STUDY OF SELECT ISSUES OF REVERSE SUPPLY CHAIN IN INDIAN CONTEXT

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CERTIFICATE

This is to certify that the thesis entitled **"Study of select issues of Reverse Supply Chain in Indian context"** being submitted by **SAURABH AGRAWAL** to the Delhi Technological University, Delhi for the award of the degree of **Doctor of Philosophy** is a bonafide record of original research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has reached the requisite standard.

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

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ABSTRACT

In recent years, reverse supply chain has gained a lot attention because of increased flow of product returns, growing concerns for the environment, government rules and regulations, and corporate social responsibility. It refers to the sequence of activities required to collect the used product from the customers for the purpose of either reuse or repair or re-manufacture or recycle or dispose of it. Perusal of the literature shows that research in the field of reverse supply chain is in evolving phase and issues pertaining to adoption and implementation, forecasting product returns, disposition decisions, outsourcing decisions, and performance evaluation system are under-represented in contemporary research on RSC and need to be explored further. The present research work attempts to fill research gaps related to these issues by using the survey method, case method, and by developing models and frameworks related to these select issues in Indian context.

Electronics industry is growing fast with the advent of new technologies and product innovation across the globe. At present, the market of electronics in India is approximately $100b and it is expected to grow to $400b by year 2020. Indian electronics industry has been selected for the research work because of its size, higher growth, shorter product life cycles, e-waste management rules and regulations, and recent developments in the Indian electronics industry. Short product life cycle coupled with huge demand of electronics products, generating a pile of discarded products results in e-waste generation. Industry is also facing the higher product returns due the increase in online business and liberal polices offered to the consumers. Effective and efficient reverse supply chain implementation may help in managing these returns along with end of life product returns. Despite a growing body of research in this area, organizations in electronics industry are reluctant to adopt best practices of reverse supply chain. The research work identified and prioritized critical success factors by using fuzzy-TOPSIS methodology for reverse supply chain implementation in Indian electronics industry.

Further, a questionnaire was developed and survey was conducted to explore the important trends, practices, critical success factors, and motivational factors, select issues, and important strategic issues of reverse supply chain in Indian electronics industry.

Questionnaire was divided into the eleven sections covering all the relevant questions related to RSC and Indian electronics industry. Total 700 forms were sent and over all 208 responses were found suitable for the research. All the necessary statistical analysis was carried out to ensure the reliability and validity of the questionnaire. The hypotheses related to select issues were developed and tested with the help of structural equation modeling. The research work justified the use of single case along with survey method, and conducted a case study in an Indian electronics organization. It was concluded from the survey, hypotheses results, and findings of case study that forecasting product returns, disposition decisions, and outsourcing decisions are important and have great influence on the economic, environmental, and social performance of reverse supply chain. A model for forecasting product returns was developed by using graphical evaluation and review technique network theory, which predicts the percentage of product returns and the time of product returns. The research work contributed to the very few studies available on disposition by developing a framework for the selection of best disposition option by using graph theory and matrix approach (GTMA). Another framework was developed by integrating sustainable balanced scorecard with GTMA for outsourcing decisions whether outsource RSC activities partly or fully to third party service providers. This framework combined traditional balanced scorecard with triple bottom line aspects of sustainability and developed sustainable balanced scorecard for the selection of attributes and sub-attributes. It incorporates the sustainability concept into the reverse supply chain and contributes to the few studies available on relationship of sustainability with reverse supply chain. The research work proposed a performance evaluation framework based on triple bottom line aspects of sustainability by using FAHPEA. The framework motivates for

evaluating the economic, environmental, and social performance of RSC, which in turn will help in determining the contribution of RSC into the sustainable efforts of an organization. The research work makes following significant contribution to the contemporary research.

- A comprehensive literature review of RSC has been carried out that establishes a sufficient basis for other contemporary researchers. The research has clearly identified the research gaps and correlated them with issues on which research was carried out.
- The research work focused on Indian electronics industry and makes significant contribution to the limited available studies related to RSC in Indian electronics industry.
- The research work identified and prioritized the critical success factors for Indian electronics Industry. No such previous study was available on critical success factors for Indian electronics industry. The study will help the managers and practitioners in identifying the factors which they need to work out for successful implementation.
- Questionnaire was developed and a survey of Indian electronics industry was conducted. The findings of the survey will help managers and researchers to have better understanding of Indian electronics industry. It will also provide base for further exploration of the industry.
- Hypotheses were developed related to forecasting product returns, disposition decisions, and outsourcing benefits and their association with performance of RSC. The managers can utilize results of hypotheses for exploring and emphasizing these issues for improving RSC performance.
- A case study of Indian electronics organization has been developed and contributes to the very few case studies available for Indian electronics industry related to RSC.
- A model for forecasting product returns considering Indian demographics and characteristics have been developed for the first time. This forecasting model provides the

percentage of product returns and also the time of product returns. Managers can utilize these RSC estimates for the future RSC planning.

- A disposition decision framework was developed by identifying various disposition attributes and selecting the best disposition option by using GTMA. The findings of the study will help in improving the overall RSC performance. The framework may help the managers and researchers in disposition decision making and further development on the disposition decisions while dealing with the product returns in RSC.
- The research attempts to incorporate concept of sustainability into the RSC and developed a framework for outsourcing decisions based on SBSC. The study provides an overview of reasons for outsourcing and solution methodologies for outsourcing reverse supply chain activities partly or fully. The alternatives, developed are scenario based which provides flexibility to the managers for developing alternatives according their business need.
- A framework incorporating the concept of triple bottom line into RSC is developed for the evaluation of performance of RSC. The framework contributes to the limited number of studies available on performance evaluation system of RSC especially from TBL perspectives. Findings of the study will help organizations in optimizing their RSC as well as in benchmarking of their performance with respect to best in industry.

