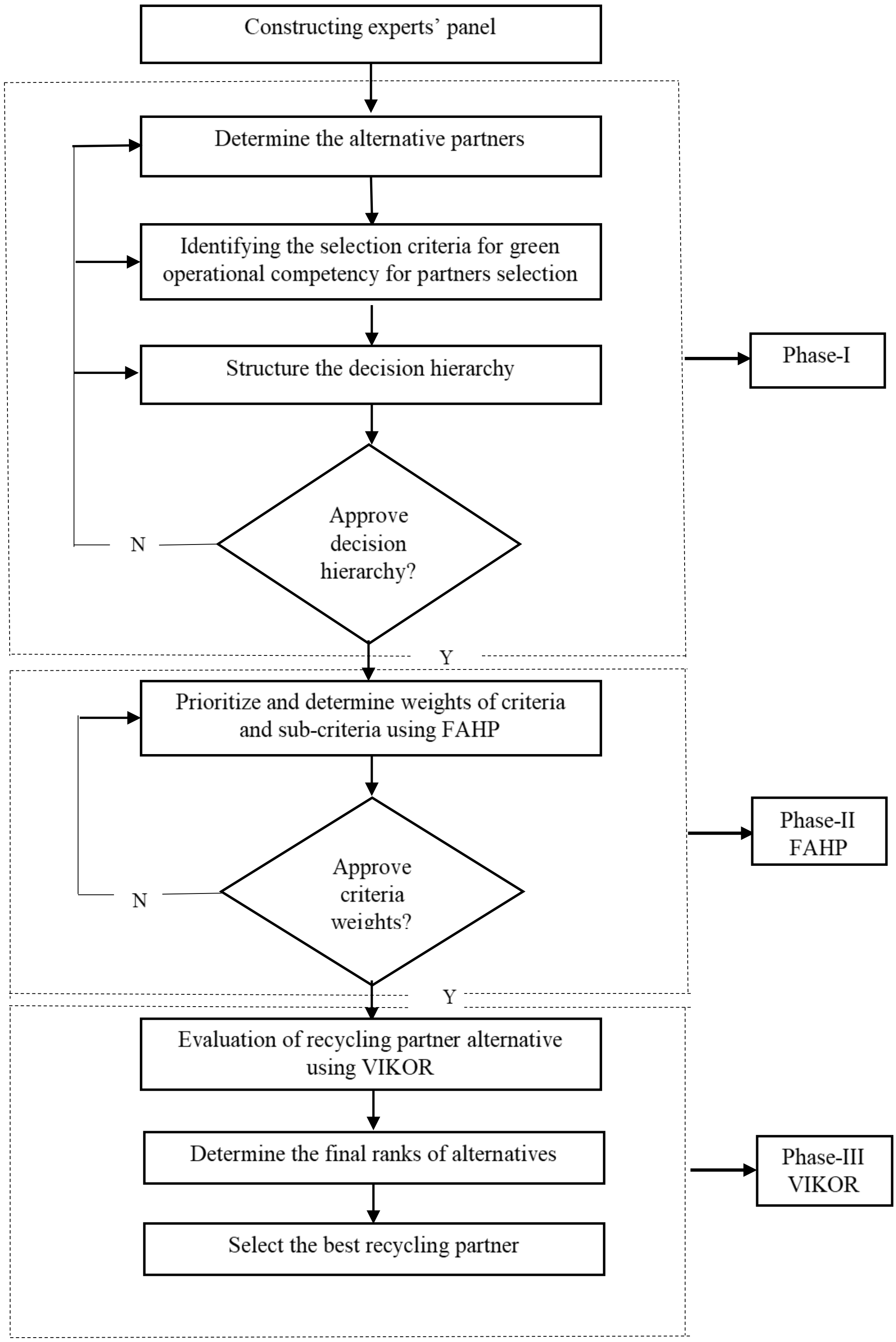

Figure 5.5 Research framework for selection of recycling partners on the basis of GC criteria.

Table 5.12 Theoretical underpinnings of criteria and sub-criteria for recycling partner selection.

Theory	**Basics of the theory**	**Main criteria**	**Sub-criteria**
Natural resource-based view (NRBV)	As recycling firm expand they can provide a bundle of their internal resources and core competencies such as R&D capabilities, environmental management competencies, and environmental management system etc.	Green core competencies	Cleaner recycling technologies
			Green product and process innovation
			Green recycling performance
			Green packaging
			Green R&D capabilities
			Green Warehousing
			Green Logistics
		Resource and Environmental management capabilities	Resources Consumption and utilization
			Renewable energy efficiency
			Pollution reduction capability
			Pollution Production
			Reduction in greenhouse gases emission
			Initiative for clean development mechanism (CDM) projects
			Environment Management System (EMS)
		Regulatory obligations and risk compliances	Geographical proximity
			Green certification and labeling
			Incentive and tax benefits schemes for green competencies
			Compliance with WEEE and environmental regulations
			Environmental auditing of recycling partners to ensure standards
		Service and delivery benefits	On time e-waste recycling and delivery
			Shortest lead time
			Post-delivery and recycling service
		Management and organizational competencies	Management of hazardous waste
			Compatibility between firms objective and green strategies
			Programs to foster staff training related green competencies
			Management commitment towards green operational practices Quality management system for waste processing
		Social responsibility benefits	Local communities influence
			Green market share
			Green Image
			Job creation for the local community
			Establishing green collaboration and alliances
			Reduction in community landfills
			Health and Safety Measures

5.5 finalization of the selection criteria

Initially, an extensive review of literature is done through academic journals and with the help of expert's opinion add or eliminate the criteria of green competencies (GC) by which to evaluate the recycling partner performance. As a result, list of seven main criteria and forty-eight sub-criteria were finalized for the study as shown in Table 5.13

Table 5.13 Criteria and sub-criteria for green competencies (GC) and recycling partner selection.

Criteria	Sub Criteria	Description	Supporting Literature
Opportunism (OPP)	Recycling Cost (OPP1)	The recycling firm lowers their recycling cost without compromising with environmental standards.	Jain et al., 2016; Wu et al., 2013; Govindan et al., 2013; Yeh and Chuang, 2011
	Green logistics Cost (OPP2)	The recycling firm handles green packaging cost, transportation and warehousing cost. This criterion is inversely proportional to the firms' satisfaction.	Grisi et al., 2010; Wu et al., 2013; Govindan et al., 2013
	Process lost cost (OPP3)	In processing recycled e-waste, the quality of the material affects the process lost cost much more than aforementioned causes.	Wen and Chi, 2010; Buyukozkan and Cifci, 2010; Buyukozkan and Cifci, 2011
	Financial capability (OPP4)	The firm's financial ability to absorb losses with its own cash in hand or borrowed from others without major disruption.	Buyukozkan and Cifci, 2011; Buyukozkan and Cifci, 2012
	Disposal cost for hazardous substances (OPP5)	Recycling firm should disposed-off toxic and hazardous waste in an environmentally sound manner on minimal charges.	Büyüközkan and Çifçi, 2012; Humphreys et al. 2003; Yeh and Chuang, 2011
	Staff training cost for green practice (OPP6)	The cost involved hiring professional to train their staff in environmental management practice.	Hsu et al., 2013; Humphreys et al. 2003; Bahinipati et al., 2009; Bahinipati and Deshmukh, 2014
Service and delivery performance (SDP)	Partner's willingness (SDP1)	Recycling partners' willingness to share their operational expertise and resolve inter or intra-activities conflicts.	Feyzioglu and Buyukozkan, 2010; Kuo et al., 2010
	Service attitude (SDP2)	It ensures that the firm's behavior and attitude towards the service and delivery of the final product.	Li and Zhao, 2009; Yan, 2009; Kuo et al., 2010; Feyzioglu and Buyukozkan, 2010
	Recycling performance and delivery history (SDP3)	The recycling performance history describes the accomplishment of past given task with accuracy and compliance with global environmental standards.	Guneri et al., 2011; Kannan et al., 2013; Kuo et al., 2010
	Flexibility in operational capabilities (SDP4)	The operational capabilities of recycling firm provide flexibility to respond to uncertain demand.	Mathew, 2006; Büyüközkan and Çifçi, 2012; Chen et al., 2006
	Archive data of service and delivery records (SDP5)	Recycling firm should keep all the data and records related to delivery, service, the quantity of waste recycled, etc.	Gencer and Gürpinar, 2007; Marufuzzaman et al., 2009; Mathew and aundhe, 2011
	Post-delivery and recycling service (SDP6)	Partners' warranties and claim policies for post delivery services	Li and Zhao, 2009; Yan, 2009

		are important due to quality issues regarding recycled e-waste materials.	
	On time waste recycling and delivery (SDP7)	The fast and effective response to recycling the WEEE by the recycling partners is required.	Yang and Wu, 2008, Kuo et al., 2010; Wen and Chi, 2010
Resource and Environmental management capabilities (REC)	Environment management System (EMS) (REC1)	The degree that it caters to the environmental certifications like ISO 14001, environmental regulations, planning to check whether the organization has its environmental issues controlled.	Chen et al., 2010; Chiou et al., 2008; Humphreys et al., 2006; Kuo et al., 2010; Lee et al., 2009; Li and Zhao, 2009; Vanalle et al., 2011; Sukitsch et al., 2015; Tseng, 2011; Tseng and Chiu, 2013
	Resources Consumption and utilization (REC2)	The consumption of resources such as water, energy, and other renewable resources during waste recycling per measurement period.	Salvado et al., 2015; Govindan et al., 2013; Bai and Sarkis, 2010; Qinghua et al., 2010
	Renewable energy efficiency (REC3)	The operational efficiency of recycling firm in terms of renewable energy is below or above industry norm compared with the other suppliers in the same industry.	Salvado et al., 2015; Sarkis and Dhavale., 2015
	Reduction in greenhouse gases emission (REC4)	The recycling firm should compliance with eco-friendly practices during e-waste handling in order to reduce greenhouse gas emissions.	Shaw et al., 2012
	Initiative for clean development mechanism (CDM) projects (REC5)	The recycling firm should integrate with the focal firm for clean development mechanism projects which leads to sustainable development.	Contributed
	Pollution Production (REC6)	The amount of pollutant such as toxic and hazardous waste, harmful air emissions, etc. released by the recycling firm per time unit.	Humphreys et al. 2003; Amin and Zhang 2012; Govindan et al., 2013
	Pollution reduction capability (REC7)	The firms green capability to minimize the average volume of hazardous and toxic pollutant releases per day during recycling.	Lee et al., 2009; Bai and Sarkis, 2010; Awasthi et al., 2010; Govindan et al., 2013
Social responsibility benefits (SRB)	Green market share (SRB1)	The recycling partner can work towards environmental sustainability is through environmentally responsible e-waste recycling.	Awasthi et al, 2010; Humphreys et al., 2006
	Local communities influence (SRB2)	Local communities influence evaluates the shaky image of a partner in their local region which in long-term may influence the normal activity of partner.	Tseng, 2011; Hussain, 2011; Gho and Zhao, 2015
	Health and safety Measures (SRB3)	The recycling firm should take health and safety measures and compliance with safety standards in practices for employees.	Tseng, 2011; Tseng and Chiu, 2013
	Establishing green collaboration and alliances (SRB4)	Establishing green alliance involves any organized or un-organized collaboration between	Contributed

		two or more firms which work on common solutions to the environmental issues.	
	Job creation for the local community (SRB5)	Recycling firms involve in e-waste recycling are capable of job creation for nearby communities.	Contributed
	Green Image (SRB6)	The green image of the recycling firms describes that the firms committed to continuous improve the green competency and reduce greenhouse gas emission in the environment.	Noci 1997; Humphreys et al. 2006; Lee et al., 2009; Wen and Chi, 2010; Govindan et al., 2013; Grisi et al., 2010; Mafakheri et al., 2011; Yeh and Chuang, 2011; Pandya, 2013
	Avoid local community landfills (SRB7)	Recycling firm ensures the processing of waste in an environmentally sound manner to avoid the community landfilling.	Contributed
Green core competencies (GCC)	Green process innovation and competencies (GCC1)	Ability to alter the recycling processes and to minimize the impact on natural resources.	Chiou et al., 2011; Lee et al., 2009; Feyzioglu and Buyukozkan, 2010; Yang and Wu, 2008; Hsu and Hu, 2009; Awasthi et al., 2010; Tseng and Chiu, 2013
	Green Warehousing (GCC2)	Firms efforts to minimize costs and increase social responsibility by an inventory of substitute material and non-hazardous substances.	Gupta and Barua, 2017
	Green R&D capabilities (GCC3)	The in-house capability of the firms to innovate green/cleaner technologies, processes and recycling method to improve environmental performance.	Contributed
	Green recycling performance (GCC4)	The ability of the firm to recycle during heavy fluctuation of supply of waste with a maximum rate of conversion.	Contributed
	Green logistics (GCC5)	Firms' efforts to reduce environmental pollution by using green fuel operated logistics fleet.	Contributed
	Cleaner recycling technologies (GCC6)	Recycling partners use green or innovative eco-friendly recycling practices to conserve the nature and natural resources and minimize the negative impact on human lives.	Humphreys et al. 2003; Humphreys et al. 2006, Chen at al., 2010; Tseng, 2011; Luthra et al., 2017
	Green packaging (GCC7)	Green packaging refers to packaging of goods that has a low impact on the environment, low energy consumption and uses the biodegradable material.	Lee et al., 2009; Kannan, 2017
Management and organizational competencies (MOC)	Management of hazardous and toxic waste (MOC1)	The firm's standards to check the waste of hazardous and toxic substances, and recording the test results.	Contributed
	Environmental auditing of recycling partners to ensure standards (MOC2)	Firms have to do time to time process auditing during the recycling of e-waste.	Contributed

	Programs to foster staff training related green competencies (MOC3)	Firm encourage the staff and train them to environmental improvement measures.	Awasthi et al., 2010; Ordoobadi, 2009; Govindan et al., 2013; Jabbour et al., 2016; Sarkis and Dhavale., 2015; Kannan, 2017; Qin et al., 2017
	Regular recyclers meeting with the focal firm (MOC4)	Recycling firms should plan and schedule their meeting with focal firms for effective communication and align the environmental as well as economic objectives.	Contributed
	Quality management systems (MOC5)	To provide a high-quality eco-friendly recycling, recycler must conform to their quality standards by using quality control tools, lean tools, and statistical process control to minimize the waste.	Lee et al., 2009; Hsu and Hu, 2009; Kuo and Lin , 2011; Wu et al., 2013; Shi et al., 2015; Sarkis and Dhavale., 2015
	Management commitment towards green operational practices (MOC6)	The degree of involvement of top management regarding green aspects in operational practices.	Jabbour et al., 2016;
	Compatibility between firms objective and green strategies (MOC7)	Formulating long-term objective of the firm which includes goals of waste minimization and green efficiency over the long run.	Li and Zhao, 2009
Regulatory obligations and Risk compliances (RRC)	Compliance with WEEE and environmental regulations (RRC1)	Recycling and disposal firm should comply with WEEE regulation in order to treat and recycle the e-waste in an environmentally sound manner to minimize the negative impact on the environment. Also consistently conform their activities to existing and appropriate regulatory requirements.	Diabat and Govindan, 2011; Dornfield et al., 2013; Hsu and Hu, 2009; Kumar and Dixit, 2018a
	Political stability (RRC2)	The political status of recycling partners and its nature towards the business policies may affect the long-term relations of a partner with the manufacturer.	Chan et al., 2008; Sridhar et al., 2010
	Incentive and tax benefits schemes for green competencies (RRC3)	Government and other financial institutions can offer lucrative incentive and tax benefit plans to recycling firms those compliance with green competencies in their recycling mechanism.	Pathak et al., 2017
	Green certification and labeling (RRC4)	Recycling firms have been certified by various green certification such as ISO 14000 series and ISO 5000 series issued by global environmental agencies (government or non-government).	Diabat and Govindan, 2011; Dornfield et al., 2013; Handfield et al., 2002; Tseng, 2011
	Criminal record (RRC5)	The manufacturers' should analyze and check whether the recycling firm owner will involve in any criminal activities like	Contributed

		terrorism, fraud, etc. while selecting the recycling partner.	
	Geographical proximity (RRC6)	The site location of recycling firm should not affect the local communities and its physical, as well as social status, should be analyzed properly before selecting a recycling firm.	Bottani et al., 2005; Büyüközkana et al., 2006; Chan et al., 2008; Sridhar et al., 2010
	Capacity change (RRC7)	Capacity change risk indicates that a supplier has a sufficient in-house capacity to meet any demand.	contributed

5.6 Application of proposed framework to case analysis

To demonstrate the application of the proposed novel hybrid methodology, a case analysis was conducted with Indian electronics company (ABC) located in western region of India. The company has been operating for past 25 years and recognized as a market leader in its product line segment. Despite of its prolonged success and sustenance in the market, the company doesn't have any concrete framework for the selection of a desirable recycling network. At present, the company has started implementing green initiatives in their supply chain activities in order to minimize the impact on environmental degradation. The present study focuses on developing a robust framework for company's stakeholders which will help them to evaluate and select the desirable recycling partner for valuable asset recovery from the WEEE. In order to select the desirable recycling partner, a team of four experts has been invited for the study. The team of experts comprises of one senior-level production manager, two middle-level supply chain managers, and one academician, having at least 10 years of experience in this domain. All experts are capable in the decision-making process and having strong expertise in various organizational activities, i.e., production planning, quality control, supply chain activities, environmental management activities, reverse logistics activities, etc. Panel consensus method is employed for the collection of data from each expert, a detailed information was given to panel regarding the case and finalized GC criteria. After that, experts were asked to assign an importance weight on the basis of prescribed scale for constructing a pair-wise comparison of each criterion and sub-criteria and also rank the recycling partners based on various GC criteria used in the study. Finally, the hierarchical structure of this decision problem is represented in Figure 5.6.