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LIST OF ABBREVIATIONS USED

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
AVE	Average Variance Extracted
BSC	Balanced Scorecard
CR	Composite Reliability
DEA	Data Envelopment Analysis
DM	Decision Maker
EA	Extent Analysis
GERT	Graph Evaluation and Review Technique
GTMA	Graph Theory and Matrix Approach
MCDM	Multi Criteria Decision Making
PLSPM	Partial Least Square Path Modelling
RSC	Reverse Supply Chain
SBSC	Sustainable Balanced Scorecard
TBL	Triple Bottom Line
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

Chapter 1. Introduction

1.1 Background

Consumer return policies have been more consumer friendly and relaxed in last few years because of business competitiveness and advent of e-commerce business. Managing product returns in supply chain is becoming more important for the success of business with the increased volume of returned products (Guide Jr et al., 2006). Product returns may be commercial returns, service returns, distribution returns or end of life returns. The customer may return the products because of many known or unknown reasons including defects, damage, or customer dissatisfaction (Barsky and Ellinger, 2001). Products are also returned because of liberal returns policies and allowances offered by the organizations as a part of business strategy for better customer satisfaction (Reda, 1998). Some organizations are also forced to deal with returns because of environmental regulations in many countries requiring remanufacturing or recycling of used products (Guide and Wassenhove, 2002). Product returns are uncertain in terms of quantity, quality, and timing of returns; and they are difficult to manage in comparison to new products in forward logistics (Rogers and Tibben-Lembke, 1999). When worn out or obsolete products are remanufactured, “it’s not uncommon for organizations to realize higher margins on these remanufactured products than they do on new items” (Stock et al., 2002). Still, product returns are eminent in a competitive business environment and organizations need to manage them efficiently. One of the ways of dealing with commercial product returns along with end of life product returns is to adopt and implement Reverse Supply Chain (RSC) practices. RSC activities include product collection, inspection and sorting, disposition (reuse, repair, remanufacture or recycle), and redistribution of products. RSC can manage both bad product returns and good product returns effectively and can contribute to the sustainability efforts of the organizations (Narayana et al., 2014).). The recovery of the products, components, and material through remanufacturing, repair,

reconfiguration, and recycling can lead to profitable business opportunities (Andel, 1997). It can make significant contribution to the number of social issues also along with environmental concerns (Sarkis et al. 2010a).

1.2 Reverse supply chain (RSC)

Supply chains have always been major focus of attention for researchers, academicians and business enterprises. Time responsiveness and cost optimization have been the ultimate goal of supply chain professionals. Researchers and practitioners have consistently given attention to the forward supply chains and ignored the RSCs (Bernon and Cullen, 2007). RSC has gained importance since last decade because of legislation, environmental concerns, and corporate social responsibility. RSC, which is also referred as reverse logistics *"is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal"* (Rogers and Tibben, 1999). RSC has been found to be beneficial to some of the organizations in terms of the improvement in the profits. Some of the organizations like HP, Dell have implemented RSC for competitive advantage. Jayaraman and Luo (2007) mentioned that Kodak has successfully implemented recycling facilities and is able to reuse up to 86% of a camera's parts. Similarly other leading manufacturers such as Canon and Xerox have also attained remanufacturing rates of nearly ninety percent. In fact, implementing RSC programs to reduce, reuse, and recycle returned products produces tangible and intangible value and may lead to better corporate image (Carter and Ellram, 1998). Research on RSC has been carried out in various sectors across the world. Lau and Wang (2009) studied the electronics industry in China, and explored the problems encountered in the implementation of RSC. Janes et al. (2010) worked on implementation of RSC in consumer electronics industry of USA. Jayaraman et al. (2003)

discussed RSC systems for recycling and reusing of beverage containers. Biehl et al. (2007) worked on carpet industry, Bernon et al.(2011) worked on retail industry, Gonzalez-Torre et al.(2004) worked on bottling, and Gonzalez-Torre and Adenso-Diaz (2006) worked on packaging organizations, Rahman and Subramanian (2012) worked on remanufacturing, Clottey et al. (2013) worked on remanufacturing, Sarath et al., 2015 worked on e-waste management, Sharma et al. (2016) worked on remanufacturing; are some of the examples of previous research on RSC.

1.3 RSC practices in India

RSC has been practiced in India since long time. Soft drink companies like Pepsi, Coca-Cola have a very effective RSC of reusing (refilling) glass bottles repeatedly. Similarly, Petroleum organizations supplies cooking gas to consumers by refilling of the LPG cylinders. Dabbawalas business in Mumbai is also very popular for managing integrated supply chain system efficiently. In retail, exchange offers on second hand items are offered by retailers like Big Bazaar's "Kuch Bhi lao Kuch Bhi Pao" (Bring anything, take away anything) exchange offer. These products are normally refurbished / remanufactured in local areas, and sold in secondary market. Exchange of new steel cooking vessels for old clothes is also very common in rural India (Abraham, 2011). Maruti True Value program, in which dealers help the customers in resale of their used cars, can also be considered as part of RSC. These are some of the examples where RSC has been managed effectively by the organizations in India. The e-waste management industry is at an emerging stage and at present, RSC market is valued USD 15b and is anticipated to grow rapidly (Gupta, 2013). Still, the RSC practices are limited in the developing countries like India. In addition, there are very few studies, which are reflected in the academic research. This may be because of absence of strong legislation or may be because of the lack of support from the top management and business partners to spend money for RSC

(Ravi and Shankar, 2005). Lack of awareness among consumers may also be one of the factors that discourage interested parties from participation. Most of the research in the area of RSC in Indian context is diversified across the various sectors. Jindal and Sangwan (2013a) investigated economic, environmental, and social drivers for the Indian industry. Ravi and Shankar (2005) identified barriers for RSC implementation in automobile industry in India. Ravi et al. (2005a) have also analyzed the barriers for the computer industry. Srivastava and Srivastava (2006) presented a framework to manage product returns for select categories of products. Mondal and Mukherjee (2006) have researched acquisition planning and the remanufacturing process. Other studies related to RSC in Indian context include computer waste management by Ahluwalia and Nema(2006), designing RSC network for paper recycling by Pati et al. (2008), a conceptual frame work for consumer durables by Srivastava (2008), a model for battery recycling by Kannan et al. (2010), and design of RSC system for tire remanufacturing. Sasikumar et al. (2010), Sinha et al. (2009) worked on the construction industry RSC network for aggregate recycling, Rathore et al. (2011) prescribed a model for mobile remanufacturing, Senthil et al. (2012) proposed a model for selection of operating channel in printing industry and so on. Although there are several studies but no one sector has been explored in depth from the perspectives of RSC.

1.4 Indian electronics industry

Electronics industry is among one of the fastest growing industry in the world. The demand of electronics products particularly consumer electronics is increasing rapidly due to computerization and mobile phone technology innovations worldwide. The Indian electronics industry is also growing with the worldwide growth and the electronics industry is among one of the fastest growing industry in the country. According to annual report of ministry of information technology, India, the market for the electronics industry is expected to be $400b

by the year 2020. At present, the contribution of domestic production is approximately $42b and this production is expected to be $100b by the year 2020. The figures related to expected demand and production are shown in figure 1.1. The difference in demand and product may be seen as potential for manufacturing and subsequently potential for the RSC activities.

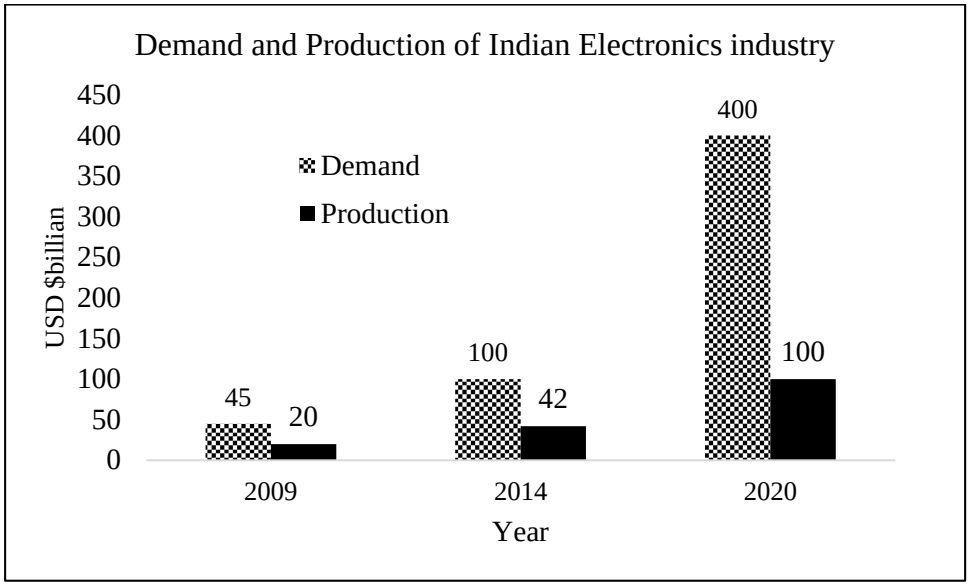

Figure 1.1 Annual Demand and Production in Indian electronics industry

Digital India, e- governance and other initiatives by the Government of India offers a lot of potential for growth of electronics industry in India. “Make in India” initiative has also turned the attention of global organizations towards India and they are looking for building up manufacturing facilities in India to serve the domestic as well as global markets. The Government has established electronic hardware technology parks, increased liberalization, and relaxed tariffs to attract a foreign direct investment in the industry. According to department of industrial policy and promotion, foreign direct investment in Indian electronics industry is continuously increasing and has doubled from $0.8b in financial year-2010 to to $1.53b in financial year-2016. Automobile industry growth is making significant contribution to the Indian electronics industry. As per report from the ministry, automotive electronics is exhibiting a growth of about 29% and expected to occupy an important segment of the industry.

In addition, digitization of cable could lead to increased new avenues for the organizations in Indian electronics industry.

Product life cycles are becoming shorter and shorter with the advent of new technologies and consumers quest for new products. The consumers are discarding products very fast which results in a new type of waste, known as e-waste (electronics-waste). According to 'Global E-Waste Monitor 2014' reported by UN, Indian is fifth largest generator of e-waste in the world and total e-waste generated in year 2014 has been estimated to be 1, 700,000 tons. It is likely to be increased by 21% in next three years. Recently, the Government of India has instituted e-waste management rules and regulations 2011, 216 to overcome the issue of e-waste. Even the organization Foxconn has been denied importing refurbished Apple mobile phone to India under these regulations. RSC is one of the ways to comply with these rules effectively. RSC may help in extending the products useful life cycle through reuse, repairing, remanufacturing, and minimizing the e-waste through recycling of discarded products. RSC also plays an important role in managing the commercial product returns along with end of life product returns.

1.5 Issues in reverse supply chain

RSC differs significantly in comparison to forward supply chain (Tibben-Lembke and Rogers, 2002). In forward supply chain, demand of products is comparatively easier to predict by using traditional forecasting techniques. Uncertainty in terms of quantity, quality, and timing of product returns significantly influences the forecasting, planning and performance of RSC. These uncertainties make RSC more stochastic in nature in comparison to forward supply chain. Distribution of products in forward supply chain is comparatively easier because of well-established distribution chain and demand quantity certainty in most of the cases. Product return policies are very important because of uncertainties and they must be designed carefully

for the efficient collection of returned products in RSC (Östlin et al., 2008). It is a challenge to balance among customer services, regulatory and operational requirements, and competitiveness in the market. While forward supply chain is the core business of most of organizations, RSC has been considered a cost driven activity. Still, RSC has gained importance due to environmental concerns, government rules and regulation, and corporate social responsibility (Ravi et al., 2005a). Many organizations have adopted and implemented RSC successfully for their business advantages as discussed in section 1.2. RSC adoption and implementation faces number of challenges because of lack of experience in the industry. Carter and Ellram (1998) stated that customer preferences, regulation, resource constraint, lack of stakeholder commitment are major barriers for RSC implementation. Sharma et al. (2011) identified lack of awareness about RSC, management inattention, financial constraints and legal issues as some of the major barriers for Indian industry. Janes et al. (2009), in a survey of consumers electronics in USA identified main barriers including lack of clear return policies, little recognition of strategic value, poor performance measurement system, inadequate IT support, limited forecasting and planning, and insufficient tax know-how. Many organizations have come across these barriers and implemented RSC successfully. However, they faced several strategic, operational, and tactical issues, and challenges in managing RSC. Lambert et al. (2011) discussed these issues for the respective RSC processes. Allocation of financial resources (Daugherty et al., 2001; Lambert et al., 2011), risk of adopting RSC (Ferrer and Ketzenberg, 2004; Ketzenberg et al. 2006), disposition of returned products (Skinner et al., 2008; Hazen, 2011), outsourcing RSC activities (Meade and Sarkis, 2002), integration of forward and RSC (Yang and Wang, 2007), performance evaluation system (Biehl et al., 2007), IT infrastructure (Brito and Dekker, 2002), product return policy (Östlin et al., 2008), availability of technology (Lambert et al., 2011) are some of major issues which are discussed frequently in the literature. Network design is also one of the important strategic issues, which