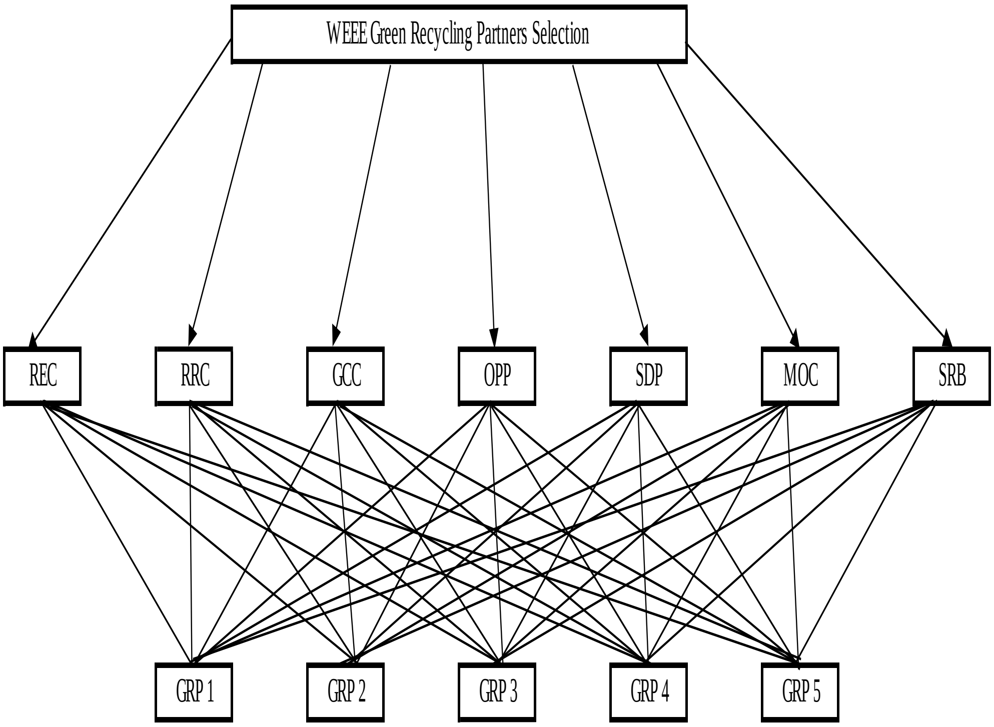

Figure 5.6 Represents the hierarchical structure of decision problem.

5.6.1 Calculation of weight of criteria and sub-criteria of green recycling partner using F-AHP

Each expert has to assign a score to construct a pair-wise fuzzy comparison matrix for each criterion and sub-criteria based on prescribed triangular fuzzy numbers (TFNs) as mentioned in Table 3.2 and 3.3. The fuzzy comparison matrices of main criteria and their sub-criteria are given in Appendix A. The weight of each criterion and sub-criteria along with established fuzzy comparison matrix is calculated with the help of Chang's extent analysis is presented in Table 5.15 – 5.16. Further, the value of fuzzy synthetic extent w.r.t. seven main criteria defined by REC, RRC, GCC, OPP, SDP, MOC and SRB respectively is calculated by using Eq. (3.17) mentioned in Section 3.3.3.3.

REC = (13.20, 18.25, 25.33) * $[(59.05), (82.89), (109.31)]^{-1}$ = (0.123, 0.221, 0.389)

Similarly,

RRC = (7.83, 11.16, 15.00) * $[(59.05), (82.89), (109.31)]^{-1}$ = (0.073, 0.135, 0.250)

GCC = (9.53, 13.75, 18.33) * $[(59.05), (82.89), (109.31)]^{-1}$ = (0.089, 0.166, 0.305)

OPP = (9.73, 13.00, 16.66) * [(59.05), (82.89), (109.31)]$^{-1}$ = (0.091, 0.157, 0.277)

SDP = (4.90, 7.16, 9.66) * [(59.05), (82.89), (109.31)]$^{-1}$ = (0.046, 0.087, 0.161)

MOC = (7.03, 9.41, 12.33) * [(59.05), (82.89), (109.31)]$^{-1}$ = (0.065, 0.114, 0.205)

SRB = (6.83, 10.16, 14.00) * [(59.05), (82.89), (109.31)]$^{-1}$ = (0.064, 0.123, 0.233)

In the next step, *V* values are calculated by using Eq. (3.18) and represented in Table 5.14.

Table 5.14. Represents the V values for main criteria.

Main criteria	REC	RRC	GCC	ECP	SDP	MOC	SRB
REC		0.5971	0.7703	0.3335	0.2212	0.4358	0.5302
RRC	1.0000		1.0000	1.0000	0.6455	0.8623	0.9299
GCC	1.0000	0.8373		0.9542	0.4755	0.6898	0.7690
ECP	1.0000	0.8775	1.0000		0.4991	0.7257	0.8060
SDP	1.0000	1.0000	1.0000	1.0000		1.0000	1.0000
MOC	1.0000	1.0000	1.0000	1.0000	0.7783		1.0000
SRB	1.0000	1.0000	1.0000	1.0000	0.7286	0.9399	

Then the minimum possibility degree among the main criteria is determined by using Eq. (3) is given as:

m (REC) = min $V(S_1 \geq S_l)$ = min (1, 1, 1, 1, 1, 1) = 1s

m (RRC) = min $V(S_2 \geq S_l)$ = min (0.5971, 0.8373, 0.8775, 1, 1, 1) = 0.5971

m (GCC) = min $V(S_3 \geq S_l)$ = min (0.7703, 1, 0.9542, 1, 1, 1) = 0.7703

m (OPP) = min $V(S_4 \geq S_l)$ = min (0.3335, 1, 0.8775, 1, 1, 1) = 0.3335

m (SDP) = min $V(S_5 \geq S_l)$ = min (0.2212, 0.6455, 0.4755, 0.4991, 0.7783, 0.7286) = 0.2212

m (MOC) = min $V(S_6 \geq S_l)$ = min (0.4358, 0.8623, 0.6898, 0.7257, 1, 0.9399) = 0.4358

m (SRB) = min $V(S_7 \geq S_l)$ = min (0.5302, 0.9299, 0.7690, 8060, 1, 1) = 0.5302

The weight vector is determined from the minimum possibility degree is given by:

W' = (1, 0.5971, 0.7703, 0.3335, 0.2212, 0.4358, 0.5302)^T

Finally, after normalizing the final weights for main criteria is given by:

W = (0.2572, 0.1536, 0.1981, 0.0858, 0.0569, 0.1121, 0.1364)^T

Table 5.15 Pair-wise comparisons of main criteria of GC.

Main criteria	REC			RRC			GCC			OPP			SOP			MOC			SRB			Weights	Rank
REC	1.00	1.00	1.00	2.00	3.00	4.00	3.00	4.00	5.00	3.00	4.00	5.00	2.00	3.00	4.00	2.00	3.00	4.00	0.20	0.25	0.33	0.2572	1
RRC	0.25	0.33	0.50	1.00	1.00	1.00	0.25	0.33	0.50	1.00	2.00	3.00	3.00	4.00	5.00	2.00	3.00	4.00	0.33	0.50	1.00	0.1536	3
GCC	0.20	0.25	0.33	2.00	3.00	4.00	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	1.00	2.00	3.00	0.33	0.50	1.00	0.1981	2
OPP	0.20	0.25	0.33	0.33	0.50	1.00	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	3.00	4.00	5.00	2.00	3.00	4.00	0.0858	6
SOP	0.25	0.33	0.50	0.20	0.25	0.33	0.25	0.33	0.50	0.20	0.25	0.33	1.00	1.00	1.00	2.00	3.00	4.00	1.00	2.00	3.00	0.0569	7
MOC	3.00	4.00	5.00	0.25	0.33	0.50	0.33	0.50	1.00	0.20	0.25	0.33	0.25	0.33	0.50	1.00	1.00	1.00	2.00	3.00	4.00	0.1121	5
SRB	3.00	4.00	5.00	1.00	2.00	3.00	1.00	2.00	3.00	0.25	0.33	0.50	0.33	0.50	1.00	0.25	0.33	0.50	1.00	1.00	1.00	0.1364	4

The result shows that resource and environmental capabilities (REC) and green core competencies (GCC) are the most important main criteria among the other criteria. The priority order of main criteria of GC are REC > GCC > RRC > SRB > MOC > OPP > SOP is presented in Table 5.15. Similarly, the pair-wise comparison for all the sub-criteria on the same scale along with the weight of each sub-criteria under the main category is done and is presented in Appendix A. Finally, the global weight of each criterion and sub-criteria of GC are presented in Table 5.16. Among the sub-criteria, environment management System (EMS) has the highest priority in the global ranking, followed by resource consumption and utilization, reduction in greenhouse gas emissions, cleaner recycling technologies, and green process innovation and competencies. Rank the recycling partners with respect to GC criteria in the next section.

Table 5.16 Global ranking of GC criteria for recycling partner selection.

Main Criteria	Local weight	Sub-criteria	local weights	Global weights	Global Ranking
REC	0.2572	REC1	0.1915	0.0493	1
		REC2	0.1478	0.0380	3
		REC3	0.1372	0.0353	4
		REC4	0.1898	0.0488	2
		REC5	0.1302	0.0335	5
		REC6	0.1007	0.0259	14
		REC7	0.1028	0.0264	12
RRC	0.1536	RRC1	0.1638	0.0252	15
		RRC2	0.1510	0.0232	17
		RRC3	0.1529	0.0235	16
		RRC4	0.1438	0.0221	20
		RRC5	0.1171	0.0180	29
		RRC6	0.1429	0.0219	21
		RRC7	0.1284	0.0197	23
GCC	0.1981	GCC1	0.1645	0.0326	7
		GCC2	0.1376	0.0273	10
		GCC3	0.1581	0.0313	8
		GCC4	0.1356	0.0269	11
		GCC5	0.0988	0.0196	26
		GCC6	0.1652	0.0327	6
		GCC7	0.1401	0.0278	9
OPP	0.0858	OPP1	0.1392	0.0119	39
		OPP2	0.2294	0.0197	24
		OPP3	0.0546	0.0047	48
		OPP4	0.2044	0.0175	31
		OPP5	0.2287	0.0196	25
		OPP6	0.1438	0.0123	38
SDP	0.0569	SDP1	0.1394	0.0079	45
		SDP2	0.1467	0.0083	44
		SDP3	0.1661	0.0095	41
		SDP4	0.1595	0.0091	42
		SDP5	0.1148	0.0065	47
		SDP6	0.1178	0.0067	46
		SDP7	0.1557	0.0089	43
MOC	0.1121	MOC1	0.2332	0.0261	13
		MOC2	0.1311	0.0147	34
		MOC3	0.1291	0.0145	35
		MOC4	0.1451	0.0163	33
		MOC5	0.1203	0.0135	37
		MOC6	0.1516	0.0170	32
		MOC7	0.0877	0.0098	40
SRB	0.1364	SRB1	0.1042	0.0142	36
		SRB2	0.1385	0.0189	28
		SRB3	0.1649	0.0225	19
		SRB4	0.1663	0.0227	18
		SRB5	0.1310	0.0179	30
		SRB6	0.1418	0.0193	27
		SRB7	0.1533	0.0209	22

5*.6.2 Ranking of recycling partners alternatives using VIKOR.*

To select a desirable recycling partner among the five alternative GRP1, GRP2, GRP3, GRP4 and GRP5 with the application of VIKOR method. Firstly evaluation matrix is constructed by each expert from the case company with the help of defined linguistic scale mentioned in Table 3.4. The constructed evaluation matrix of expert 1 is presented in Table 5.17. After obtaining the individual rating matrix from each expert, the next step is to establish aggregate rating evaluation matrix by using Eq. (3.22) and shown in Table 5.18. The maximum and minimum values of all the criteria of GC are calculated by using Eq. (3.23) and (3.24). Further, the values of S, R and Q are calculated by using Eq. (3.25) and (3.26) are shown in Table 5.19. To determine the value of S and R global weight of each sub-criteria is multiplied by the rating of the alternatives. Since 'S' represents the utility measure, 'R' represents regret measure and 'Q' represents the ranking measure. The value of Q for each alternative are evaluated by using the maximum group utility weight and is taken as $v = 0.5$ in this study. According to the crisp Q index values, the final ranking of alternatives are determined in descending order as follows GRP5 > GRP3 > GRP4 > GRP2 > GRP1 is shown in Table 5.20. The obtained final ranking shows that green recycling partner (GRP5) holds the first rank among the other alternatives with lowest Q values and also satisfy both conditions 1 and 2, which employs that Q (GRP5)-Q (GRP4) ≥ 1/5-1. Similarly, GRP5 obtains top ranking according to both S and R values which ensures the stability of the experts' judgment. Rest of the other important tables are presented in Appendix B.

Table 5.17 Rating evaluation matrix for recycling partner alternatives (Expert 1).

Partners	**REC1**	**REC2**	**REC3**	**REC4**	**REC5**	**REC6**	**REC7**	**…**	**…**	**SRB1**	**SRB2**	**SRB3**	**SRB4**	**SRB5**	**SRB6**	**SRB7**
GRP1	2	4	5	1	2	4	5	…	…	1	1	2	1	3	3	3
GRP2	1	2	1	1	1	2	1	…	…	2	4	3	3	5	4	5
GRP3	5	4	4	5	5	2	4	…	…	3	2	2	2	3	3	4
GRP4	5	5	2	3	5	5	2	…	…	5	4	3	4	5	3	4
GRP5	4	2	1	3	4	2	1	…	…	3	3	5	5	2	3	2
Criterion weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	…	…	0.014	0.019	0.022	0.023	0.018	0.019	0.021

Table 5.18 Aggregate rating of alternatives.

Partners	**REC1**	**REC2**	**REC3**	**REC4**	**REC5**	**REC6**	**REC7**	**…**	**…**	**SRB1**	**SRB2**	**SRB3**	**SRB4**	**SRB5**	**SRB6**	**SRB7**
GRP1	2.75	3.25	3	2.75	2.25	1.75	3	…	…	2.75	2.75	2.75	2	2	1.75	4.5
GRP2	3	3	1.75	3.25	2.25	3.25	2.25	…	…	2.25	3	2.25	3.25	3.25	2.5	2.75
GRP3	3.25	3.25	4	3.5	4	3	3.75	…	…	4	2.5	3	2	3	3.25	2.75
GRP4	2.75	3.75	3.5	3.25	3.25	3	3.25	…	…	3.75	3.75	3.25	3.25	4.25	3.75	3.75
GRP5	4	3.25	3.75	3.75	3.75	2.5	3.75	…	…	3.75	3.25	3.5	4	3.25	3.25	3.5
Criterion weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	…	…	0.014	0.019	0.022	0.023	0.018	0.019	0.021
Max f_i^*	4	3.75	4	3.75	4	3.25	3.75	…	…	4	3.75	3.5	4	4.25	3.75	4.5
Min f_j^-	2.75	3	1.75	2.75	2.25	1.75	2.25	…	…	2.25	2.5	2.25	2	2	1.75	2.75

Table 5.19 Calculated values of S, R, and Q for alternatives.

Partners	**S**		**R**		**Q**
GRP1	0.689		0.049		1.000
GRP2	0.666		0.039		0.747
GRP3	0.518		0.030		0.340
GRP4	0.355		0.049		0.586
GRP5	0.286		0.027		0.000
	$S^- = 0.689$		$R^- = 0.049$		
	$S^* = 0.286$		$R^* = 0.027$		

5.6.3 Results and discussions

Recycling plays a crucial role in waste management and assets recovery from the obsolete electronic products. The present study identifies various GC criteria for the selection of recycling partners from the exhaustive literature and discussions with an expert panel. The finalized seven main criteria and forty-eight sub-criteria are then evaluated and analyzed with the application of the proposed hybrid framework in order to select the appropriate recycling partner for Indian electronics industry. But it is difficult to answer which of the GC criteria is very important than others, but prioritizing them by using novel approach made it more flexible, logical and tactical for industries. To resolve the complexity of the decision problem, F-AHP has been employed for analyzing and prioritizing the identified GC criteria, whereas, VIKOR is used to select the desirable recycling partner.

Table 5.15 shows the importance weights and rankings of main GC criteria, whereas global weights and ranking of each criterion is obtained by multiplying the relative weight of main criteria with each sub-criteria as shown in Table 5.16. From the main category, Resource and environmental management capabilities (REC) is considered as the most important criteria for the selection of green recycling partners. In addition, the main criteria are associated with seven sub-criteria are represented as REC1- REC7. These sub-criteria are prioritized to their local weights and ranking of these in order as follows, REC1 > REC4 > REC2 > REC3 > REC5 > REC7 > REC6 (See Appendix A). A knowledge-based environmental management system (ISO 14001) and reduction in greenhouse gas emissions holds the top priorities among the other sub-criteria and also ranked first and second in the global ranking (see Table 5.16), past studies also recognized that these two sub-criteria are important for the partners selection on the basis of sustainable environmental practices (Chen et al., 2010; Hsu et al., 2013; Humphreys et al., 2006; Kuo et al., 2010; Shaw et al., 2012). Recycling firm who acquires environmental management system (EMS) certification and implement greenhouse gases mitigation measure that firm can be improved continuously and gain economic advantage over the time (Bansal and Hunter, 2003; Darnall, 2006; Lee et al., 2009; Li and Zhao, 2009; Vanalle et al., 2011; Zhu et al., 2008a,b). Rest of the sub-criteria are prioritized in order as follows, Resources Consumption and utilization (REC2), Renewable energy efficiency (REC3), Initiative for clean development mechanism (CDM) projects (REC5), Pollution reduction capabilityity (REC7) and Pollution Production (REC6).

Green core competencies (GCC) ranked second among main criteria and is considered as a key criterion in the partners' selection (Table 5.15). GCC is one of the most important criteria in partner selection which exhibits the competencies like cleaner technologies, green logistics, green warehousing, green packaging, process innovation which leads to environmentally sound supply chain management (Chiou et al., 2011; Humphreys et al., 2003; Govindan et al., 2017; Lee et al., 2009). Firms enforced with strong regulatory and environmental pressure have to implement green operational capabilities in their business process thus promoting environmental improvement (Awasthi et al., 2010; Kumar and Dixit, 2018a, b). GCC has comprises with seven sub-criteria and their priority order as GCC6 > GCC1 > GCC3 > GCC7 > GCC2 > GCC4 > GCC5 (see Appendix A). Cleaner recycling technologies (GCC6) holds the top position among other sub-criteria of this main criteria and ranked sixth in the global ranking (refer Table 5.16), to achieve the goals of sustainable environment, recycling firms must equipped with green and clean recycling technologies for assets recovery and final disposal of waste (Luthra et al., 2017). Green process innovation and competencies (GCC1) and green R&D capabilities (GCC3) ranked second and third on the priority list. Recycling firms should integrate with R&D capabilities for green process innovation to meet the current and future demand of the focal electronics manufacturing firms (Gupta and Barua, 2017; Kannan et al., 2013). Apart from this three crucial sub-criteria, other sub-criteria are ranked in descending order as follows, Green packaging (GCC7), Green Warehousing (GCC2), Green recycling performance (GCC4) and Green Logistics (GCC5). A study by Dechant and Altman (1994) suggests integrating green core competencies into firm downstream supply chain considers the environmental impact of product and their packaging from raw materials acquisition to end-of-life product disposal. With the help of these competencies the focal firm geared towards reducing the environmental damage arising from WEEE and leads to sustainable development by improving economic as well as social benefits. According to the NRBV, the green core competencies and bundles of individual skills must have a unique combination of characteristics and difficult to replicate in order to influence firms performance by generating cost benefits. A firm can achieve economical as well as environmental sustainability if it has the capability to utilize its resources optimally and preserve natural resources during entire supply chain activities. Finally, these counterintuitive findings reveals that green competencies of the WEEE recycling partner are desirable for WEEE management which also reflects by its economic impact in terms of net profit of the focal firm (Wong et al., 2012).

Regulatory obligations and risk compliance (RRC) acquire a third position among the other GC criteria and considered as important criteria for the selection of recycling partner (refer Table 5.15). Recycling firms are very prone to monetary and resources crisis and mostly depends on government support in order to implement green competencies at their end so as to minimize the negative impact on the environment (Garlapati, 2016; Wath et al., 2010). The various sub-criteria of Regulatory obligations and risk compliance (RRC) are ranked in descending order as follows, RRC1 > RRC3 > RRC2 > RRC4 > RRC6 > RRC7 > RRC5 (see Appendix A). Compliance with WEEE and environmental regulation (RRC1) is ranked first among the other sub-criteria. Environmental policies and regulation enforce recycling firms should compliance with WEEE and RoHS laws and motivate the firms to contribute little amount of the profit investing in the development of clean or green recycling technologies (Chiou et al., 2011; Eiadat et al., 2008; Frondel et al., 2007; Govindan et al., 2016). Incentives and tax benefits scheme for green competencies (RRC3) are ranked second among other sub-criteria. The government should provide good incentives and tax benefits to the recyclers who integrate green operational capabilities in their business activities to meet their goals of environmental protection. Incentives and tax benefits play as a motivating role for firms to integrate green competencies (GC) in their entire supply chain which leads to environmental and social developments (Govindan et al., 2016; Kumar and Dixit, 2018a; Pathak et al., 2017). Political stability (RRC2) ranked third among the other sub-criteria. The nature of the relationship between recycling partners and the focal firm may affect by the political legitimacy and their conduct towards the business policies (Chan and Kumar, 2007). Rest of other important sub-criteria are ranked as follows, Green certification and labeling (RRC4), Geographical proximity (RRC6), Capacity change (RRC7) and Criminal record (RRC5). Regulation comes from the pressures enforced by those in authority bodies, and in the case of WEEE recycling firm it is the central and local government bodies. As compared to central regulatory body, local bodies are more authoritative and exert direct pressure by implementing stringent WEEE management policies related to economic activities (Kumar and Dixit, 2018a; ; Somsuk and Laosirihongthong, 2017; Yawar and Kauppi, 2018; Zailani et al., 2015; Zhu et al., 2013). A study by Kumar and Dixit (2018a), identified regulatory/institutional obligation as the most crucial criteria for WEEE recycling partner selection in Indian context. Similarly, the other main criteria are ranked in descending order as follows, Social responsibility benefits (SRB), Management and organizational competencies (MOC), Opportunism (OPP) and Service and delivery performance (SDP) and the global ranking of their sub-criteria as shown in Table 5.16. The findings of FAHP and ranking of the main criteria and sub-criteria have been validated by industrial experts with the objective to understand each dimension comprehensively of selection criteria of WEEE recycling partner which will support in the selection process, and hence, improve the sustainable business practices of the organization.

It is difficult to determine which of the GC criteria is more vital or which is not, but evaluating them with the application of proposed novel framework makes the recycling partner selection more logical. The weight obtained from the fuzzy AHP are then used in the VIKOR analysis for ranking the alternatives. In this study, five recycling partners' alternatives have been finalized and with the help of expert panel, evaluation matrix for each alternative are constructed. According to the VIKOR analysis, the ranking of alternatives is determined based on S, R and Q index values and represented in descending order is GRP5 > GRP3 > GRP4 > GRP2 > GRP1 (see Table 5.20). Results show that GRP5 is the best recycling partner and GRP1 is the worst recycling partner derived in all S, R and Q index values. By using a proposed hybrid novel framework, decision-makers can evaluate supplier selection problem more logically and achieve sustainability in the business.

Table 5.20 Final ranking of alternatives.

	S	Ranking	R	Ranking	Q	Ranking
GRP1	0.689	5	0.049	5	1.000	5
GRP2	0.666	4	0.039	3	0.747	4
GRP3	0.518	3	0.030	2	0.340	2
GRP4	0.355	2	0.049	4	0.586	3
GRP5	0.286	1	0.027	1	0.000	1

5.6.4 Sensitivity analysis

Sensitivity analysis can be performed in two ways, either by varying the weight given to the criteria or by altering the weight given to a particular expert. Sensitivity analysis is used to validate the robustness of the proposed framework as well as eliminating any possible human judgmental biases which may influence the results (Gupta and Barua, 2017; Mangla et al., 2015; Prakash and Barua, 2015). In this study, a sensitivity analysis was carried out by varying the weight v varies from 0.1 to 0.9 to the criteria that achieved maximum weight (REC=0.2572) and subsequently influence the other main criteria (Table 5.21). With the effect of the variation in the main criteria weights, the change in the global ranking of sub-criteria is also observed and presented in Figure

5.7. Similarly, the sensitivity analysis was also performed for recycling partners' alternatives. In order to check the consistency of the final ranking and expert influence in the decision-making process, it is recommended to assigning a different weight *v* varies from 0.1 to 0.9 to assess the variation in the final ranking (Luthra et al., 2017). The changed ranking of recycling partners' alternatives for 10 different runs is shown in Table 5.22 and the pictorial illustration is representing in Figure 5.8. GRP5 and GRP3 are considered as top ranked recycling partners and in the sensitivity analysis. Finally, it is concluded that the proposed model for this study is free from any biases and the obtained results are robust in nature.

Table 5.21 Variation in main criteria weights w.r.t. varying the REC weight value from 0.1 to 0.9.

Main Criteria	**Normalized weight**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**	**Run 9**
REC	0.2572	0.1000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000
GCC	0.1981	0.2400	0.2134	0.1867	0.1600	0.1334	0.1067	0.0800	0.0534	0.0267
RRC	0.1536	0.1861	0.1654	0.1448	0.1241	0.1034	0.0827	0.0620	0.0414	0.0207
SRB	0.1364	0.1653	0.1469	0.1285	0.1102	0.0918	0.0735	0.0551	0.0367	0.0184
MOC	0.1121	0.1358	0.1207	0.1056	0.0906	0.0755	0.0604	0.0453	0.0302	0.0151
OPP	0.0858	0.1040	0.0924	0.0809	0.0693	0.0578	0.0462	0.0347	0.0231	0.0116
SDP	0.0569	0.0689	0.0613	0.0536	0.0460	0.0383	0.0306	0.0230	0.0153	0.0077
Total	1	1	1	1	1	1	1	1	1	1

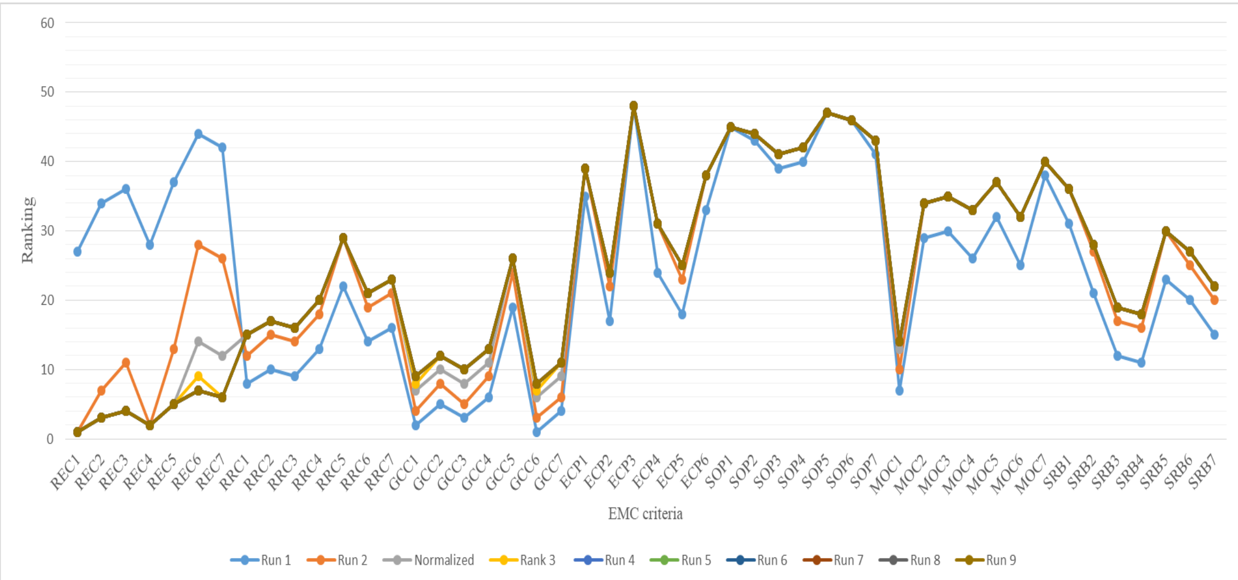

Figure 5.7 Represents the variation in the ranking of sub-criteria after each different runs.

Table 5.22 Ranking of alternatives in sensitivity runs when v varies from 0.1 to 0.9.

	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10
Partners	**Normalized Ranking**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
GRP1	5	5	5	5	5	5	5	5	5	5
GRP2	4	4	4	4	4	4	4	4	4	4
GRP3	2	3	2	2	2	2	2	2	2	2
GRP4	3	1	3	3	3	3	3	3	3	3
GRP5	1	2	1	1	1	1	1	1	1	1

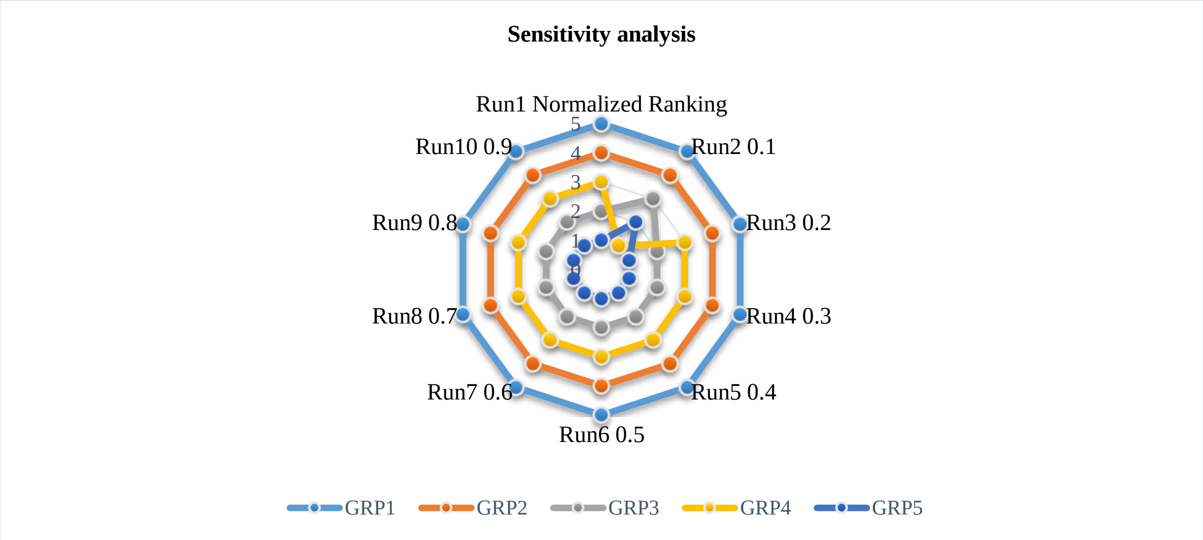

Figure 5.8 Results of sensitivity analysis.

5.7 Chapter Summary

This chapter dealt with ranking various enablers and also determining the cause-effect relationship among the enablers of sustainable WEEE management implementation. This section also provides a robust framework using hybrid methodology to the electronic manufacturing industries to effectively select their WEEE recycling partner selection based on green competencies. Thus the objectives two and three of the study are achieved. Next chapter deals with the selection of sustainable WEEE recycling plant location problem.

CHAPTER - VI

ANALYSIS OF WEEE RECYCLING PLANT LOCATION

6.1 Introduction

This chapter deals with the identification and finalization and selection criteria by considering social, economic, environmental, technical and political aspects. And then proposes a novel STEEP-BWM-VIKOR framework for the selection of best and sustainable location for WEEE recycling plant among the identified alternatives (candidate locations).

6.2 Proposed framework for selection of sustainable location for WEEE recycling plant using STEEP-BWM-VIKOR

Waste of electrical and electronic equipment (WEEE) recycling is gaining tremendous attention from the authorities and the whole society owing to the increasing rate of urbanization, advancement of electronic and electrical equipment (EEE) industries, and growth of population (Wath et al., 2010; Awasthi et al., 2016). The changing trend in the production and consumption behavior of electronic products among consumers has increased over the years, which has contributed to the sheer rise in volume of WEEE stream worldwide as well as increased the need of environmentally sound waste recycling and safe disposal (Kahraman et al., 2009; Kharat et al., 2016; Wu et al., 2018). Moreover, WEEE consists of various hazardous and toxic substances but also carrys some valuable resources like gold, platinum, copper, titanium, and other area earth metals, etc. (Chen et al., 2016). At the same time, the growth in informal WEEE recycling practices increases the rate of natural resource depletion, which leads to environmental degradation (Kumar and Dixit, 2018a, b). According to the report of 'Solving the E-waste Problem' (StEP, 2017), the world will generate further 33 % more WEEE from 49 million metric tons to 65 million metric tons per year. However, an alarming 95% of waste is managed by the informal sector for recovery activities and mere 5 % of India's total waste gets recycled because of poor infrastructure, weak policy instruments, and framework, which leads to environmental degradation and cause adverse effect on human lives (Awasthi and Li, 2017; Kumar and Dixit, 2018a).

From the above statistics, it is clearly observed that safe recycling and disposal of WEEE to be one of the requirement for sustainable development. Despite the negative environmental effects in many developing countries like India, the landfilling and backyard recycling plays a central role in waste disposal because it is less expensive and easier in practice (Menikpura et al., 2013; Bentaha et al., 2014; Bosompem et al., 2016). Hence, residents are more prone to complain about "Not In My Back Yard (NIMBY)". Further, the unplanned setting of recycling plant can arouse numerous concerns like slope and faults issues, emissions of greenhouse gases (GHGs), noise, odor, releaze of leachate, visual impact problems for adjacent residential areas, which can adversely affect sustainable development (Chang et al., 2008; Zheng et al., 2015; Wan et al., 2015; Wu et al., 2016; Kheybari et al., 2019). In view of this, the selection of the optimal plant location is a complex and strategic decision for any organization that requires a rigorous evaluation based on sustainability principle (Govindan et al., 2013).

To accomplish the above goals, this study proposed a three-phase novel STEEP-BWM-VIKOR approach as the research methodology (see Figure 6.1). The first phase identifies and finalizes, the criteria for the selection of WEEE recycling plant location through a rigorous literature review and discussion with experts in a Delphi study. The second phase employes BWM for prioritizing the five main criteria and 29 sub-criteria in a taxonomical way according to their importance based on experts rating. BWM utilizes lesser pairwise comparisons and subsequently uses a small sample of data in comparison to AHP, which is a widely accepted method for ranking and prioritizing criteria. Also, BWM provides more consistent results compared to the other MCDM technique (Rezaei, 2015). By integrating BWM with other MCDM tool, it is possible to get better results (Gupta and Barua, 2017, 2018). Hence, the third phase involves selecting the best location for WEEE recycling plant among the other alternatives by using the VIKOR ranking techniques. VIKOR is also recognized as an effective decision tool for evaluating the alternatives, especially in case the experts are incompetent to express their ratings in the decision-making process (Gupta and Barua, 2018). In addition, VIKOR is suitable in circumstances where the selection attributes are complex in nature and it can determine the weight stability intervals (Opricovic, 2011). Considering the management opinion, the novel STEEP-BWM- VIKOR methodology may help all the stakeholders in advance to manage and plan the eventualities in an operational, strategical, and flexible decision-making situation. Figure 6.1 presents each phase of the study.

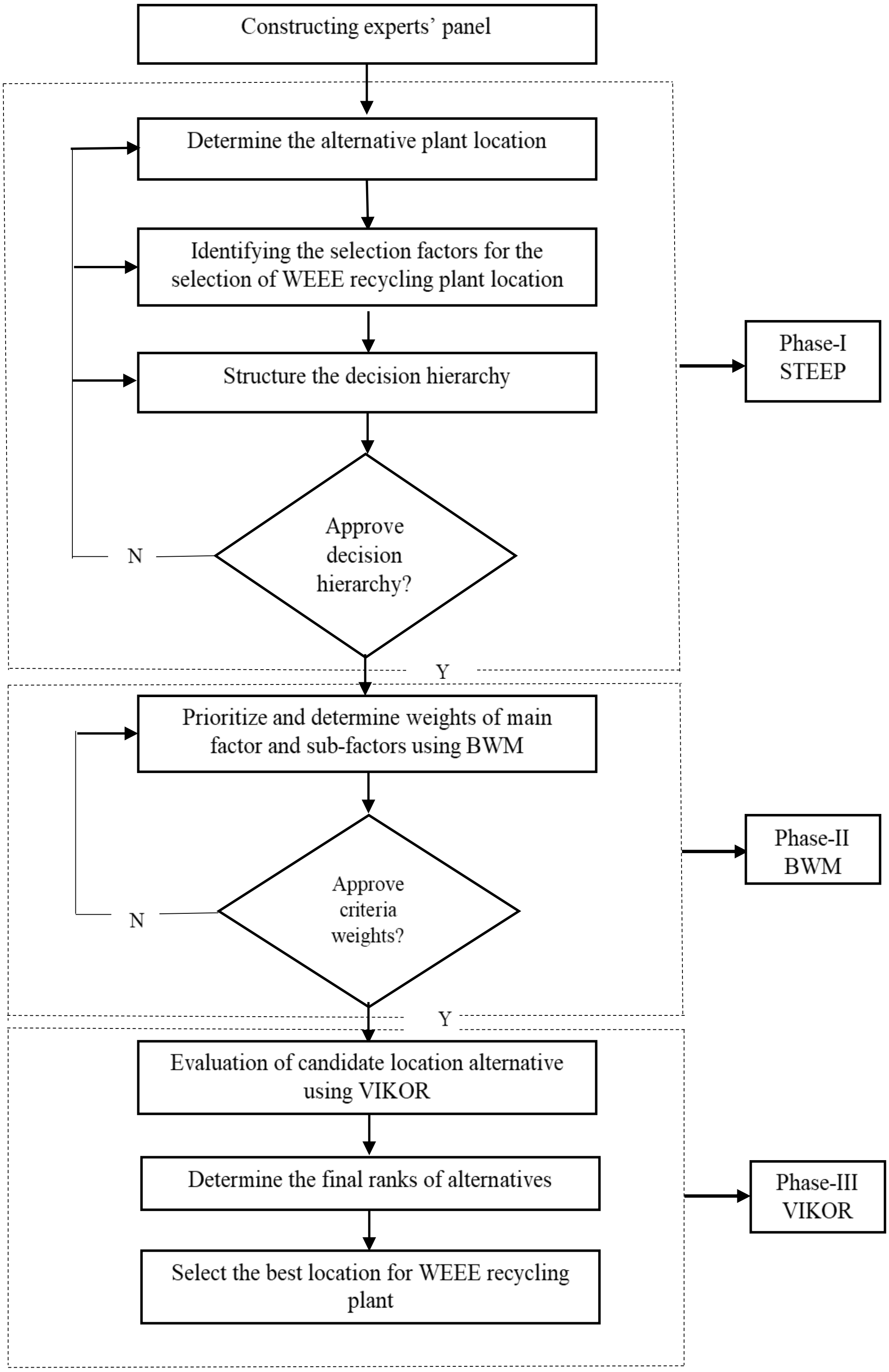

Figure 6.1 Represents the phases of the research methodology.