may have long-term impact on the RSC. Strategic decisions for designing RSC include number of facilities in the network, their location and region to be covered, and their capacity or size (Brito and Dekker-2002). There are number of issues faced by the organizations because RSC is relatively new area and a lot of exploration is going on for the improvement in its efficiency and effectiveness. The research work is focused on select issues such as adaptation and implementation, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC.

Product flows in RSC are uncertain in terms of quantity, quality, and timing of returns. Forecasting product returns is important for the strategic and operational decision-making in RSC. Long term forecasting may not only help in determining the future capacity required and expected business from the RSC but also in its outsourcing decisions. Short term forecasting is important for the day-to-day planning and control of recovery processes (Xiaofeng and Tijun, 2009).

Once the products are collected, inspected, and sorted into different categories, they are disposition for either reuse, or repairing, or remanufacturing, or recycling depending on number of factors. Disposition of returned products may be industry or product specific and depends upon the number of factors including price / value / shelf life of product, transportation cost, and the demand outlook (Skinner et al., 2008). The consumer expects the credit or replacement of returned product as quickly as possible while the manufacturer wants to disposition these products for recapturing the maximum value (Hall et al., 2013). Strategic disposition of returned product is important for the better performance of RSC system of an organization (Attia, 2015).

Another important issue is outsourcing of RSC activities. Manufacturers may adopt RSC by choice or by force but they have to decide whether performing the activities themselves or outsourcing to the third party service providers (Martin et al., 2010). Outsourcing may

reduce the cost because of economies of scale and manufacturers can reduce their asset base, and deploy the capital released for other productive usage by outsourcing RSC. Other advantages include less uncertainty in operations, more focused on core competency, more flexible, better consumer responsiveness, and better excess to new technology (Govindan et al., 2012; Kumari et al., 2015). However, some firms realized unexpected higher costs because of complexity, lack of flexibility, and other hidden problems with outsource service providers (Tadelis, 2007). Therefore it is important to explore and examine the pros and cons of outsourcing RSC activities.

Another key issue is the performance evaluation system of RSC. According to Cui and Zhang (2008), 'the performance measurement systems can provide organizations with relevant, appropriate, complete, and accurate information. The organizations have opportunities to monitor, and reposition their management and operations to obtain highly competitive environment'. Shaik and Kader (2012) developed a RSC performance evaluation framework by using balanced scorecard approach and analytic hierarchy process. Paksoy et al. (2011) developed a mathematical model for investigating a number of operational and environmental performance measures consisting of total transportation costs, total environmental costs, emission rates, consumer demand. Bai and Sarkis (2013) introduced a performance evaluation framework by using AHP for evaluating the economic, environmental, and the operational performance. Most of the performance evaluation systems for RSC are related to economic performance and directly or indirectly related to environmental performance (Biehl et al. 2007; Bai and Sarkis 2013; Paksoy et al. 2011; Tsoulfas et al. 2002; Huang and Yang 2014). There are very few studies evaluating the social performance along with economic and environmental performance of RSC (Devika et al., 2014; Williams et al., 2014). RSC can make a significant contribution to the social performance of an organization (Sarkis et al. 2010a).

1.6 Motivation for the research

RSC is at nascent stage and there is a huge potential for future scope of work. Pertinent of literature indicates that research is staggered and diversified across the sectors and some of the issues are under-represented in the past research. The research work is aimed at identifying and exploring these issues and analyzes them in Indian context. Indian electronics industry was selected for the research work because of its higher growth, size, and e-waste management rules and regulations 2011, 2016 by the Government of India. The study addresses the issues related to adaptation and implementation of RSC, forecasting product returns, disposition decisions, outsourcing decisions, and performance evaluation of RSC through descriptive analysis and hypotheses testing, case study, and development of models and frameworks. The contemporary research on RSC issues and recent developments in Indian industry, particularly electronics industry motivated for the research work in this area. Some of the key motivations for the research are enumerated as follows.

- It is evident from the literature review (Discussed in Chapter 2) that RSC is in evolving phase and very few studies have been carried out in developing countries like India.
- The research is diversified across the sectors and no single sector has been explored and analyzed in depth.
- Indian industry is growing very fast and it is second fastest growing economy in the world.
- Initiatives like “Make in India”, “Digital India”, “E-waste management rules & regulations-2011, 2016”, corporate social responsibility policy-2014, and several other initiatives offers a lot of potential for RSC in Indian industry.
- India is mostly dependent on import of electronics parts, components, and goods from other countries. The initiatives by the Government of India may boost the investment in the

electronics industry. Growth of electronics industry coupled with e-waste management regulations offers a lot of potential for RSC.

- It was found that select issues like adoption and implementation, forecasting product returns, disposition decisions, outsourcing decisions, and performance evaluation of RSC are not covered in depth and need to be explored. These issues offer a lot of potential for research work particularly in Indian electronics Industry. These issues are elaborated in detail in chapter 2, literature review.

1.7 Research objectives

Based on the research gaps analysis discussed above following research objectives were identified for the research work:

- To study and analyze Indian electronics industry in reference to reverse supply chain
- To analyze different issues of reverse supply chain through questionnaire based survey
- To Identify and study the critical success factors (drivers or barriers) for reverse supply chain implementation
- To study the strategic development issues for effective reverse supply chain
- To develop a forecasting model for product returns
- To develop a decision framework for disposition options
- To develop a decision framework for outsourcing
- To develop a framework for performance evaluation of reverse supply chain
- To validate the findings of research through case studies

1.8 Organization of the thesis

The thesis is organized in nine chapters. The description of different chapters in the thesis are briefly explained in the following section.

Chapter 1- "Introduction" provides the overview of research work and discusses about various RSC issues in contemporary research. It presents the RSC practices adopted by the various industries globally as well as in India. This chapter explains briefly the select issues and motivation for considering these issues for the research work. Importance of RSC and motivation for the research are also discussed. Organization of the thesis with brief description of chapters is also enumerated in this chapter.

Chapter 2- "Literature Review" is based on state of art studies in RSC. Definitions and basic processes of RSC are elaborated in the chapter. It also focusses on the literature review of select issues for research work such as adoption and implementation including drivers and barriers to RSC, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC. The literature review helped in identifying the research gaps and future directions for the research work**.**

Chapter 3- "Research Methodology" deals with procedural framework for the present research work. Research objectives were established based on research gap analysis. To meet these research objectives, different methodologies / tools are required. The chapter discusses about the various methodologies used for the research work such as descriptive analysis and hypotheses testing, case method, and methodologies for the development of decision frameworks and models. Various methodologies utilized for the development of decision frameworks include Fuzzy-TOPSIS methodology for identification and prioritization of critical success factors for RSC implementation, GERT for forecasting product returns, and GTMA for the development of framework for disposition decisions in RSC. The GTMA is combined with sustainable balanced scorecard for the development of framework for outsourcing

decisions in RSC. Extent Fuzzy AHP is used for the development of framework for performance evaluation of RSC.

Chapter 4- "Identification and Prioritization of Critical Success Factors for Reverse Supply Chain" deals with thorough study of critical success factors and their ordered implementation for successful RSC implementation in Indian electronics industry. The chapter begins with the introduction, and provides the information on selection critical success factors with the help of literature review, and discussion with the experts. A framework, based on Fuzzy-TOPSIS methodology is developed for prioritizing these CSFs. A case of Indian electronics industry is discussed for the illustration of the methodology.

Chapter 5- "Descriptive Analysis and Hypotheses Testing" deals with descriptive analysis and hypotheses testing developments. The chapter describes the hypotheses formulation based on the comprehensive literature review and research gap analysis. The chapter discussed and explained a questionnaire development, questionnaire administration, respondents profile along with reliability and validity tests of the constructs. The chapter discusses about the findings from the survey of Indian electronics industry. It also elaborated structural equation modeling technique, Partial Least Square Path Modeling including development of causal relationship constructs, measurement model, and hypotheses testing. The hypotheses related to select issues are tested and results are discussed in detail.

Chapter 6- "Case Study" deals with exploration and examination of key strategic issues and challenges faced by the electronics industry in reference to RSC by using case study method. A case of Indian Electronics organization is discussed and analyzed to identify key strategic issues and challenges in managing RSC. The case study validates the findings of the research

work, which will help the managers in understanding the complexities of RSC in electronics industry such as critical success factors, outsourcing, disposition decisions, performance evaluation, and forecasting product returns.

Chapter 7- "Development of decision frameworks in Reverse Supply Chain" deals with development of three decision frameworks on select issues of RSC.

In first decision framework, a model for forecasting product returns in RSC is developed based on the GERT. The forecasting model provides the percentage of product returns and the time of product returns. The model has been validated through a case example of a leading mobile phone manufacturing organization in India. Organizations can utilize these RSC forecasting estimates for the future planning of RSC.

In Second decision framework, a framework is developed for the disposition decisions in RSC. The research work explores the disposition options and develops a framework for the selection of best disposition option by using GTMA. A case of mobile manufacturing organization is discussed for the illustration of methodology.

In third decision framework, the chapter focuses on the development of framework for the outsourcing decisions in RSC. The research work develops the framework for outsourcing decisions in RSC whether outsource RSC activities partly or fully. The research work utilized SBSC for the selection of attributes and sub-attributes and GTMA as a decision making approach. A case of mobile manufacturing organization is discussed for the illustration of the approach.

Chapter 8- "Performance evaluation of Reverse Supply Chain" deals with development of a framework for evaluating the performance of RSC. The research work incorporates the relationship of RSC into the economic, environmental, and social sustainability, known as

triple bottom line. The performance measures, based on triple bottom line approach were selected and Fuzzy-AHP extent analysis approach was applied for estimating the weights, global weights of performance measures and hence the RSC performance index. A case of three electronics organization was considered for the illustration of methodology by evaluating and comparing their performance indices.

Chapter 9- "Conclusions and future directions" summarizes the key research findings and syntheses of the work done. Furthermore, significant contributions, and implications of the research work for the managers, researchers, and academicians are enumerated along with the limitations, and future scope of research in the area of RSC. Based on the findings of the study, the research work also suggested recommendations for the Indian electronics industry.

In this chapter, mainly introduction of RSC and emerging issues have been briefly described along with motivation for study, and research objectives. Detailed analysis of different issues of RSC will be discussed in next chapter i.e. literature review.

Chapter 2. Literature Review

2.1 Introduction

Researchers and practitioners have consistently given attention to the forward supply chains and ignored the reverse flow of supply chains (Bernon and Cullen, 2007). Now the scope for the forward supply chain has extended to include the reverse flow of products from the point of consumption back to the source because of economic, environmental, legal issues, and corporate social responsibility (Rogers and Tibben-Lembke, 2001). This chapter reviews the literature on key definitions, processes, networks, and selects issues of reverse supply chain (RSC) through a systematic review methodology and explores the gaps in contemporary research in RSC. A literature review seems to be a valid approach for reviewing thoroughly and structuring a research area (Easterby-Smith et al., 2002). Literature review helps in identifying the conceptual content of the research area (Meredith, 1993) and guides towards the theory development. A comprehensive literature review is carried out to explore the previous studies related to RSC. In this chapter, developments of definitions of RSC adopted by the academicians and researchers broadly are discussed along with key RSC processes. Different classifications of RSC processes are enumerated in the literature. The RSC processes are illustrated based on the most common theoretical concepts developed by researchers in the past. The RSC networks are also classified in a multiple way in the literature. The research work explored the reuse, repair, remanufacture, recycle, and secondary market networks to have a better insight of RSC activities. A systematic methodology, suggested by Mayring (2003) is adopted for the literature review. The methodology involves the material collection, followed by descriptive analysis of material collected. In next step, category selection is made followed by the material evaluation. The literature review identified select issues based on past literature review and research gaps in the literature reported by various authors. The research work explores the select issues such as adaptation and implementation, forecasting product

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returns, disposition decisions, outsourcing decisions, and performance evaluation of RSC. An in-depth analysis on these select issues was made and research gaps in the literature were identified. The literature review ensured a high level of inter-rater reliability and the rigor in validity has been achieved by validation tests. The literature review is explained in the following sections.