6.3 Criteria for selection of WEEE recycling plant site based on the STEEP framework

Although WEEE recycling is an efficient way to minimize the concern of resource scarcity and waste disposal in landfills, it has not been widely accepted in the Indian context. For the smooth functioning of WEEE management, it is very critical for policymakers and stakeholders to design a framework that helps in determining the optimal site for WEEE recycling and treatment plants that have least harmful effect on the environment and human lives; rather it improves the economic gain. However, the selection of WEEE treatment plant site is dependent upon various main criteria and sub-criteria. Based on the systematic literature review, the consultation with experts and assessment of the current scenario, a STEEP framework has been established covering different aspects like social criterion, technical criterion, environmental criterion, economic criterion, and policy criterion. In addition, five main criteria constitute of 29 sub-criteria, which are taken into consideration for the study (see Table 6.1).

6.3.1. Social criterion

Social criterion plays a vital role in the strategic construction and operation of WEEE recycling plant. Public opinion and acceptability is considered as one of the crucial factor for the establishment of recycling plant and future developments (Kahraman et al., 2009; Wang et al., 2009; Amer and Daim, 2011; Kharat et al., 2016; Wu et al., 2018; Kheybari et al., 2019). Initially, poor public acceptability will hamper the planning and execution of recycling plant. Therefore, the willingness of local residents is very critical in relation to the acceptance of the construction and operation of recycling plant (Wu et al., 2018). The collaboration with near locating enterprises and suppliers can reduce the operation cost effectively by taking care of mutual benefits (Deveci et al., 2015). Under this condition, the WEEE recycling plant can generate new job opportunities for local residents and subsequently improve the development of local economy (Wu et al., 2016, 2018). With respect to sustainable development, public health and safety should be taken into consideration by authorities to ensure long-term functioning of recycling plant (Tavares et al., 2011; Choudhary and Shankar, 2012; Kheybari et al., 2019).

6.3.2. Technical criterion

The well-equipped and reliable infrastructures include the availability of resources, skilled workforce, logistics facilities, accessible collection centers, proximity with electronic manufacturing cluster, etc., which are always considered as an important technical factor for recycling plant site selection (Azizi et al., 2014). For smooth operation and construction functions (such as logistics, transportation of waste, material transmission, etc.), there is need of close proximity to rail and road network, as it would increase the economic feasibility of the site (Wu et al., 2016; Karimi et al., 2018). Thus, it is an apparently desirable location to build a WEEE recycling plant near the waste collection centers. Under these circumstances, the increasing proximity to the existing electronic manufacturing clusters is beneficial for economic gains by sharing infrastructural facility to recycle their WEEE for resource recovery and reuse the rare earth material for new product design and development (Bosompem et al., 2016).

6.3.3. Environmental and natural criterion

Environmental criterion should be a prime vision and an integral part of decision making for the selection of WEEE recycling and disposal facilities while considering the issues related to the protection of natural resources and environment (Zavadskas et al., 2015; Liu et al., 2018). Compared to the conventional waste disposal activities such as landfill, the environmentally sound WEEE recycling treatment facilities can promote waste to energy (WTE), resource recovery, and reduce the domestic status of importing raw material and energy from the developed nations (Wu et al., 2018). Further, the optimal use of land has interdependency on the initial planning; hence, the future developments of the plant location ultimately minimize the impact of greenhouse gases (GHGs) emissions and other hazardous pollution (such as odors, noise pollution, optical pollution) on the close proximity areas with wildlife sanctuary, agriculture land, wetlands, etc. (Wang et al., 2009; Aragonés-Beltrán et al., 2010; Khadivi et al., 2012; Kharat et al., 2016). According to the national WEEE management law, the government has defined some set of parameters that consider recycling location must be at a distance of more than 1000 m from the rural and urban areas (Banar et al., 2010; Eskandari et al., 2012).

6.3.4. Economic criterion

The economic instrument plays a vital role in the initial planning of sustainable WEEE recycling plant site (Queiruga et al., 2008; Tavares et al., 2011; Kharat et al., 2016; Kheybari et al., 2019). The WEEE recycling site should have close proximity to road and rail network for minimizing the construction as well as logistics and transportation costs (Song et al., 2013; Banar et al., 2014;

Karimi et al., 2017). Close proximity to the collection point with higher waste availability and supply is considered the most economical feasible site owing to lower transportation cost (Bahrani et al., 2016). Land slope lope is one of the most important criteria in selecting an optimal site; the high slope is not economically suitable for the recycling plant. The location at a safe distance from faults line is preferred to avoid seismic activities for the facility development (Khadivi et al., 2012; Azizi et al., 2014). Besides, the average resource and energy acquisition cost of the existing WEEE recycling plant also needs to be determined for the estimation of return on investment (Wu et al., 2018).

6.3.5. Policy and legal criterion

The policy and legal factor plays an important role in the selection of WEEE recycling plant location (Wath et al., 2010; Wu et al., 2016). The majority of the revenue earned in a recycling plant relies on the financial support from the government because high risks, low income, and high environmental return are involved as compared to landfill disposal (Zeng et al., 2015). The government should provide tax subsidies and environmental grants to the investors for minimizing investment cost and expenses related to facilities (Song et al., 2013; Banar et al., 2014). It is reported that 30% of plant revenue can increase by higher feed-in tariff than normal coal-fired energy costs (Wu et al., 2018). The smooth functioning of waste recycling plant requires support of local authorities (Gupta and Barua, 2016; Kheybari et al., 2019). Moreover, WEEE recycling plant can also get waste disposal subsidy based on the amount of waste disposed from the local municipal authorities. Finally, the recycling plant should adhere to the WEEE management handling policies for assuring environmental sound WEEE recycling and disposal (Muhammad et al., 2015; Kumar and Dixit, 2018a, b).

Table 6.1 WEEE recycling plant location criteria based on STEEP framework.

Main criteria	Sub-criteria	Description	Supporting references
Social criteria (SOC)	Social acceptance (SOC1)	Public opinion and acceptability is very crucial for the establishment of recycling plant and future development.	Amer and Daim, 2011; Kharat et al., 2016; Wu et al., 2018; Kheybari et al., 2019
	Social network (SOC2)	Recycling plant must have formal and informal collaboration with near locating firms and suppliers to take care of mutual benefits.	Deveci et al., 2015; Shamimul Islam et al., 2019
	Create new job opportunities for locals and economic development (SOC3)	Recycling plant should generate employment for local residents and have policy to attract and retain local talents in order to achieve local economic development	Choudhary and Shankar, 2012; Wu et al., 2016, 2018
	Maintaining the living standard (SOC4)	Public health and safety should be on high consideration, especially people working in recycling plant are highly prone to disease and air pollution in atmosphere.	Kontos et al, 2005; Tavares et al., 2011; Choudhary and Shankar, 2012; Kheybari et al., 2019
	Impact on tourism (SOC5)	Location of recycling plant should have legal distance from the tourist places.	Feyzi et al., 2019
Technical criteria (TEC)	Proximity with electronic manufacturing cluster (TEC1)	More than one electronic manufacturing may use the recycling facility for resource recovery to minimize the infrastructure cost.	Bosompem et al., 2016; Kharat et al., 2016
	Availability of renewable resource (TEC2)	Availability of renewable resources (wind, water and solar energy, etc.) to recycle the WEEE.	Amer and Daim, 2011
	Availability of skilled workforce (TEC3)	Recycling plant requires expert and skilled human resource available in the region to install, operate and maintain the recycling equipment.	Amer and Daim, 2011; Xie et al., 2013
	Road and rail network accessibility (TEC4)	Accessibility to road, rail and waterways play an important role for smooth functions of transportation and logistics activities of recycling plant.	Azizi et al., 2014; Bosompem et al., 2016; Kharat et al., 2016; Karimi et al., 2018

	System reliability (TEC5)	Reliability refers to the ability of WEEE recycling system to perform their processing activities under standard condition for a specific period of time.	Experts input
Environmental/ Natural criteria (ENV)	Suitability of land use (ENV1)	More emphasis should be given to the existing and potential future developments of the plant location with respect to local and adjacent areas. For example, site with close proximity to the areas (such as wildlife sanctuary, agriculture, wetlands, etc.) should not be considered.	Chang et al., 2008; Kharat et al., 2016
	Hydro-geological condition of the location (ENV2)	The construction quality of recycling plant is highly depends on hydro-geological condition. Poor hydro-geological condition will pose stability and safety threats to the building structures.	Bosompem et al., 2016
	Distance from residential areas (ENV3)	According to national WEEE management and handling rules, recycling facilities must be at a distance (more than 1000m) from the residential areas.	Azizi et al., 2014; Bosompem et al., 2016
	Distance from surface and ground water resources (ENV4)	Recycling sites should be away from the water bodies in order to minimize the major concern of pollution and toxicities of water resource by leachates	Azizi et al., 2014; Bosompem et al., 2016; Kharat et al., 2016; Karimi et al., 2018; Kheybari et al., 2019
	Impact of emissions and pollution (ENV5)	Emissions and pollution released by recycling plant (such as greenhouse gases, air and noise pollution, small particles, etc.) should poses low impact on environment.	Ozgen et al., 2012; Wu et al., 2016; Kheybari et al., 2019
	Biodiversity conservation (ENV6)	To conserve the biodiversity and natural habitation (wildlife sanctuary) of the region, WEEE recycling sites should be constructed away to minimize the cause of disruption to them.	Experts input
Economic criteria (ECO)	Land acquisition cost for recycling plant site (ECO1)	Minimum cost of land is more preferable for development of recycling plant.	Queiruga et al., 2008; Khadivi et al., 2012; Banar et al., 2014; Kharat et al., 2016; Farahbakhsh and Forghani, 2019; Kheybari et al., 2019

	Energy and resources acquisition cost (ECO2)	Minimum cost incurred for the acquisition of energy and other resources used for the recycling operation.	Wu et al., 2018
	Proximity to landfill (ECO3)	WEEE contains some amount of non-treatable material that do not recycle, and have a necessity to dispose in the landfills.	Argones-Beltran et al., 2010; Khan et al., 2018; Feyzi et al., 2019
	Operation (Logistics and transportation cost) and maintenance cost of recycling plant (ECO4)	Operation and maintenance cost of recycling plant play a vital role for the site selection which directly determines the financial efficiency and payoff period.	Queiruga et al., 2008; Tavares et al., 2011; Korucu and Erdagi, 2012; Song et al., 2013; Kheybari et al., 2019
	Number of existing competitor (ECO5)	Lesser the number of competition is the better.	Bahrani et al., 2016; Wu et al., 2018
	Waste availability (ECO6)	Close proximity to the collection point with higher waste availability and supply is considered most economical feasible. Lesser the number of competition is the better.	Queiruga et al., 2008; Khadivi et al., 2012; Bahrani et al., 2016; Kharat et al., 2016; Khan et al., 2018; Wu et al., 2018
	Slope and faults criteria (ECO7)	Slope and faults criteria plays an important role in terms of economic consideration, lower the slope criteria require low cost of leveling whereas, and safe distance from the faults line are suitable for plant site.	Azizi et al., 2014; Bahrani et al., 2016; Bosompem et al., 2016
Policy and legal criteria (POL)	Waste disposal subsidy (POL1)	Majority of recycling plant revenue comes from waste disposal subsidy depends on how much waste disposed from the local authorities.	Song et al., 2013; Wu et al., 2018
	Support from local authorities (POL2)	Support from local bodies such as local municipal department plays vital role for smooth functioning of WEEE recycling plant operations.	Gupta and Barua, 2016; Kheybari et al., 2019
	Tariffs and tax preferences (POL3)	Tax credit and subsidies benefits policies can encourage the investors for the construction of WEEE recycling plant.	Wath et al., 2010; Song et al., 2013
	Financial support for low carbon and climate change (LCR) infrastructure (POL4)	Government and local authorities should support financially for the installation of low carbon and climate change infrastructure to maintain the ecological balance.	Experts input

	Compliance with RoHS directives and ISO certification (POL5)	Recycling plant must compliance with RoHS directives and should have certification like ISO 14000 series and ISO 8000 series for satisfying the audit process.	Muhammad et al., 2015; Kumar and Dixit, 2018a,b
	Ease of environmental grants and funds (POL6)	Plant must have an access to get environmental grants in order to minimize investment cost and facilities expenses.	Experts input

6.4 Problem description (study area)

According to the national WEEE management policy introduced by the government of India (GOI), all the electronics producer are now required to take extended responsibility for their obsolete electronics product and build their waste recycling and processing infrastructure to solve the worsening issue of WEEE management in the metropolitan cities (MoEF, 2016). Unfortunately, the guidelines offered by the national WEEE management policy are not fully implemented in practice. In this study, we selected Mumbai, which is known as financial capital of India and is located in the western coast of the country as a case study area for analyzing the feasibility aspects of the proposed framework. The total area of Mumbai is 603.4 km^2 and contains 24 wards with municipal boundaries. The Mumbai city has a tropical wet and dry climate with the annual average temperature is 27.2°C, whereas, the annual average rainfall is around 1,100 millimeters (mm). The reasons for choosing the study area are: Firstly, Mumbai is the most populated metropolitan city in India with a population of 21.3 million, which leads to high land demand with elevated prices. Secondly, Mumbai generates around 1.2 million metric tonnes of WEEE, which is growing at the rate of 30% every year. However, an alarming 95% of WEEE is collected, processed, and disposed by strong un-organized recycling network and merely 2.5% of WEEE is recycled by the organized recycling plant (Kumar and Dixit, 2018a, b). Moreover, the estimated and monitoring data of the varying quantity of WEEE generated and recycled has consistency issues. Therefore, the selection and usage of these un-organized recycling sites has given rise to many sustainability issues. To resolve the complexity of the problem, this study utilized the novel STEEP-BWM-VIKOR method for identifying the sustainable WEEE recycling plant location in Mumbai considering the socio-economic, political, legal, and environmental dimensions of the study area.

6.5 Application of proposed framework to study area

6.5.1 Data collection and analysis

In this study, a team of qualified experts was chosen from the academics as well as executive expert category with experience of more than 10 years in the domain of environmental planning and waste management. The team of five experts constituted of facility planner, environment consultant dealing in waste management solutions, executives from MPCB (Maharashtra pollution control board), and academicians. All the experts were capable of participating in the decision-making process because they have strong expertise in various organizational activities, i.e., facility planning, supply chain activities, environmental management activities, activities, etc. Panel consensus method is employed for the collection of data from each expert; a detailed information was given to the panel regarding the case and finalized main factor and sub-factor of STEEP consideration for the selection of sustainable WEEE recycling plant location. Subsequently, the experts were asked to assign an importance weight on the basis of prescribed scale (refer section 3) for constructing a pair-wise comparison of each main factor and sub-factor and also for ranking the four candidate locations (LOC1, LOC2, LOC3, and LOC4) that are considered as different alternatives based on weights obtained from BWM used in the study. Finally, the hierarchical structure of this decision problem is represented in Figure 6.2.

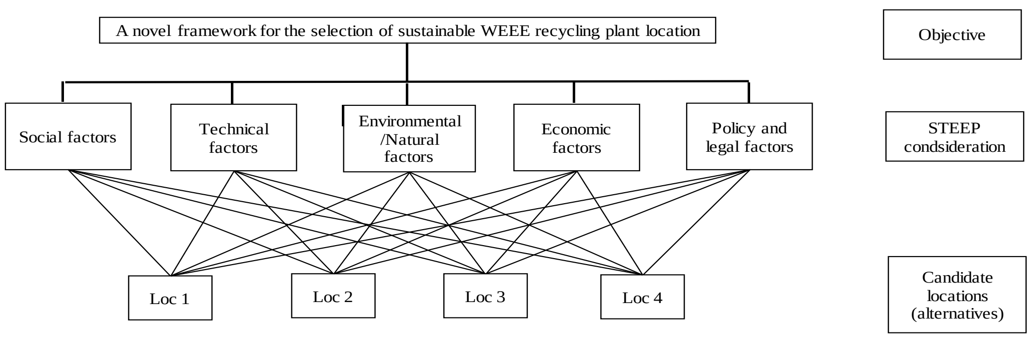

Figure 6.2 Represents the decision hierarchical structure of the problem

6.5.2 Calculation of weight of the main criteria and sub-factor using the BWM approach

After finalizing the five main criteria and 29 sub-criteria for the selection of optimal WEEE recycling plant location based on the STEEP consideration, the weights of the STEEP criteria were calculated using the novel BWM approach. Five experts were asked to identify the best and worst criteria from both the categories, i.e., main criteria as well as sub-criteria category on a scale of 1-9 used in this study. Finally, the best and worst factors identified by the different experts are presented in Table 6.2. After obtaining the best and worst criteria from individual experts, they were asked to give importance rating or weight of the best criterion to the other, and the other compared to the worst factor for the main category. The preference rating obtained by expert 1 for main criteria category is presented in Table 6.3.

Similarly, all the experts were asked to rate the best to others and others to the worst factor for the category under sub-criteria as well. The importance rating given by expert 1 for the category under sub-criteria are presented in Table 6.4-6.8.

The next step is to determine the weights of all the criteria and sub-criteria based on the STEEP framework by using equation (3.28) discussed in section 3.3.3.5. The aggregated weights for all the main factor and sub-criteria are determined by using equation (3.28) for ratings given by all the five experts and subsequently their aggregates are taken, which are presented in Table 6.9 and Table 6.10. Finally, the results obtained from BWM indicated high consistency index value among the pairwise comparison matrix. (Ksi*), which is equal to 0.0433, and so it is acceptable being less than 0.1.

Table 6.2. Best and worst main criteria and sub-criteria by each expert.

Main criteria and sub-criteria for WEEE recycling plant location	**Determined as Best by experts**	**Determined as Worst by experts**
Social criteria (SOC)		3,5
SOC1	1,2,3,5	
SOC2		
SOC3	4	
SOC4		2,5
SOC5		1,3,4
Technical criteria (TEC)		1,2,4
TEC1		2,4
TEC2	4,5	
TEC3		
TEC4	1,2,3	
TEC5		1,3,5
Environmental and Natural criteria (ENV)	1,2,3,5	
ENV1		
ENV2		1,2,3
ENV3	1,2,5	
ENV4		
ENV5		4,5
ENV6	3,4	
Economic criteria (ECO)		
ECO1	1,2,3,4	
ECO2		
ECO3		
ECO4		
ECO5		1,2,5
ECO6		3,4
ECO7	5	
Policy and legal criteria (POL)	4	
POL1		
POL2	1,2,3	
POL3		
POL4	4,5	
POL5		2,5
POL6		1,3,4

Table 6.3 Pair-wise comparison for main category factor by expert 1.

Best to Others	Social (SOC)	Technical (TEC)	Environmental/Natural (ENV)	Economic (ECO)	Policy and legal (POL)
Best main criteria Environmental/Natural (ENV)	4	9	1	3	2
Others to the Worst	**Technical (TEC)**				
SOC	5				
TEC	1				
ENV	9				
ECO	7				
POL	6				

Table 6.4 Pair-wise comparison for social criterion (SOC) by expert 1.

Best to Others	SOC1	SOC2	SOC3	SOC4	SOC5
Best sub-criteria SOC1	1	4	3	6	9
Others to the Worst	**SOC5**				
SOC1	9				
SOC2	3				
SOC3	5				
SOC4	2				
SOC5	1				

Table 6.5 Pair-wise comparison for technical criterion (TEC) by expert 1.

Best to Others	TEC1	TEC2	TEC3	TEC4	TEC5
Best sub-criteria TEC2	9	1	5	3	7
Others to the Worst	**TEC1**				
TEC1	1				
TEC2	9				
TEC3	2				
TEC4	6				
TEC5	2				

Table 6.6 Pair-wise comparison for environmental/natural criterion (ENV) by expert 1.

Best to Others	**ENV1**	**ENV2**	**ENV3**	**ENV4**	**ENV5**	**ENV6**
Best sub-criteria ENV3	7	9	1	2	5	3
Others to the Worst	**ENV2**					
ENV1	2					
ENV2	1					
ENV3	9					
ENV4	7					
ENV5	3					
ENV6	5					

Table 6.7 Pair-wise comparison for economic criterion (ECO) by expert 1.

Best to Others	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**	**ECO7**
Best sub-criteria ECO1	1	4	6	4	9	4	3
Others to the Worst	**ECO5**						
ECO1	9						
ECO2	5						
ECO3	3						
ECO4	3						
ECO5	1						
ECO6	5						
ECO7	6						

Table 6.8 Pair-wise comparison for policy and legal criterion (POL) by expert 1.

Best to Others	**POL1**	**POL2**	**POL3**	**POL4**	**POL5**	**POL6**
Best sub-criteria POL2	3	1	3	2	7	9
Others to the Worst	**POL6**					
POL1	5					
POL2	9					
POL3	6					
POL4	7					
POL5	2					
POL6	1					

Table 6.9 Aggregate weights of main factor for all experts.

Main Criteria	**Code**	**Weights**	**Ksi***
Social	SOC	0.115	0.0433
Technical	TEC	0.060	
Environmental/Natural	ENV	0.445	
Economic	ECO	0.142	
Policy and Legal	POL	0.238	

Table 6.10 Global weights and global ranking for all the criteria

Main criteria	**Local weights**	**Sub-criteria**	**Local weights**	**Global Weights**	**Global Ranking**
SOC	0.115	SOC1	0.440	0.051	7
		SOC2	0.143	0.017	17
		SOC3	0.272	0.031	11
		SOC4	0.074	0.009	25
		SOC5	0.070	0.008	26
TEC	0.060	TEC1	0.085	0.005	28
		TEC2	0.277	0.017	18
		TEC3	0.175	0.010	23
		TEC4	0.396	0.024	15
		TEC5	0.067	0.004	29
ENV	0.445	ENV1	0.106	0.047	8
		ENV2	0.056	0.025	14
		ENV3	0.350	0.156	1
		ENV4	0.143	0.063	4
		ENV5	0.067	0.030	13
		ENV6	0.278	0.124	2
ECO	0.142	ECO1	0.362	0.052	6
		ECO2	0.091	0.013	21
		ECO3	0.094	0.013	20
		ECO4	0.119	0.017	16
		ECO5	0.049	0.007	27
		ECO6	0.064	0.009	24
		ECO7	0.221	0.032	10
POL	0.238	POL1	0.153	0.036	9
		POL2	0.348	0.083	3
		POL3	0.126	0.030	12
		POL4	0.260	0.062	5
		POL5	0.059	0.014	19
		POL6	0.054	0.013	22

6.5.3 Ranking of location (alternatives) using the VIKOR method

In this section, the weights of all the criteria and sub-criteria of the selection criteria were obtained and it involved the ranking of these selected candidates recycling plant location (LOC1, LOC2, LOC3, and LOC4) with respect to weights of these criteria. The VIKOR methodology as discussed in section 3.3.3.4 was employed for ranking the alternative locations. All the experts were asked to give importance ratings for each plant location using the prescribed scale presented in Table 3.4. The ratings given by expert 1 for each selected location with respect to the evaluation criteria for selection are shown in Table 6.11. Similarly, all the experts were requested to rate the alternatives with respect to the evaluation criteria. The average rating of all the experts obtained using equation (3.22) is presented in Table 6.12. Using the equations (3.23) and (3.24), the best and worst values ($max\ f_b^*$ and $minf_b^-$) for all the selection criteria is determined and presented in Table 6.12.

Further, the values of S, R, and Q index were calculated using equations (3.25), (3.26), and (3.27) as shown in Table 6.13. Here the "S index" represents a positive ideal solution, "R index" depicts the negative ideal solution, and "Q index" suggests the optimal compromise solution. To decide about the best recycling plant location, the candidate location (alternatives) were ranked on the basis of Q index values, the alternative having the lowest Q index value was selected as the best alternative subjected to satisfying both the conditions as mentioned in step 6 of the section 3.3.3.4. Here the plant location (LOC3) holds the first position, as it has the lowest Q index value and also satisfied both the conditions, i.e., Q(LOC3) – Q(LOC2) ≥ 1/(5 – 1) and also Q(LOC3) obtained the top ranking according to both the R and S index values as presented in Table 6.14.

Table 6.11 Pair-wise comparison matrix for recycling plant location alternatives (Expert 1).

Alternatives	**SOC1**	**SOC2**	**SOC3**	**SOC4**	**SOC5**	**TEC1**	**TEC2**	**TEC3**	**TEC4**	**TEC5**	**ENV1**	**ENV2**	**ENV3**	**ENV4**	**ENV5**	**ENV6**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**	**ECO7**	**POL1**	**POL2**	**POL3**	**POL4**	**POL5**	**POL6**
LOC1	2	2	5	2	5	3	4	2	3	2	5	2	5	3	2	2	1	5	2	4	2	2	4	2	5	4	2	2	3
LOC2	4	4	1	2	3	1	4	2	5	4	1	4	3	1	2	4	4	2	3	5	5	2	3	3	3	4	4	3	5
LOC3	5	5	3	3	4	5	1	3	4	5	3	5	4	4	4	4	4	5	5	2	4	4	5	2	3	4	4	4	4
LOC4	2	2	1	1	4	2	5	2	5	3	1	2	4	1	1	3	4	1	3	1	1	3	2	3	1	1	3	5	1

Table 6.12 Aggregate rating of alternatives with best and worst values.

Alternatives	**SOC1**	**SOC2**	**SOC3**	**SOC4**	**SOC5**	**TEC1**	**TEC2**	**TEC3**	**TEC4**	**TEC5**	**ENV1**	**ENV2**	**ENV3**	**ENV4**	**ENV5**	**ENV6**	**ECO1**	**ECO2**	**ECO3**	**ECO4**	**ECO5**	**ECO6**	**ECO7**	**POL1**	**POL2**	**POL3**	**POL4**	**POL5**	**POL6**
LOC1	2.8	3	3.4	3.4	2.8	2.4	3.2	3.6	3.4	3.6	3.6	3.4	4.2	2.6	3.6	3.4	2.8	3.2	2.8	3	3	3	3.2	2.4	2.6	3.4	3	2.6	3.6
LOC2	3.6	1.6	2	2.4	2.8	3.2	3.8	2	4.2	1.6	3.4	1.8	3.2	2.8	2.8	2.6	3.4	4	2.4	4.8	3.2	4.2	3.2	4	2.2	3.2	2.6	2.6	2.6
LOC3	4.4	4	2.8	4	4	4	4.2	4.2	3.6	4.2	3.2	4.4	4.6	2.4	3.2	2.2	4	4.2	4.2	3.8	2.8	3.2	3.6	3	3.4	2.6	3.6	4.2	3.6
LOC4	2	2.4	3.2	1.4	4.4	3.6	3	2.4	2.2	3.4	1.4	2.2	2.6	2.6	1.6	3.8	2.6	1.4	2.6	3.6	3	1.6	2.8	3.8	3.4	2.2	3.2	2.8	1.6
Weights	0.440	0.143	0.272	0.074	0.070	0.085	0.277	0.175	0.396	0.067	0.106	0.056	0.350	0.143	0.067	0.278	0.362	0.091	0.094	0.119	0.049	0.064	0.221	0.153	0.348	0.126	0.260	0.059	0.054
Max f_i^*	4.4	4	3.4	4	4.4	4	4.2	4.2	4.2	4.2	3.6	4.4	4.6	2.8	3.6	3.8	4	4.2	4.2	4.8	3.2	4.2	3.6	4	3.4	3.4	3.6	4.2	3.6
Min f_j^-	2	1.6	2	1.4	2.8	2.4	3	2	2.2	1.6	1.4	1.8	2.6	2.4	1.6	2.2	2.6	1.4	2.4	3	2.8	1.6	2.8	2.4	2.2	2.2	2.6	2.6	1.6

Table 6.13 Calculated the values of S, R, and Q for alternatives

Alternatives	**S -index**		**R -index**		**Q-index**
LOC1	2.509		0.310		0.408
LOC2	2.681		0.348		0.561
LOC3	1.026		0.278		0.000
LOC4	3.428		0.440		1.000
	S*	1.026	R*	0.278	
	S-	3.428	R-	0.440	

Table 6.14 Final ranking of alternatives

Alternatives	**S**	**Ranking**	**R**	**Ranking**	**Q**	**Ranking**
LOC1	2.509	2	0.310	2	0.408	2
LOC2	2.681	3	0.348	3	0.561	3
LOC3	1.026	1	0.278	1	0.000	1
LOC4	3.428	4	0.440	4	1.000	4

6.5.4 Results and discussions

In comparison to other factors, it is difficult to determine the most vital selection factor, but evaluating them with the application of proposed novel framework makes the selection of recycling plant location more logical and helpful for the decision makers. The selection of WEEE recycling plant location is a complex decision for any electronic manufacturing company. To resolve the complexity of the decision problem, this study utilizes a novel STEEP-BWM-VIKOR framework, which has been identified as appropriate for carrying out further investigation
From Tables 6.9 and 6.10, the relative weights and priority ranking of selections criteria and sub-criteria are obtained through the application of BWM. Amongst the STEEP criteria, the environmental and natural criterion (ENV) got the top position with the highest weight (0.445) in the priority list. Further, the main factor constitutes of six sub-criteria, which are suitability of land use (ENV1), hydro-logical conditions of the location (ENV2), distance from the residential areas (ENV3), distance from the water bodies (ENV4), impact of emissions and pollutants (ENV5), and biodiversity conservation (ENV6). According to Table 6.10, the sub-criteria are prioritized with respect to their relative weights, i.e, ENV3 > ENV6 > ENV4 > ENV1 > ENV5 > ENV2. The distance from the residential areas (ENV3), biodiversity conservation (ENV6) and distance from the water bodies (ENV4) hold the top three ranks among the other sub-criteria. Out of these three sub-factors, the distance from the residential areas (ENV3) and biodiversity conservation (ENV6) are also given the first and second position in the global ranking (refer Table 6.10). The distance from the urban areas and natural habitat are very crucial while planning for the optimal location of WEEE recycling plant. According to the national WEEE management and handling rules, the recycling facilities must be at a distance (more than 1000m) from the residential areas (Azizi et al., 2014; Kharat et al., 2016; MoEF, 2016). A WEEE recycling plant significantly contributes to emission of greenhouse gases (GHG) and other pollutants in the nearby surrounding. Karimi et al. (2018) reported that environmental stability can be maintained by considering the permissible limit of surface and ground water resource while selecting the location for WEEE recycling facilities in order to minimize the impact of hazardous emissions and pollutant released from the recycling facilities into ecosystem.

The policy and legal criterion (POL) acquire second position among the other selection criteria considered for the location of WEEE recycling plant (refer Table 6.9). The location of recycling plants is prone to crisis and is mostly considered as financial and resources burden for the electronic manufacturing companies (Kumar and Dixit, 2018a). The policy and legal criterion (POL) are associated with six sub-criteria such as waste disposal subsidy (POL1), support from local authorities (POL2), tariffs and tax preferences (POL3), financial support for low carbon and climate change (LCR) infrastructure (POL4), proper compliance with RoHS directives and ISO certification (POL5), and ease of environmental grants and funds (POL6). All the sub-criteria are ranked in descending order, i.e., POL2 > POL4 > POL1 > POL3 > POL5 > POL6 (see Appendix C). The support from local authorities (POL2) and financial support for low carbon and climate change (LCR) infrastructure (POL4) are ranked as the first and second criteria among the other sub-criteria. Local municipal authorities should provide legal support to the recycling firm for land acquisition and financial benefits as tariffs and tax subsidies for installation of LCR infrastructure (POL4) because it can contribute toward sustainable development by stringently following carbon reduction policies, thereby improving the overall social and environmental performance (Wath et al., 2010; Song et al., 2013). In fact, the nature of the support between local municipal authority and recycling firms may be affected by the political legitimacy and other conduct toward recycling plant operations policies (Guan and Zhao, 2013; Gupta and Barua, 2016). The support from local authorities (POL2) is given the third position in the global ranking, and it is considered as one of the important criteria for selecting the WEEE recycling plant location. Moreover, proper compliance with RoHS directives and ISO certification (POL5) have forced recycling facility firms to integrate green or sustainable operational capabilities in their WEEE recycling and treatment processes for fulfilling their goals of environmental protection developments (Govindan et al., 2016; Kumar and Dixit, 2018a).

Economic criterion (ECO) is ranked the third among the other main criteria and is considered as one of the primary factor for the selection of sustainable WEEE recycling plant location (Table 6.9). The various sub-criteria are ranked in descending order, i.e, ECO1 > ECO7 > ECO4 > ECO3 > ECO2 > ECO6 > ECO5 (see Appendix C). The recycling plants are prone to financial and resources crisis. The plant site is mostly dependent on financial support from government in the form of low tariffs and tax subsidies for land acquisition (ECO1) and requires resources (such as energy, water, renewable resources, skilled labor) for its installation (Queiruga et al., 2008; Banar et al., 2014; Kharat et al., 2016; Farahbakhsh and Forghani, 2019). Slope has great impact on the selection of WEEE recycling facilities as the direction and angle of the slope helps in maximizing the constructional costs, for instance; land leveling cost, water drainage cost, etc. (Baharani et al., 2016). In addition, the location of WEEE recycling facilities should be far from the fault lines to avoid aggravation of any hazard along these faults lines (Wang et al., 2009; Gbanie et al., 2013; Azizi et al., 2014). Furthermore, the other main criteria, i.e., social criterion (SOC) is ranked fifth in the priority list followed by the technical criterion (TEC), which is considered vital for the selection of sustainable location for WEEE recycling plant and the global ranking of their sub-criteria are shown in Table 6.10.

Finally, the weight obtained from the BWM was used in the VIKOR analysis for ranking the alternatives. In this study, four alternatives of the WEEE recycling plant locations were finalized with the help of expert panel and a pair-wise evaluation matrix for each expert was established. According to the VIKOR analysis, the ranking of alternatives was determined based on the S, R, and Q index values. The alternatives were ranked on the basis of the lowest Q index value and represented in descending order. i.e., LOC3 > LOC2 > LOC1 > LOC4 (see Table 6.14). The best alternative is the one with the lowest Q index value. The results showed that LOC3 is the best location for the WEEE recycling plant site and LOC4 is the worst allocation as observed from the S, R and Q index values. By using a proposed integrated novel framework, policy makers can evaluate site location problem more logically and further integrate sustainability in the business.

6.5.5 Sensitivity analysis

Sensitivity analysis helps to check the robustness of the proposed framework as well as elimination of any possible human judgmental biases that may influence the results (Gupta and Barua, 2017; Mangla et al., 2015; Prakash and Barua, 2015). Sensitivity analysis can be performed in two ways, either by varying the weight given to the main criteria or by altering the weight given to a particular expert by varying the weight *v* from 0.1 to 0.9 and subsequently influencing the other main factor (Table 6.15). Owing to the variation in the main criteria weights, the change in the global ranking of sub-criteria is also observed and presented in figure 6.3. Similarly, the sensitivity analysis was performed for candidate locations alternatives. Therefore, to check consistency in decision making, we recommended testing the obtained ranks of location alternatives on different weights. The maximum group utility varied from v = 0.1 to v = 1.0. On analyzing, it can be identified that the ranks remained constant for all the values of v, which were LOC3 > LOC1> LOC2 >LOC4 as shown in Table 6.16 and also presented graphically in figure 6.4. Finally, it is concluded that the proposed framework for this study is quite robust in nature and the experts' judgment has not been influenced by variations given in the weights of different criteria.

Table 6.15 Variation in main criteria weights w.r.t. varying the SOC weight value from 0.1 to 0.9.