2.2 Definitions of reverse logistics / reverse supply chain

Reverse supply chain is sometimes referred as reverse flows or reverse logistics by many researchers. The definition, given by Guide and Wassenhove (2003a) is adopted and cited by many authors worldwide. According to them reverse supply chain is "the series of activities required to retrieve a used product from customer and either dispose of it or use it". Reverse logistics and RSC, both the term are used synonymously in the literature by many authors. According to Prahinski and Kocabasoglu (2006) reverse logistic can be seen as one of the components of RSC and its scope is broader than reverse logistics. The research work uses the term reverse supply chain (RSC) throughout the thesis. In the early nineties, the Council of Logistics Management gave a formal definition of Reverse Logistics.

"...the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all issues relating to logistics activities to be carried out in source reduction, recycling, substitution, reuse of materials and disposal."

Some of the key definitions are shown in table 2.1. Murphy and Poist (1989) mentioned the flow of goods from consumer to producer. Carter and Ellram (1998) introduced the term "environment" in the definition of reverse logistics. Rogers and Tibben (1999) stressed on the purpose of the reverse logistics and introduced the most widely accepted definition. Srivastava (2008) further modified this definition of reverse logistics. In brief, definitions of reverse

logistics have changed over time and widening its scope with the interest of researchers in this area.

Table 2.1 Definitions of reverse logistics / reverse supply chain

Authors	***Definition***
Murphy and Poist (1989)	*'movement of goods from a consumer towards a producer in a channel of distribution'*
REVLOG (1998) definition by (Brito and Dekker, 2002)	*"The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal"*
Stock (1998)	*'the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing'*
Carter and Ellram (1998)	*'the process whereby organizations can become more environmentally efficient through recycling, reusing, and reducing the amount of materials used'*
Rogers and Tibben-Lembke (1999)	*'is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal'*
Dowlatshahi (2000)	*'is defined as a supply chain that is redesigned to efficiently manage the flow of products or parts from end user for remanufacturing, recycling, or disposal'*
Srivastava (2008)	*'the process of planning, implementing and controlling the efficient, effective inbound flow inspection and disposition of returned product and related information for the purpose of recovering value'*
Reverse Logistics Association (2009)	*"as all activity associated with a product/service after the point of sale, the ultimate goal to optimize or make more efficient aftermarket activity, thus saving money and environmental resources"*

2.3 Reverse supply chain processes

Many authors, in different perspectives have explained various RSC processes. Based on the work carried out in the past, different key processes of RSC have been identified and are shown in Figure 2.1. The used or returned products are collected after their acquisition and are inspected for sorting into the different categories. The next step is to disposition them for repair, remanufacturing, recycling, reuse or final disposal depending on the decision taken to either recapture value or dispose of it. The key processes are identified as product acquisition,

collection, inspection/sorting, disposition, and redistribution are described in the following section:

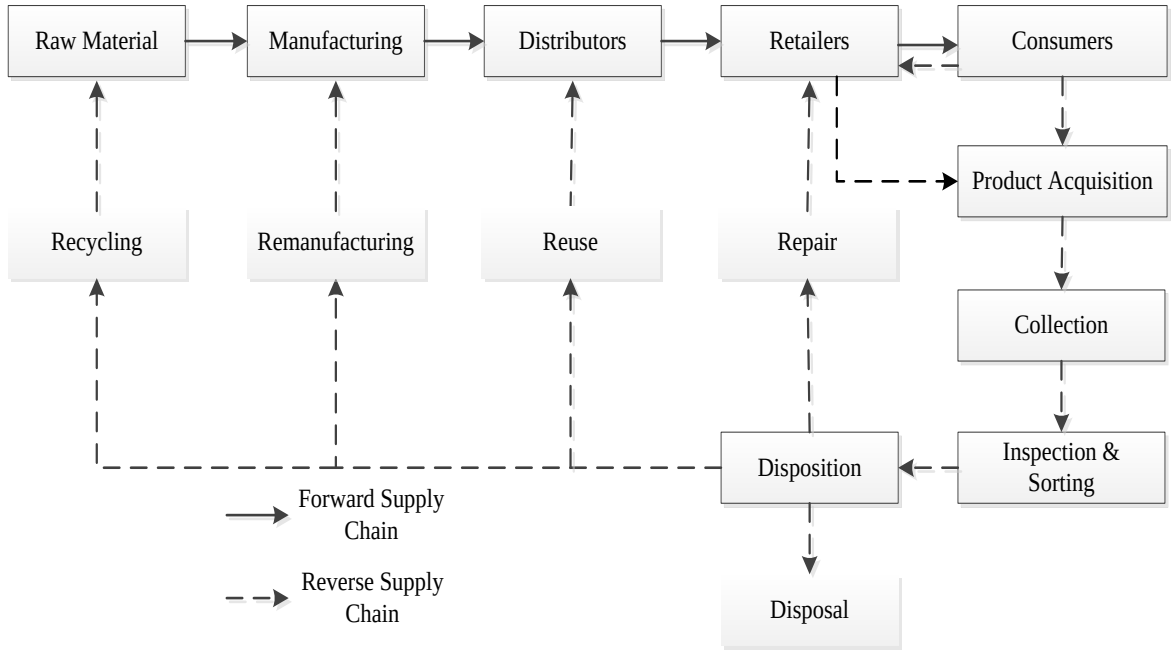

Figure 2.1 Basic flow of forward and RSC Processes

2.3.1 Product acquisition / Gate keeping

Product acquisition is the process of acquisition of used products, components or materials from the end users for further processing. Since product returns are uncertain in terms of time, quantity and quality, their acquisition is important for the success of RSC (Fleischmann et al., 1997). According to Guide and Wassenhove (2003a), product acquisition is first step and is critical process for establishing the profitable RSC.