Main criteria	Normalized	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
SOC	0.115	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
TEC	0.060	0.061	0.054	0.047	0.040	0.034	0.027	0.020	0.013	0.007
ENV	0.445	0.453	0.402	0.352	0.302	0.251	0.201	0.151	0.101	0.050
ECO	0.142	0.145	0.129	0.113	0.097	0.081	0.064	0.048	0.032	0.016
POL	0.238	0.242	0.215	0.188	0.161	0.134	0.107	0.081	0.054	0.027
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

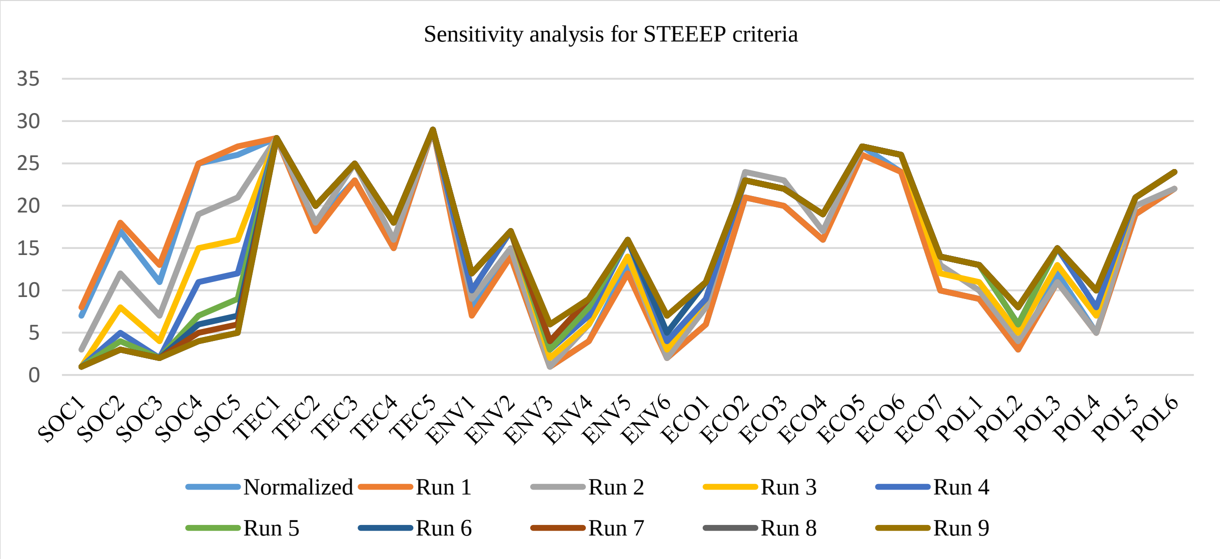

Figure 6.3 Represents the variations in the ranking of sub-criteria after 10 different runs.

Table 6.16 Ranking of alternatives in sensitivity runs when v varies from 0.1 to 0.9.

Alternatives	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
LOC1	2	2	2	2	2	2	2	2	2
LOC2	3	3	3	3	3	3	3	3	3
LOC3	1	1	1	1	1	1	1	1	1
LOC4	4	4	4	4	4	4	4	4	4

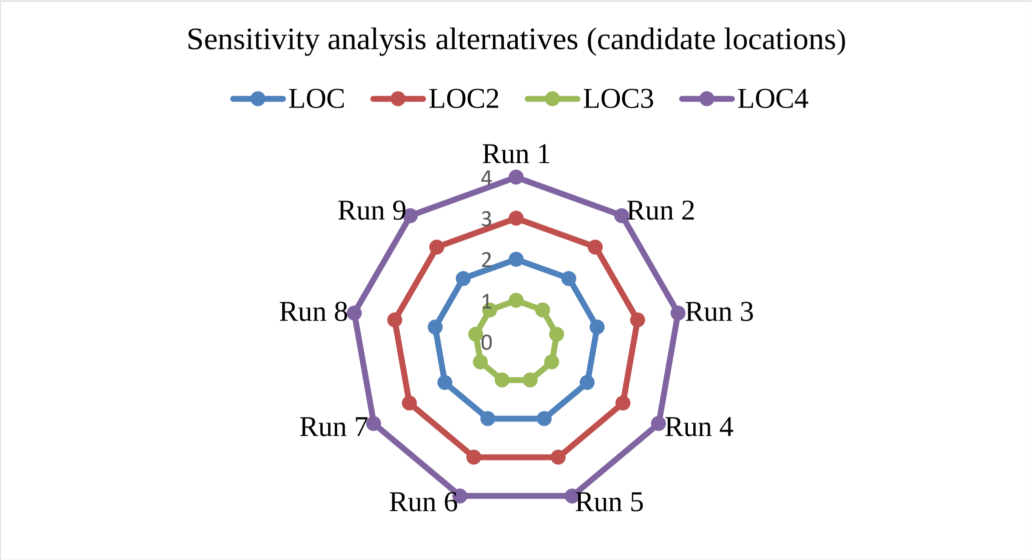

Figure 6.4 Results of sensitivity analysis.

6.6 Chapter Summary

This chapter has developed a comprehensive framework to identify the criteria for the selection of sustainable WEEE recycling plant location. The framework was developed with the help of systematic literature review and discussion with domain experts. A total of twenty-nine criteria were identified for the study and categorized these criteria into five main category such as social technical environmental, economic, and policy criteria for the selection of desired location for the WEEE recycling plant. Finally, objective fourth of my research work is accomplished by determining the best location for the WEEE recycling plant facilities based on STEEP consideration.

CHAPTER - VII

RESEARCH SUMMARY AND CONTRIBUTIONS, CONCLUSIONS, IMPLICATIONS, LIMITATIONS, AND FUTURE SCOPE

7.1 Preview

This chapter summarizes the work carried out in the research. The key findings and major outcomes of the results have also been discussed. The unique contributions, theoretical and practical implications of the study are also highlighted so that academicians and practitioners can utilize the implications of the present research work. Lastly, the limitations and future scope of the study have been presented.

7.2 Summary and Contributions

A brief summary and contributions made in this research work is given as follows:

Chapter I

This chapter presents the basic background and the need for the study. It highlights the importance of WEEE management. The basic definition of WEEE or e-waste and various types of WEEE categories. Discussion on composition of WEEE including hazardous and non-hazardous components along with their impact on surrounding. After that the need for environmentally sound WEEE management is discussed. In the last section, the complete organization of the thesis is provided.

Chapter II

This chapter provided an in-depth systematic review of literature on WEEE management. It presented the method and steps of literature review. An extensive review of literature on enablers and barriers to WEEE management in Indian context is also presented in this chapter. The recommendations to mitigate these barriers are also discussed in this chapter. After that an extensive review of recycling partner selection and optimal plant site selection methodologies was done. Through extensive review of literature, various gaps have been identified. The identification of these gaps have led to formulation of research objectives for this thesis and a total of four research objectives were formulated based on the literature review and identified gaps.

Chapter III

This chapter presents the research approach followed for the accomplishment of the research objectives. Various types of approaches viz. Qualitative and Quantitative method were discussed briefly in this chapter. Four phases of research viz. clarifying the context, understanding and assessing the current situation, developing a model for evaluating the causal relationship among the barriers and WEEE recycling partner selection involved detailed discussion about various steps of MCDM techniques namely – DEMATEL, Fuzzy AHP, VIKOR, Best Worst Method, and Grey DEMATEL and developing a framework for selection of sustainable location for WEEE recycling plant. Details about each of these methodologies were also discussed in this chapter.

Chapter IV

This chapter has developed a comprehensive framework to identify barriers of WEEE management adoption in Indian context. The framework was developed with the help of literature review and help from eighteen expert in the domain waste management. In this chapter, an illustrative circumstance of the implementation of WEEE management in India has been studied by using the proposed methodology, where in forty-four barriers have been identified and categorized into seven main criteria of barriers related to the adoption of WEEE management initiatives as per the relevant literature and experts inputs. And then, these barriers are supported by various socio-economic theories such as TCE, RBT, TPB, INT, SNT and ST. The research findings reveal that the policy and regulatory (PR) and technological barrier (T) barriers possess the highest importance, which implies that WEEE management initiative requires attention from the regulatory bodies. Out of forty four barriers, the results exhibit that top two barriers from each category are considered to be most critical barriers in adoption of WEEE management such as delay in EPR approaches (PR1), violation Basel Ban amendment (PR7), lack of skilled workforce (T1), lack of green recycling practices for handling WEEE issues (T1),), low recycling penetration and supply of domestic WEEE (SE7), competition between formal and informal recycling sector (SE1), lack of financial support from government for WEEE recycling start-ups (F4), lack of funds for initial capital investment for recycling plants (F3), lack of infrastructural facilities such as storage, transportation and treatment technology (I1), lack of coordination or collaboration between partners (I3), limited public awareness towards WEEE recycling (K2), less awareness about the advanced recycling fee (K5), low public environmental consciousness (SC1) and need for change in the mindset and to develop a habit for recycling WEEE (SC6). Further, the main barriers PR, I, SE, and SC come under cause group, while K, T, and F come under the effect group. The main barriers PR, I, SE, and SC have a tendency to drive the overall system performance. Thus, the researchers and practitioners should focus on the cause group for improving the overall performance of the WEEE management practices.

Chapter V

Due to enforced legislation and increased awareness of environmental protection, the organizations are more willing towards adopting green and sustainable practices in their entire supply chain activities which provide a competitive advantage over the long term. The government forced producers to take extended responsibility for their end of life electronics product and manage the huge stream of waste generated with respect to continuous changing trend and consumer taste for electronics product. In view of this, selection of desirable WEEE recycling partner is very crucial and complicated decision for managers. For large industries, the desirable recycling partner is the one who can recycle and recover the valuable assets from the WEEE in an environmentally sound manner and reduce the negative impact on the external environment as well as move towards the goal of green enabled supply chain. Hence, in this chapter three-phase methodology that has been used to select desirable recycling partner on the basis of green competencies (GC). The proposed novel hybrid methodology is well suited with illustrated case and shows potential advantage in the partner selection process. First phase involved identification of criteria from the extensive literature review and expert opinion was used for finalization of selection criteria of GC. A total of seven main criteria and forty-eight sub criteria of GOC were taken for the study. In the second phase, fuzzy AHP was used to construct a pairwise comparison and evaluates the relative weights of the main criteria as well as the sub-criteria of GC. Resource and environmental management (REC) ranked first in the main category followed by Green core competencies (GCC) ranked second and Regulatory obligations and risk compliance (RRC) ranked third in the analysis. In third phase of the study, VIKOR has been used for selecting the desirable recycling partner among the various alternatives. The ranking of the alternatives was done by employing the weight of GC criteria obtained from the fuzzy AHP as input for VIKOR analysis.

Final selection of recycling partner has been done on the basis of S, R and Q index values. Alternative who obtained lowest the Q index value was ranked first among the others. Study shows that GRP5 emerged as best recycling partner among all the five alternatives on the basis of selection criteria. This chapter also dealt with more sub objective i.e. to find the relationship among enablers of sustainable WEEE management implementation, grey DEMATEL methodology was applied to establish the causal relationship among the enablers of sustainable WEEE management. A case study of a company was taken and a total of twenty one enablers were selected for the analysis. The cause and effect relationship among these enablers was established using grey DEMATEL methodology. Finally, sensitivity analysis was also conducted to check the robustness of the proposed novel framework and found no serious bias on the influence of ratings given by the experts.

Chapter VI

This chapter has developed a novel integrated framework for the election of optimal location of WEEE recycling plant which helps to maximize the recycle and recovery rate of the valuable assets from the WEEE and minimizing the hazardous impact into the environment caused by landfill disposal option. This chapter proposed a novel STEEP-BWM-VIKOR framework that has been used to prioritize the selection attributes by considering social, technical, environmental, economic and policy aspects and then select the desirable location in accordance with sustainable environmental performances and efficiency in recycling as well as recovery services. The proposed framework is well suited with illustrated case study and presents valuable outcomes in the facility location problem. The present study makes the first attempt to offer a comprehensive framework covering all the sustainability aspects for the selection of WEEE recycling plant location. Based on the literature and experts opinions, a total of twenty-nine criteria were taken for the study based on STEEP consideration that provides additional knowledge to the existing body of literature. Moreover, proposed framework provides valuable insights into the stakeholders' decision-making process related to select and eliminate existing recycling facilities by enhancing environmental competencies to achieve sustainable and economic gain. According to the analysis, environmental and natural criteria (ENV) ranked top priority in the main category followed by policy and legal criteria (POL) and economic criteria (ECO) ranked second and third in the Best-worst analysis. All the three main criteria refers to as sustainability issues with regards to plant location. Moreover, the policy and legal support play a vital role in land acquisition for siting of recycling facility and also provide financial benefits in terms of tariffs and tax subsidies for the installation of low carbon climate change infrastructure which can contribute more towards the sustainable development by stringently follow carbon reduction policies and thus improve the overall social and environmental performance To enhance the environmental performances, Indian electronics industry need to establish a well-designed recycling and collection infrastructure to resolve the complexities in product return and recycling for their extended reuse . Besides these key criteria, the other criteria cannot be ignored, as those criteria help in achieving the goal of green innovation and competitiveness in the organizations. Next, VIKOR method has been used for selecting the optimal location for WEEE recycling plant among the various alternatives (i.e. LOC1, LOC2, LOC3 and LOC4). The ranking of the alternatives was done on the basis of S, R and Q index values. Findings showed that LOC3 obtained lowest the Q index value was ranked first among the other alternatives. A sensitivity analysis was also conducted to check the robustness of the proposed novel framework and found no serious bias on the influence of ratings given by the experts. Further, to validate and check the robustness of the obtained results, sensitivity analysis has been carried out and hence reported no variation in the results.

7.3 Implications of the study

The outcomes of the current research work has certain practical as well as theoretical implications for the WEEE management literature. The main aim of this research is to develop a sustainable framework for WEEE management implementation in Indian context. The other objectives included identification of barriers as well as enablers of WEEE management implementation and also, determining the cause-effect relationship among them and developing a hybrid framework for WEEE recycling partner selection for large electronic manufacturing organizations based on green competencies. Next, developing a novel hybrid framework for the selection of WEEE recycling plant location on the basis of STEEP criteria. In accumulation, this study may help researchers and practitioners to understand the advantages in adopting flexible WEEE management practices, where the world deals with enforced legislation, poor infrastructure, take-back channel of the end of life products, resource scarcity, and environmental issues. The key research implications of this study are categorized as follows:

Theoretical implications: India, an emerging economy, is experiencing economic growth which is raising the living standards but the consequent increase in WEEE waste volumes is way more than the country's waste-management systems can handle. However, WEEE management practices have not yet been implemented effectively due to the presence of barriers. Therefore, we identified the crucial role of barriers in implementing WEEE management, and their importance has been established with the help of DEMATEL methodology. In addition, this study is based on the underpinning of a multiple theories which provides a theoretical lens for describing the effect of the barriers towards the implementation of WEEE management. To the best of our knowledge, we believe that the consideration of multiple theories such as TCE, RBT, TPB, INT, SNT and ST provides a number of additional insights into stakeholders' decision making process to develop a sustainable strategies by enhancing their environmental and organizational capabilities to gain competitive advantage. From the empirical analysis, policy and regulatory barrier (PR), technological barrier (T) and socio-economic barrier (SE) are highly prioritized barrier criteria among other barrier criteria. In addition, PR and SE barrier criteria belong to the cause group as well. These particular criteria are referred to as governance issues. Besides, proper management of WEEE can be attained by strategically rectifying the cause group barriers.Acknowledge the various criteria and sub-criteria of green competencies (GC) for recycling partner selection among recycling network. This study presents seven main and forty-eight GC criteria for evaluating the recycling partner from the electronics industries viewpoint. To the best of our knowledge, the present study is a first attempt that has considered various dimensions of green competencies (GC) for electronics manufacturing industries. Based on extensive literature and rigorous discussions with experts group seven main criteria related to GC viz. Resource and environmental capabilities (REC), Regulatory obligations and risk compliance (RRC), Green core competencies (GCC), Opportunism (OPP), Service and operational performance (SOP), Management and organizational competencies (MOC) and Social responsibility benefits (SRB) have been recognized. Due to Poor landfill siting, a significant percent of the collected waste finds its way into the ecosystem. This has negative impacts on the environment, public health and economy.These negative externalities along with global pressure of meeting the sustainability targets, necessitates larger number of sustainability driven WEEE recycling plants in the country. A WEEE recycling plant can reduce landfilling and increase resource recovery for a sustainable growth of the firm as well as the economy as a whole. However, if plant location is not sustainable, all the benefits of resource recovery by the plant will get offset by the pathway the plant got the WEEE waste to recycle and recover in the first place. So far, sustainability is being discussed through domain specific measures like carbon emission reduction, water waste reductions etc. But, though all of these measures are admirable, they are not all equal in their sustainability impact. The actual sustainability impact depends on the location and the resource efficiency. At present there are no universal sustainability measures for recycling plant location. The study is the first to offer a comprehensive framework covering all the sustainability aspects related to the selection of a sustainability driven WEEE recycling plant location. Based on the literature and expert opinions, 29 criteria were taken for the study considering STEEP, which extends the knowledge in the existing body of literature. To account for the vagaries of location, this paper attempts to create measures for selecting an optimum location for a WEEE recycling plant for its sustainable environmental performance. The study employs a novel hybrid MCDM framework to prioritize the selection attributes related to social, technical, environmental, economical, and policy aspects. The framework has been designed by overcoming the limitations of the existing MCDM approaches and has so far not been used in the existing literature. The study is the first to offer a comprehensive framework covering all the sustainability aspects related to the selection of a sustainability driven WEEE recycling and management which extends the knowledge in the existing body of literature.

Managerial implications: Due to enforced environmental policies, electronics manufacturers need to invest in green competencies in order to sustain in the competitive business on the basis of environmental performance. To achieve the sustainability in the business, managers of case company need to understand and aware of various criteria and sub-criteria related to green competencies (GC) which can help to accomplish the goal of improving economic as well as the environmental performance of the company. The integrated framework provides fruitful insights for managers and practitioners by identifying the critical criteria of green competencies and hence focus on these criteria to improve the green image in the global market. Furthermore, the proposed framework will help managers of case company to select and evaluate the recycling partner on the basis of green competencies among the various alternatives taken for the study. The research model may provide some fruitful insights and help waste management professional in designing flexible, long run, and short run decision strategies for implementing WEEE management practices in an environmental friendly way. The sustainable outcomes of recycling plant are as much a function of its location as it is of the way the plant capacities are built. An unplanned setting of recycling plant can result in several issues like slope and faults issues, pollution, health hazards, noise etc. which, can have adverse impact on sustainable growth objectives laid by the firm. Therefore, before building a recycling plant, comparison of different plant locations based on sustainability criteria is highly recommended (Govindan et al., 2013). However, sustainable location decisions in absence of sufficient guidance is a complex strategic decision for electronic goods manufacturers. For actually creating the desired sustainable impacts of a WEEE recycling plant, it is important to factually understand and accurately estimate the location impacts of such plants before decisions on investments into the same. The proposed framework is well suited with illustrated case study and presents valuable outcomes in the facility location problem. The present study makes the first attempt to offer a comprehensive framework covering all the sustainability aspects for the selection of WEEE recycling plant location. Moreover, proposed framework provides valuable insights into the stakeholders' decision-making process related to select and eliminate existing recycling facilities by enhancing environmental competencies to achieve sustainable and economic gain. Further, the present study employed a novel integrated framework, which provides many implications for academia, managers, and stakeholders having knowledge about critical criteria that helps in selecting the optimal location for WEEE recycling plant. Additionally, this novel framework provides a fruitful insight to managers of Indian electronics industry to foresee future developments with regard to global environmental and climate change issues and to take proactive measure while designing policies and strategies for the WEEE management and handling activities. Finally, the results outcome of the novel framework conducted in this study is determined by experts and found that the results are quite reliable and provide fruitful insights in the decision-making process.

Policy implications: Emerging country context warrants focused and deeper studies on specific aspects of solid waste management which, is a mounting environmental and economic problem in these countries. This study provides focused inputs on the locational aspect of the sustainable waste management practice in India. Right Policy approach, has the potential to transform waste streams into sustainable income streams for the electronic goods manufacturers. In the WEEE processing, policy push can create economic incentives for firms to shift backyard recycling which, is harmful to both workers and environment, to locations with strong environmental controls. This will increase the recovery rate and sustainability of these recycling plants along with helping the country in achieving its broader sustainability goals. From the empirical analysis, policy and regulatory barrier (PR), technological barrier (T) and socio-economic barrier (SE) are highly prioritized barrier criteria among other barrier criteria. In addition, PR and SE barrier criteria belong to the cause group as well. These particular criteria are referred to as governance issues. Besides, proper management of WEEE can be attained by strategically rectifying the cause group barriers. The government as well as other stakeholders work upon these barriers and come up with robust policies and framework to deal with the WEEE management issues from its roots. These implications are straightforward because the policies and regulations have pressurized the electronic industries for enactment of the EPR law after the end of the product life cycle. The study finding that policy and legal criterion is one of the most important issues in selecting a sustainable recycling plant location is robust and has direct implication for policy making. Newer policy support mechanisms can be developed and the existing ones expanded to incentivize the consideration of the tested sustainability issues, by the electronics manufacturers in their decision for recycling plant locations. Policy makers can introduce disclosure and reporting regulations for electronics industry, based on the sustainability parameters established in this study. The tested framework can also be used by the regulators for creating evaluation guidelines and benchmarks for: 1) new site locations and 2) measuring and reporting the social and environmental performance and impacts of the WEEE recycling plants by the electronic manufacturers.

7.4 Limitations of the Study

The major limitations and future scope of the study are as follows:

- The work has been limited to Delhi, Maharashtra, Bangalore and Hyderabad. Most of the results are dependent on the experts' judgment and opinions and results might change if the experts are changed.
- In this research no mathematical modelling and statistical validation has been done to calculate the contribution of various main criteria of sustainable WEEE management in overall implementation/adoption process.
- In this study, case study based approach has been used for all the analysis. Hence, results cannot be generalized.
- This study has utilized a DEMATEL approach for establishing the cause-effect relationship among the barriers of WEEE management adoption. The study identified seven main category barriers, forty-four sub category barriers to the adoption of WEEE management. These numbers

are for certain selected case companies. There might be other barriers and solutions that are left and are not discussed in this study.

- This study has utilized a hybrid of Fuzzy AHP and VIKOR for identification and ranking of enablers of green competencies for the WEEE recycling partner selection among the alternatives. The study identified seven main category enablers and forty seven sub category enablers. These numbers are for certain selected case companies. There might be other green competencies enablers that are left and are not discussed in this study.

- This study has utilized a novel STEEP-BWM-VIKOR framework for the identification and ranking the main criteria and sub-criteria for the selection of sustainable WEEE recycling plant location among the other candidate locations. The study identified five main criteria and twenty-nine sub-criteria as a selection criteria. These number are for certain selected study area (Mumbai). There might be other criteria that are left and are not discussed in this study.

7.5 Scope for Future Work

While carrying out the present study, a number of areas have come to focus, where detailed research can be taken up. These areas demand more exploration and analysis through further research. The scope for future work has been presented as follows:

- All the electronic manufacturing organizations taken in this study were from India, future work may involve organizations from both developed and developing countries, so that a comparative study can be done for both the countries.

- The present study involved few experts for each objective, future studies can be conducted by taking a larger data set of experts so that more robust results can be obtained.

- The study involved the use of MCDM techniques for quantitative analysis and no statistical technique is used for the analysis. Future studies can involve use of statistical techniques like SEM to find out the relationship among different variables of WEEE management.

- This study can be further carried out to compare the results using different MCDM techniques like ANP, SWARA, MAUT, ELECTRE either in integrated or individual form for recycling partner selection and prioritizing the barriers to WEEE management implementation.

- The results of grey DEMATEL analysis can be compared with ISM-MICMAC analysis which is mostly used to establish the hierarchal relationship among variables.
- Future studies will develop a qualitative model integrating sustainable practices in the WEEE management implementation program.
- Future studies will carried out optimization modelling for waste transportation network by using MILP, MOLP, GP, etc.

7.6 Concluding Remarks

This study presents a summary of the research work carried out in this study. A summary of each phase of the study is presented in this chapter. WEEE management is considered by electronic industries as an underrated part of supply chain management due to the numerous reasons such as lack of regulatory pressure, lack of awareness regarding assets recovery from the used product, lack of integrated supply chain design towards WEEE management. However, the mismanagement in handling WEEE can create tremendous negative impact on the ecological and economic performances of organizations. They need to develop sustainable WEEE management infrastructure and technical know-how to handle this pressure from government and competitors. Lack of policies related to extended producer responsibilities has emerged as the most important barrier to WEEE management adoption in Indian context. The formalization of unorganized recycling units and the need to bring an advanced recycling Fee (ARF) from consumers recognized as an effective strategy that helps to increase the supply of waste for recycling. For sustainable WEEE management, electronics industry need to integrate recycling partner based on green competencies who can recycle and recover the valuable assets from the WEEE in an environmentally sound manner and reduce the negative impact on the external environment as well as move towards the goal of green enabled supply chain. The importance of 'achieving and sustaining competitiveness in the long run' and 'investing self-efforts and resources' needs to be realized by the industry. This will play a crucial role in their long term development in future.

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- Kumar, A., & Dixit, G. (2017) "Recycling partner selection on the basis green competencies using hybrid MCDM approach", presented at *International conference on Research and Business Sustainability* held on 16-17 Dec, 2017 at Greater Noida Campus-IIT Roorkee.

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APPENDIX A

Fuzzy AHP Analysis used in Chapter V

List of enablers for sustainable WEEE management implementation

Enablers	**Code**	**References**
Advanced recycling Fee	EN1	Nixon and Saphores, 2007; Nnorom and Osibanjo, 2008; Wath et al., 2010; Hong et al., 2014; Zhou et al., 2017; Cheng and Chang, 2018
Tax policies and subsidies benefits	EN2	Nnorom and Osibanjo, 2008; Mudgal et al., 2009; Shaik and Abdul Kader, 2012; Zhu et al., 2012; Abdulrahman et al., 2014; Gupta and Barua, 2017
Financial institution offers loan to promote green practices	EN3	Hilson and Nayee, 2002; Azapagic, 2004; Mathiyazhagan et al., 2013; Govindan et al., 2016; Gupta and Barua, 2017
Capacity Change	EN4	
Flexibility in operational capabilities	EN5	Büyüközkan and Çifçi, 2012; Chen et al., 2006
Material and energy recovery	EN6	Franke et al., 2006; Seuring and Muller, 2008; Zhu et al., 2008; Zailani et al., 2010; Akdogan and Coskun, 2012; Wang et al., 2012; Arena and Di Gregorio, 2014; Lee et al., 2014; Brunner and Rechberger, 2015; Yuan Pan et al., 2015; Arikan et al., 2017; Coban et al., 2018
Environmental auditing of recycling partners to ensure standards	EN7	

Job creation for the local community	EN8	Expert input
Community awareness and involvement	EN9	Sharp, 2006; Brandenburg et al., 2014; Govindan et al., 2012; Abba et al., 2013; Kwatra et al., 2013; Sarath et al., 2015; Borthakur and Govind, 2016; Kumar and Dixit, 2018a,b
Collaboration with green partners	EN10	Vachon and Klassen, 2008; Ravi and Shankar, 2017; Roehrich et al., 2017
Health and safety measures	EN11	An et al., 2015
Green training programs	EN12	Awasthi et al., 2010; Zhu and Geng, 2011; Agamthu et al., 2011; Campos, 2014; An et al., 2015
Clean development mechanism (CDM)	EN13	Wilson, 2007; Singh and Debnath, 2012; Grant and Marshburn, 2014
Avoid community landfills disposal	EN14	Babu et al., 2007; Arena and Di Gregorio, 2014; Wibowo and Deng, 2015
Green image of the firm	EN15	Grisi et al., 2010; Wen and Chi, 2010; Yang et al., 2011; Yeh and Chuang, 2011
Reduction of hazardous and toxic substances in environment	EN16	Yang et al., 2011; Grant and Marshburn, 2014
Environmental management systems (EMS)	EN17	Gonzalez et al., 2008; Hsu and Hu, 2008; Manomaivibool, 2009; Diabat and Govindan, 2011; Xu et al., 2013; Chen et al., 2015; Cholewa et al., 2016; Shaharudin et al., 2017
Use of cleaner technologies for waste recycling	EN18	Chi et al., 20111; Kim et al., 2011; Jadhao et al., 2016; Zhang and Xu, 2016
R &D capabilities to improve WEEE management system	EN19	Lucas, 2010; Zailani et al., 2012; Gupta and Barua, 2016, 2017

Green packaging	EN20	Lee et al., 2009; Gupta and Barua, 2017; Somsuk and Laosirihongthong, 2016; Gupta and Barua, 2017; Kumar and Dixit, 2018
Green logistics and infrastructral facilities	EN21	Zhu et al., 2010; Liu et al., 2011; Min and Kim, 2012; Kannan et al., 2014; Jabbour et al., 2015; Rostamzadeh et al., 2015; Coban et al., 2018
Green information system (GIS)	EN22	Debrito, 2002; Zhu and sarkis, 2006; Bani et al., 2009; Hsu and Hu, 2009; Govindan and Diabat, 2011; Shah khan et al., 2015; Fang et al., 2016
Resources Consumption and utilization	EN23	Salvado et al., 2015; Govindan et al., 2013; Bai and Sarkis, 2010; Qinghua et al., 2010
Defined role of the government	EN24	Wath et al., 2010; Chung and Zhang, 2011; Rotter et al., 2011; Luthra et al., 2014; Garlapari, 2016; Kumar and Dixit, 2018a
Environmental regulations and WEEE policies	EN25	Lau and Wang, 2009; Wath et al., 2010; Diabat and Govindan, 2011; Ho et al., 2012; Garlapti, 2016; Govindan et al., 2016; Kumar and Dixit, 2018a,b
Joining informal sector with formal sector	EN26	Widmer et al., 2005; Tsoulfas and Pappis, 2006; Wilson, 2007; Yu et al., 2010; Chi et al., 2011; Velis et al., 2012; Chi et al., 2014; Wilson et al., 2015; Wu and Chang, 2015; Garlapati, 2016
Extended producers reponsibility (EPR)	EN27	Lindhqvist, 2000; Widmer, 2005;Manomaivibool, 2009; Wath et al., 2010; Kiddee et al., 2013; OECD, 2015; Garlapati, 2016; Zhou et al., 2017
Monitoring of illegal import and dumping	EN28	Anyango Tocho and Mwololo Waema, 2013; Shah Khan et al., 2014
Reduction in greenhouse gases emission	EN29	Shaw et al., 2012

Political stability	EN30	Chan et al., 2008; Sridhar et al., 2010
Geographical proximity	EN31	Bottani et al., 2005; Büyüközkana et al., 2006; Chan et al., 2008; Sridhar et al., 2010
Life cycle assessment (LCA)	EN32	Kim et al., 2004; Lu et al., 2006; Nakamura and Kondo, 2006; Ahluwalia and Nema, 2007
Material Flow analysis (MFA)	EN33	Yoshida et al., 2009;

Pair-wise comparison of resource and environmental management capabilities (REC).

Sub criteria	REC1			REC2			REC3			REC4			REC5			REC6			REC7			Weights	Rank
REC1	1.00	1.00	1.00	2.00	3.00	4.00	0.33	0.50	1.00	0.20	0.25	0.33	3.00	4.00	5.00	2.00	3.00	4.00	3.00	4.00	5.00	0.1915	1
REC2	0.25	0.33	0.50	1.00	1.00	1.00	2.00	3.00	4.00	0.25	0.33	0.50	3.00	4.00	5.00	2.00	3.00	4.00	0.25	0.33	0.50	0.1478	3
REC3	1.00	2.00	3.00	0.25	0.33	0.50	1.00	1.00	1.00	3.00	4.00	5.00	0.33	0.50	1.00	0.20	0.25	0.33	2.00	3.00	4.00	0.1372	4
REC4	3.00	4.00	5.00	2.00	3.00	4.00	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	0.25	0.33	0.50	2.00	3.00	4.00	0.1898	2
REC5	0.20	0.25	0.33	0.20	0.25	0.33	1.00	2.00	3.00	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	0.1302	5
REC6	0.25	0.33	0.50	0.25	0.33	0.50	3.00	4.00	5.00	2.00	3.00	4.00	0.20	0.25	0.33	1.00	1.00	1.00	0.20	0.25	0.33	0.1007	7
REC7	0.20	0.25	0.33	2.00	3.00	4.00	0.25	0.33	0.50	0.25	0.33	0.50	0.25	0.33	0.50	3.00	4.00	5.00	1.00	1.00	1.00	0.1028	6

Pair-wise comparison of regulatory and risk compliance (RRC).

Sub criteria	RRC1			RRC2			RRC3			RRC4			RRC5			RRC6			RRC7			Weights	Ranks
RRC1	1.00	1.00	1.00	0.25	0.33	0.50	0.20	0.25	0.33	2.00	3.00	4.00	3.00	4.00	5.00	0.33	0.50	1.00	3.00	4.00	5.00	0.1638	1
RRC2	2.00	3.00	4.00	1.00	1.00	1.00	1.00	2.00	3.00	2.00	3.00	4.00	0.20	0.25	0.33	1.00	2.00	3.00	0.33	0.50	1.00	0.1510	3
RRC3	3.00	4.00	5.00	0.33	0.20	1.00	1.00	1.00	1.00	0.33	0.50	1.00	1.00	2.00	3.00	3.00	4.00	5.00	0.20	0.25	0.33	0.1529	2
RRC4	0.25	0.33	0.50	0.25	0.33	0.50	1.00	2.00	3.00	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	0.33	0.50	1.00	0.1438	4
RRC5	0.20	0.25	0.33	3.00	4.00	5.00	0.33	0.50	1.00	0.20	0.25	0.33	1.00	1.00	1.00	0.20	0.25	0.33	2.00	3.00	4.00	0.1171	7
RRC6	1.00	2.00	3.00	0.33	0.50	1.00	0.20	0.25	0.33	0.25	0.33	0.50	3.00	4.00	5.00	1.00	1.00	1.00	2.00	3.00	4.00	0.1429	5
RRC7	0.20	0.25	0.33	1.00	2.00	3.00	3.00	4.00	5.00	1.00	2.00	3.00	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	0.1284	6

Pair-wise comparison of green core competencies (GCC).

Sub criteria	GCC1			GCC2			GCC3			GCC4			GCC5			GCC6			GCC7			Weights	Rank
GCC1	1.00	1.00	1.00	2.00	3.00	4.00	0.20	0.25	0.33	2.00	3.00	4.00	1.00	2.00	3.00	0.33	0.50	1.00	3.00	4.00	5.00	0.1645	2
GCC2	0.25	0.33	0.50	1.00	1.00	1.00	0.20	0.25	0.33	2.00	3.00	4.00	3.00	4.00	5.00	0.33	0.50	1.00	1.00	2.00	3.00	0.1376	5
GCC3	3.00	4.00	5.00	3.00	4.00	5.00	1.00	1.00	1.00	0.20	0.25	0.33	0.33	0.50	1.00	2.00	3.00	4.00	0.25	0.33	0.50	0.1581	3
GCC4	0.25	0.33	0.50	0.25	0.33	0.50	3.00	4.00	5.00	1.00	1.00	1.00	0.20	0.25	0.33	2.00	3.00	4.00	1.00	2.00	3.00	0.1356	6
GCC5	0.33	0.50	1.00	0.20	0.25	0.33	1.00	2.00	3.00	3.00	4.00	5.00	1.00	1.00	1.00	0.20	0.25	0.33	0.20	0.25	0.33	0.0988	7
GCC6	1.00	2.00	3.00	1.00	2.00	3.00	0.25	0.33	0.50	3.00	4.00	5.00	3.00	4.00	5.00	1.00	1.00	1.00	0.33	0.50	1.00	0.1652	1
GCC7	0.20	0.25	0.33	0.33	0.50	1.00	2.00	3.00	4.00	0.33	0.50	1.00	3.00	4.00	5.00	1.00	2.00	3.00	1.00	1.00	1.00	0.1401	4

Pair-wise comparison of opportunism (OPP).

Sub criteria	OPP1			OPP2			OPP3			OPP4			OPP5			OPP6			Weights	Rank
OPP1	1.00	1.00	1.00	1.00	2.00	3.00	0.33	0.50	1.00	2.00	3.00	4.00	0.25	0.33	0.50	0.33	0.50	1.00	0.13922	5
OPP2	0.33	0.50	1.00	1.00	1.00	1.00	1.00	2.00	3.00	1.00	2.00	3.00	3.00	4.00	5.00	2.00	3.00	4.00	0.22936	1
OPP3	1.00	2.00	3.00	0.33	0.50	1.00	1.00	1.00	1.00	0.33	0.50	1.00	0.20	0.25	0.33	0.20	0.25	0.33	0.05459	6
OPP4	0.25	0.33	0.50	0.33	0.50	1.00	1.00	2.00	3.00	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	0.20436	3
OPP5	2.00	3.00	4.00	0.20	0.25	0.33	0.20	0.25	0.33	3.00	4.00	5.00	1.00	1.00	1.00	3.00	4.00	5.00	0.22867	2
OPP6	1.00	2.00	3.00	0.25	0.33	0.50	0.25	0.33	0.50	3.00	4.00	5.00	0.20	0.25	0.33	1.00	1.00	1.00	0.14381	4

Pair-wise comparison of service and delivery performance (SDP).