Gate keeping represents the main entrance of RSC. It is a set of practices performed usually by retailers to identify the products which are allowed into the system or given back to the user after resolving issues at their end. For example, if consumer returns the product to retailer and retailer decides whether product must be sent for further processing (Acquisition) or given back to consumer. This act of decision making is known as “Gate keeping”.

2.3.2 Collection

Products after acquisition are collected and delivered to the facilities for inspection, sorting, and disposition. Collection refers to the activity in which an organization gains the possession of the products (Fleischmann et al., 2003). Kumar and Putnam (2008) discussed three collection methods as manufacturers directly collect from the customers, manufacturers collect via retailers or manufactures collect through third party logistics service providers. Webster and Mitra (2007) considered two alternative take back methods for collection which are distinguished by the "degree of control" on product returns. First method is collective take back in which the manufacturer has no control over returns while second method is individual collection which gives complete control to the manufacturer. Choice of collection method depends on the cost structure and collection quantity decisions (Atasu et al., 2008). Decision of collection centres and related parameters must be involved considerably in designing RSC for its successful implementation (Pochampally and Gupta, 2004).

2.3.3 Inspection and sorting

Product returns may be commercial returns, service returns, distribution returns or end of life returns. Rogers and Tibben-Lembke (1999) reported that the customer may return the products because of known or unknown reasons, and the condition of returned products may differ greatly. Therefore, a separate inspection of each item is required for sorting the products into different categories. Its overall appearance and state of the constituting elements need to be evaluated. Products and components are sorted out based on this evaluation (Brito and Dekker, 2002). In a study, Zikopoulos and Tagaras (2007) found that sorting before disassembly and remanufacturing depends on the transportation, disposal and disassembly cost, and quality of returned product. Loomba and Nakashima (2010) examined the role of sorting used products before disassembly by using Markov decision process. Some of the previous research examples

include distinguishing repairable and recyclable subassemblies of copiers (Krikke et al., 1999a), inspection of sieved sand for pollution (Barros et al., 1998), and separation of non-relevant waste paper (Pati et al., 2008). Galbreth and Blackburn (2006) derived optimal acquisition and sorting policies with used product condition variability and uncertain demand.

2.3.4 Disposition

Once the products are inspected, next step is to take disposition decision for further processing. Thierry et al. (1995) illustrated three disposition alternatives as product reuse, product recovery, and waste management. Krikke et al. (2003), and Tibben-Lembke and Rogers (2002) further modified these alternatives as reuse, product upgrade, material recovery, and waste management. Norek (2003) reported that organizations mostly have five recovery options including sell as new; repair or repackage and resell as new; repair or repackage and resell as used; resell at lower value to salvage house; and sell by weight to salvage house. There are different combinations, which have been discussed for disposition alternatives. Each study emphasized slightly different alternatives and definitions. Five common disposition alternatives discussed by authors are reuse, repair, remanufacturing, recycling, and disposal (Thierry et al., 1995, Brtio and Dekker, 2002, Fleischmann et al., 1997). These alternatives are shown in figure 2.1, and discussed in the chapter in subsequent sections.

2.3.5 Redistribution

Redistribution refers to directing reusable products to a potential market for resale to users. Reusable products need to be sold the proper market through redistribution. These products may be sold with the new product or may be sold in the secondary markets.

2.4 Reverse supply chain networks

Network design is one of the important strategic issues which may have long term impact on the performance of RSC. Strategic decisions for designing RSC include number of facilities in the network, their location and region to be covered, and their capacity or size (Brito and Dekker, 2002). RSC network designs have been studied for different business scenario through various modeling techniques. Different types of RSC networks are discussed in the literature. Four most common types of RSC network (repairing, remanufacturing, recycling, and direct reuse) along with secondary market are discussed in this section. The secondary market are also considered because of their importance in developing countries like India for disposition of returned products. The characteristics and features of these networks are illustrated in the following section.

2.4.1 Recycling network

Recycling network is generally concerned with the material recovery from rather low value products (Blackburn et al., 2004). In many cases, investment costs are high due to advanced technological equipment requirements for recycling. Low recovery value of products and high investments in equipment for recycling necessitates higher processing volume to make it economically feasible. That is the reason that a centralized, open loop network structure involving a small number of levels is preferred. In addition, these networks tend to be highly susceptible to the uncertainty in the volume of product returns (Fleischmann et al., 2000).

Barros et al. (1998) reported a case study for the recycling of sand coming from construction waste for multi-level capacitated warehouse location problem. The model determined the optimal number, capacities, and locations of the depots and cleaning facilities. Louwers et al. (1999) considered the design of a recycling network for carpet waste and proposed a continuous location model that used a linear approximation. Pati et al. (2008)

formulated a mixed integer goal-programming model for paper recycling logistics system and studied the inter-relationship between multiple objectives with changing priorities of recycled paper distribution network. Kara and Onut (2010) proposed a stochastic programming model for paper industry to determine long-term strategies including optimal facility locations and optimal flow amounts for large-scale RSC network design problem under uncertainty. Zebabllos et al. (2012) developed a scenario based model simultaneously considering planning and design decisions under uncertainty in terms of quantity and quality of the flow of products for Portuguese glass manufacturing company. Qiang et al. (2013) investigated a network model with decentralized decision-makers consisting of raw material suppliers, retail outlets, and the manufacturers who collect the recycled product directly from the demand market. They discussed the effects of competition, investment, yield and conversion rates on equilibrium quantity transactions and prices. Schweiger and Sahamie (2013) considered a combined continuous and discrete facility location problem and utilized a hybrid Tabu Search approach to develop the scenario-based model for a paper manufacturer. Recycling network models are designed for strategic decisions including number of facilities, location, region to be covered, and their capacity or size. Previous studies have been carried out in wide range of sectors for various propositions. The solution methodologies utilized by the previous researchers include deterministic, stochastic modeling, simulations, and heuristic methods.