Sub criteria	SDP1			SDP2			SDP3			SDP4			SDP5			SDP6			SDP7			Weights	Rank
SDP1	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	0.20	0.25	0.33	0.25	0.33	0.50	1.00	2.00	3.00	0.33	0.50	1.00	0.1394	5
SDP2	0.20	0.25	0.33	1.00	1.00	1.00	0.25	0.33	0.50	3.00	4.00	5.00	0.20	0.25	0.33	2.00	3.00	4.00	2.00	3.00	4.00	0.1467	4
SDP3	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	3.00	4.00	5.00	1.00	2.00	3.00	2.00	3.00	4.00	0.25	0.33	0.50	0.1661	1
SDP4	3.00	4.00	5.00	0.20	0.25	0.33	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	2.00	3.00	4.00	0.33	0.50	1.00	0.1595	2
SDP5	2.00	3.00	4.00	3.00	4.00	5.00	0.33	0.50	1.00	0.20	0.25	0.33	1.00	1.00	1.00	0.25	0.33	0.50	0.20	0.25	0.33	0.1148	7
SDP6	0.33	0.50	1.00	0.25	0.33	0.50	0.25	0.33	0.50	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	3.00	4.00	5.00	0.1178	6
SDP7	1.00	2.00	3.00	0.25	0.33	0.50	2.00	3.00	4.00	1.00	2.00	3.00	3.00	4.00	5.00	0.20	0.25	0.33	1.00	1.00	1.00	0.1557	3

Pair-wise comparison of management and organizational competencies (MOC).

Sub criteria	MOC1			MOC2			MOC3			MOC4			MOC5			MOC6			MOC7			Weights	Rank
MOC1	1.00	1.00	1.00	2.00	3.00	4.00	2.00	3.00	4.00	3.00	4.00	5.00	0.20	0.25	0.33	2.00	3.00	4.00	3.00	4.00	5.00	0.2332	1
MOC2	0.25	0.33	0.50	1.00	1.00	1.00	3.00	4.00	5.00	0.25	0.33	0.50	2.00	3.00	4.00	1.00	2.00	3.00	0.20	0.25	0.33	0.1311	4
MOC3	0.25	0.33	0.50	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	1.00	2.00	3.00	0.25	0.33	0.50	2.00	3.00	4.00	0.1291	5
MOC4	0.20	0.25	0.33	2.00	3.00	4.00	0.20	0.25	0.33	1.00	1.00	1.00	2.00	3.00	4.00	0.25	0.33	0.50	3.00	4.00	5.00	0.1451	3
MOC5	3.00	4.00	5.00	0.25	0.33	0.50	0.33	0.50	1.00	0.25	0.33	0.50	1.00	1.00	1.00	3.00	4.00	5.00	0.25	0.33	0.50	0.1203	6
MOC6	0.25	0.33	0.50	0.33	0.50	1.00	2.00	3.00	4.00	2.00	3.00	4.00	0.20	0.25	0.33	1.00	1.00	1.00	3.00	4.00	5.00	0.1516	2
MOC7	0.20	0.25	0.33	3.00	4.00	5.00	0.25	0.33	0.50	0.20	0.25	0.33	2.00	3.00	4.00	0.20	0.25	0.33	1.00	1.00	1.00	0.0877	7

Pair-wise comparison of social responsibility benefits (SRB).

Sub criteria	SRB1			SRB2			SRB3			SRB4			SRB5			SRB6			SRB7			Weights	Rank
SRB1	1.00	1.00	1.00	1.00	2.00	3.00	1.00	2.00	3.00	1.00	2.00	3.00	0.33	0.50	1.00	0.33	0.50	1.00	0.20	0.25	0.33	0.1042	7
SRB2	0.33	0.50	1.00	1.00	1.00	1.00	2.00	3.00	4.00	1.00	2.00	3.00	0.20	0.25	0.33	0.33	0.20	1.00	1.00	2.00	3.00	0.1385	5
SRB3	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	0.33	0.50	1.00	2.00	3.00	4.00	1.00	2.00	3.00	1.00	2.00	3.00	0.1649	2
SRB4	0.33	0.50	1.00	0.33	0.50	1.00	1.00	2.00	3.00	1.00	1.00	1.00	2.00	3.00	4.00	2.00	3.00	4.00	1.00	2.00	3.00	0.1663	1
SRB5	1.00	2.00	3.00	3.00	4.00	5.00	0.25	0.33	0.50	0.25	0.33	0.50	1.00	1.00	1.00	0.25	0.33	0.50	0.33	0.50	1.00	0.1310	6
SRB6	1.00	2.00	3.00	1.00	2.00	3.00	0.33	0.50	1.00	0.25	0.33	0.50	2.00	3.00	4.00	1.00	1.00	1.00	0.33	0.50	1.00	0.1418	4
SRB7	3.00	4.00	5.00	0.33	0.50	1.00	0.33	0.50	1.00	0.33	0.50	1.00	1.00	2.00	3.00	1.00	2.00	3.00	1.00	1.00	1.00	0.1533	3

APPENDIX B

VIKOR Analysis used in Chapter V

Evaluation matrix for recycling partners (Expert 1).

	REC 1	REC 2	REC 3	REC 4	REC 5	REC 6	REC 7	RRC 1	RRC 2	RRC 3	RRC 4	RRC 5	RRC 6	RRC 7	GCC 1	GCC 2	GCC 3	GCC 4	GCC 5	GCC 6	GCC 7	ECP 1	ECP 2	ECP 3
GRP1	2	4	5	1	2	4	5	1	3	2	5	4	1	2	4	2	5	3	4	3	2	4	5	1
GRP2	1	2	1	1	1	2	1	1	4	1	1	3	2	2	5	3	5	1	5	5	1	2	1	1
GRP3	5	4	4	5	5	2	4	5	5	2	3	2	3	2	4	2	3	3	3	4	3	2	4	3
GRP4	5	5	2	3	5	5	2	3	4	4	4	4	5	3	1	4	3	1	4	4	5	5	2	3
GRP5	4	2	1	3	4	2	1	3	5	3	2	1	5	3	3	1	4	3	5	2	4	2	1	3
Criterion Weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	0.025	0.023	0.023	0.022	0.018	0.022	0.020	0.033	0.027	0.031	0.027	0.020	0.033	0.028	0.012	0.020	0.005

	ECP 4	ECP 5	ECP 6	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	MOC 1	MOC 2	MOC 3	MOC 4	MOC 5	MOC 6	MOC 7	SRB 1	SRB 2	SRB 3	SRB 4	SRB 5	SRB 6	SRB 7
GRP1	2	4	5	1	3	2	5	4	3	5	5	2	3	4	3	5	4	1	1	2	1	3	3	3
GRP2	1	2	3	3	4	3	3	3	3	3	4	4	3	4	2	4	4	2	4	3	3	5	4	5
GRP3	5	4	4	3	3	4	3	2	4	2	2	4	2	2	3	3	3	3	2	2	2	3	3	4
GRP4	5	5	2	3	4	4	4	4	4	5	4	5	2	4	4	4	5	5	4	3	4	5	3	4
GRP5	4	2	1	3	5	3	2	1	4	3	4	1	4	5	5	4	4	3	3	5	5	2	3	2
Criterion Weights	0.018	0.020	0.012	0.008	0.008	0.009	0.009	0.007	0.007	0.009	0.026	0.015	0.014	0.016	0.013	0.017	0.010	0.014	0.019	0.022	0.023	0.018	0.019	0.021

Evaluation matrix for recycling partners (Expert 2).

	REC 1	REC 2	REC 3	REC 4	REC 5	REC 6	REC 7	RRC 1	RRC 2	RRC 3	RRC 4	RRC 5	RRC 6	RRC 7	GCC 1	GCC 2	GCC 3	GCC 4	GCC 5	GCC 6	GCC 7	ECP 1	ECP 2	ECP 3
GRP1	4	3	5	4	1	1	5	1	5	5	1	1	5	1	5	5	4	3	5	4	1	1	5	1
GRP2	1	2	1	4	2	2	3	3	5	1	2	2	3	3	5	1	1	2	1	4	2	2	3	3
GRP3	4	5	3	3	4	4	4	4	3	3	4	3	2	4	3	4	4	5	3	3	3	4	4	4
GRP4	4	4	4	5	5	4	3	4	5	3	5	4	3	4	5	3	4	4	4	5	5	4	3	4
GRP5	5	5	4	4	3	3	5	5	2	3	3	3	5	5	2	3	5	5	4	4	3	3	5	5
Criterion Weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	0.025	0.023	0.023	0.022	0.018	0.022	0.020	0.033	0.027	0.031	0.027	0.020	0.033	0.028	0.012	0.020	0.005

	ECP 4	ECP 5	ECP 6	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	MOC 1	MOC 2	MOC 3	MOC 4	MOC 5	MOC 6	MOC 7	SRB 1	SRB 2	SRB 3	SRB 4	SRB 5	SRB 6	SRB 7
GRP1	5	5	4	3	1	1	1	1	1	1	2	4	2	5	3	4	3	2	4	5	1	3	2	5
GRP2	5	1	5	5	4	1	1	1	4	2	2	5	3	5	1	5	5	1	2	1	1	4	1	1
GRP3	3	3	1	2	4	3	5	4	4	3	2	4	2	3	3	3	2	5	2	4	2	2	2	3
GRP4	5	3	2	2	5	5	2	4	1	5	3	1	4	3	1	4	4	5	5	2	3	4	4	4
GRP5	2	3	3	3	2	5	5	3	2	5	3	3	1	4	3	5	2	4	2	1	3	5	3	2
Criterion Weights	0.018	0.020	0.012	0.008	0.008	0.009	0.009	0.007	0.007	0.009	0.026	0.015	0.014	0.016	0.013	0.017	0.010	0.014	0.019	0.022	0.023	0.018	0.019	0.021

Evaluation matrix for recycling partners (Expert 3).

	REC 1	REC 2	REC 3	REC 4	REC 5	REC 6	REC 7	RRC 1	RRC 2	RRC 3	RRC 4	RRC 5	RRC 6	RRC 7	GCC 1	GCC 2	GCC 3	GCC 4	GCC 5	GCC 6	GCC 7	ECP 1	ECP 2	ECP 3
GRP1	3	1	1	1	1	1	1	2	4	2	5	3	4	3	2	4	5	1	3	2	5	1	5	5
GRP2	5	4	1	1	1	4	2	2	5	3	5	1	5	5	1	2	1	1	4	1	1	3	5	1
GRP3	2	1	5	3	4	3	3	2	4	2	3	3	3	2	3	4	4	3	3	4	3	4	3	4
GRP4	2	5	5	2	4	1	5	3	1	4	3	3	4	4	5	5	2	3	4	4	4	4	5	3
GRP5	3	2	5	5	3	2	5	3	3	1	4	3	5	2	4	3	3	3	5	3	3	5	2	3
Criterion Weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	0.025	0.023	0.023	0.022	0.018	0.022	0.020	0.033	0.027	0.031	0.027	0.020	0.033	0.028	0.012	0.020	0.005

	ECP 4	ECP 5	ECP 6	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	MOC 1	MOC 2	MOC 3	MOC 4	MOC 5	MOC 6	MOC 7	SRB 1	SRB 2	SRB 3	SRB 4	SRB 5	SRB 6	SRB 7
GRP1	1	1	5	1	5	5	4	3	5	4	1	1	5	1	2	2	4	4	3	2	4	1	1	5
GRP2	2	2	3	3	5	1	1	2	1	4	2	2	3	3	5	1	5	1	2	1	4	2	2	3
GRP3	3	4	4	4	3	3	3	3	3	5	3	4	2	4	3	3	1	4	2	3	2	3	4	2
GRP4	5	4	3	4	5	3	4	4	4	5	5	4	3	4	5	3	2	4	4	4	5	5	4	3
GRP5	4	3	5	5	4	3	5	5	4	5	3	4	5	5	4	3	3	5	5	4	4	3	4	5
Criterion Weights	0.018	0.020	0.012	0.008	0.008	0.009	0.009	0.007	0.007	0.009	0.026	0.015	0.014	0.016	0.013	0.017	0.010	0.014	0.019	0.022	0.023	0.018	0.019	0.021

Evaluation matrix for recycling partners (Expert 4).

	REC 1	REC 2	REC 3	REC 4	REC 5	REC 6	REC 7	RRC 1	RRC 2	RRC 3	RRC 4	RRC 5	RRC 6	RRC 7	GCC 1	GCC 2	GCC 3	GCC 4	GCC 5	GCC 6	GCC 7	ECP 1	ECP 2	ECP 3
GRP1	2	5	1	5	5	1	1	3	1	1	3	4	3	2	4	5	5	1	3	2	5	1	5	5
GRP2	1	1	3	5	1	2	2	5	4	1	1	5	5	1	2	1	1	1	4	1	1	3	5	1
GRP3	2	3	4	3	3	3	4	2	1	3	3	3	2	3	2	4	3	5	3	2	3	2	3	3
GRP4	4	4	4	5	3	5	4	2	3	3	1	4	4	5	5	2	4	3	4	4	4	4	3	3
GRP5	4	4	5	3	5	3	4	3	4	5	3	5	4	4	2	3	4	4	5	3	4	5	4	3
Criterion Weights	0.049	0.038	0.035	0.049	0.033	0.026	0.026	0.025	0.023	0.023	0.022	0.018	0.022	0.020	0.033	0.027	0.031	0.027	0.020	0.033	0.028	0.012	0.020	0.005

	ECP 4	ECP 5	ECP 6	SOP 1	SOP 2	SOP 3	SOP 4	SOP 5	SOP 6	SOP 7	MOC 1	MOC 2	MOC 3	MOC 4	MOC 5	MOC 6	MOC 7	SRB 1	SRB 2	SRB 3	SRB 4	SRB 5	SRB 6	SRB 7
GRP1	1	1	3	1	1	1	1	2	3	2	2	2	3	3	4	3	2	4	3	2	2	1	1	5
GRP2	2	2	5	4	4	4	1	4	4	4	5	3	5	1	5	5	1	2	4	4	4	2	4	3
GRP3	3	4	2	1	2	2	4	3	2	2	3	2	1	3	3	4	2	4	4	3	2	4	4	2
GRP4	3	4	2	3	3	2	4	1	3	3	1	4	3	1	3	4	3	4	2	4	2	3	3	3
GRP5	4	3	3	4	5	5	3	3	5	3	3	3	4	3	5	4	5	3	3	4	4	3	3	5
Criterion Weights	0.018	0.020	0.012	0.008	0.008	0.009	0.009	0.007	0.007	0.009	0.026	0.015	0.014	0.016	0.013	0.017	0.010	0.014	0.019	0.022	0.023	0.018	0.019	0.021

Normalized weighted evaluation matrix for experts 1-4.

	REC1	REC2	REC3	REC4	REC5	REC6	REC7	RRC1	RRC2	RRC3	RRC4	RRC5	RRC6	RRC7	GCC1	GCC2	GCC3	GCC4	GCC5	GCC6	GCC7	ECP1	ECP2	ECP3
GRP1	0.049	0.025	0.016	0.049	0.033	0.026	0.013	0.025	0.023	0.016	0.000	0.012	0.015	0.020	0.015	0.000	0.000	0.020	0.011	0.033	0.011	0.012	0.000	0.001
GRP2	0.039	0.038	0.035	0.024	0.033	0.000	0.026	0.004	0.000	0.023	0.011	0.012	0.002	0.008	0.033	0.027	0.031	0.027	0.014	0.033	0.028	0.008	0.015	0.005
GRP3	0.030	0.025	0.000	0.012	0.000	0.004	0.000	0.004	0.023	0.016	0.006	0.018	0.022	0.011	0.024	0.007	0.012	0.000	0.020	0.022	0.013	0.006	0.015	0.000
GRP4	0.049	0.000	0.008	0.024	0.014	0.004	0.009	0.014	0.023	0.008	0.022	0.000	0.015	0.000	0.000	0.010	0.010	0.012	0.008	0.000	0.000	0.000	0.017	0.001
GRP5	0.000	0.025	0.004	0.000	0.005	0.013	0.000	0.000	0.019	0.000	0.011	0.012	0.000	0.003	0.027	0.020	0.007	0.002	0.000	0.027	0.009	0.002	0.020	0.000

	ECP4	ECP5	ECP6	SOP1	SOP2	SOP3	SOP4	SOP5	SOP6	SOP7	MOC1	MOC2	MOC3	MOC4	MOC5	MOC6	MOC7	SRB1	SRB2	SRB3	SRB4	SRB5	SRB6	SRB7
GRP1	0.018	0.016	0.000	0.008	0.008	0.009	0.005	0.007	0.005	0.009	0.026	0.015	0.002	0.013	0.011	0.011	0.004	0.010	0.015	0.013	0.023	0.018	0.019	0.000
GRP2	0.016	0.020	0.004	0.000	0.000	0.008	0.009	0.003	0.003	0.002	0.000	0.000	0.002	0.013	0.004	0.006	0.000	0.014	0.011	0.022	0.009	0.008	0.012	0.021
GRP3	0.008	0.000	0.011	0.004	0.006	0.005	0.000	0.000	0.003	0.009	0.026	0.002	0.014	0.016	0.011	0.017	0.010	0.000	0.019	0.009	0.023	0.010	0.005	0.021
GRP4	0.000	0.008	0.012	0.003	0.000	0.004	0.002	0.000	0.007	0.000	0.000	0.005	0.002	0.016	0.013	0.006	0.004	0.002	0.000	0.004	0.009	0.000	0.000	0.009
GRP5	0.008	0.016	0.009	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.002	0.002	0.008	0.000	0.000	0.008	0.005	0.012

APPENDIX C

BWM analysis used in Chapter VI

Aggregate weights of Social (SOC) criteria for all experts.

Sub-criteria	Weights	Ksi*
SOC1	0.440	0.046
SOC2	0.143	
SOC3	0.272	
SOC4	0.074	
SOC5	0.070	

Aggregate weights of Technical (TEC) criteria for all experts.

Sub-criteria	Weights	Ksi*
TEC1	0.085	0.045
TEC2	0.277	
TEC3	0.175	
TEC4	0.396	
TEC5	0.067	

Aggregate weights of Environmental and natural (ENV) criteria for all experts.

Sub-criteria	Weights	Ksi*
ENV1	0.106	0.058
ENV2	0.056	
ENV3	0.350	
ENV4	0.143	
ENV5	0.067	
ENV6	0.278	

Aggregate weights of Economic (ECO) criteria for all experts.

Sub-criteria	Weights	Ksi*
ECO1	0.362	0.058
ECO2	0.091	
ECO3	0.094	
ECO4	0.119	
ECO5	0.049	
ECO6	0.064	
ECO7	0.221	

Aggregate weights of Policy and legal (POL) criteria for all experts.

Sub-criteria	Weights	Ksi*
POL1	0.153	0.057
POL2	0.348	
POL3	0.126	
POL4	0.260	
POL5	0.059	
POL6	0.054	