2.4.2 Reuse network

Direct reusable products require only minor inspection, cleaning, and minor maintenance. They are expected to form a flat network structure comprising a small number of levels. These products generally go back to forward supply chain and form a closed loop supply chain network (Fleischmann et al., 2000). A large number of reuse cycles and absence of other processing steps results in a higher transportation cost (Flapper, 1995). This may be one of the

reasons for having a decentralized network. At the same time, decentralization renders balancing of product flows as an important task in direct reuse networks (Crainic et al., 1993). Guide and Wassenhove (2001) developed a framework for analyzing the profitability of reuse activities and explored the influences of product returns on operational efficiency.

In past, different types of models and methodologies have been developed for strategic decisions in reuse networks for different categories of products. Kroon and Vrijens (1995) reported a case study for reusable transportation packages, considering a single level decentralized structure with timing of returns as an important element of uncertainty to determine the number of containers, the number of container depots, and their locations. Mollenkopf et al. (2005) proposed a cost model to evaluate the combined impact of logistics and packaging costs on the reuse of containers. They pointed out that most of the models consider logistics cost and ignoring packaging costs, which may be substantial in some of the cases and may result in higher purchasing cost. Gonza´lez-Torre et al. (2004) considered joint implementation of environmental practices in collaboration with suppliers and customers, and analyzed the existing differences in the relations between bottling / packaging organizations and their suppliers. Silva et al. (2013) developed a returnable packaging model to minimize waste generation and environmental impacts, which resulted in 18 % less material consumption than the disposable packaging model thus reducing costs. Carrasco-Gallego et al. (2013), in a review of case studies discussed the reuse network studies including returnable glass bottles by Del Castillo and Cochran (1996), reusable wheelchairs by Rudi et al. (2000), postal maintainers by Duhaime et al. (2001), chemical railcars by Young et al. (2002), and work on variety of items like pallets, tote boxes, trays, kegs, trolleys, and bins by Breen (2006). Atasu et al. (2008) reviewed analytical research on the business economics of product reuse from the industrial practice perspective. Park (2014) studied the impact of various factors in technical, economic, regulatory, and behavioral perspective for industrial waste reuse in Unites States. Reuse

network models include the models based on cost evaluation, and operational effectiveness. The solution methodologies include mathematical, stochastic, simulation, and MCDM.

2.4.3 Remanufacturing network

Remanufacturing network is generally concerned with material recovery from high value products (Blackburn et al., 2004). In most of the cases, remanufacturing is carried out by the manufacturers because of their knowledge of products. Products are remanufactured by utilizing existing facilities that forms a closed loop supply chain network (Fleischmann et al., 2000). Uncertainty in terms quality, quantity and timing of product returns are important factor for the success of remanufacturing network (Rogers and Tibben-Lembke, 1999). Since this network works as intermediary between the collection and redistribution, they form a complex multi-level structure (Fleischmann et al., 1997). Kocabasoglu et al. (2007) conducted a survey empirically for assessing the linkages between supply chain investments, organizational willingness to take risk and business uncertainty, and found that ongoing investment in the forward supply chain was more inclined towards recycling and waste management, but not in remanufacturing. Wilcox et al. (2011) stated that the organizations must manage uncertain cash flow problems due to the erratic and unpredictable cash transactions associated with uncertain product returns.

Krikke et al. (1999a) reported a case for the returns, processing, and recovery of discarded copiers. Products taken back from the customers were stored at pre-determined locations and from there, were routed via recovery processing facilities to the demand locations for determining the locations and capacities of the recovery facilities as well as transportation links connecting various locations. Jayaraman et al. (1999) developed a model to determine the location of distribution remanufacturing facilities, the transshipment, production, and stocking of the optimal quantities of the remanufactured products and cores. Guide and Pentico (2003)

considered the case of a cellular phone remanufacturing organization that acquired used phones with different quality levels, remanufactured them to a single quality level, and sold them at a certain price. Pishvaee et al. (2009) developed a stochastic model for recovery and disposal considering uncertainty in the quantity and quality of returned products. Sasikumar et al. (2010) developed a MCDM model for maximizing the profit of a multi echelon RSC network for tire remanufacturing in India. Millet (2011) proposed different RSC channels for supplying reusable modules for remanufacturing products with less environmental impact and higher economic benefits. Ramezani et al. (2013) developed a stochastic model under uncertainty for maximizing the profit, responsiveness, and quality focusing on financial risk in RSC. Soleimani et al. (2014) developed a remanufacturing model incorporating three important risk measures mean absolute deviation, value at risk, and conditional value at risk. Remanufacturing networks model have been developed for wide range of products providing solutions to various propositions of strategic issues.

2.4.4 Repairing network

Repairing network is concerned with repairing, and servicing of products and return of those products to the customers. Since there is no link with forward supply chain, they form an open loop supply chain network (Fleishmann et al., 2000). In decentralized operations, testing and grading close to the source may reduce transportation costs but investment for test equipment may require more centralized operations. Tradeoffs between centralized / decentralized operations and transportation cost are needed for effective decision-making. Generally, a decentralized structure close to customer is preferred for this type of network (Fleischmann et al., 2000).

Amini et al. (2005) discussed the competitive value of service management activities, particularly repair services. A binary integer-programming model was developed for the case

study of a medical diagnostics center. Du and Evans (2008) analyzed RSC networks dealing with the returns requiring repair service for post sales services with objective of minimization of the overall costs, and minimization of total tardiness of cycle time. Lieckens et al. (2013) build a stochastic model for profit maximization model to determine the optimal service delivery for a multi-product, multi-level network for repairable service parts.

2.4.5 Secondary market network

For some organizations, selling through the secondary market such as factory outlet store, owned and operated by the manufacturer can be more profitable than their forward channel of distributors or retailers (Rogers and Tibben-Lembke 1999). Abraham (2011) conducted an empirical study to map and understand the RSC systems in the apparel aftermarket in India and found that collaboration between stakeholders can improve logistics, business predictability and margins. Louwers et al. (1999) developed a model for recycling and reusing old carpets with an option of considering secondary market for resale of carpets. Listes and Dekker (2005) proposed a stochastic programming model for recycling sand while considering selling the sand into the secondary market. Alumur et al. (2012) developed a RSC model for washing machines and considered an option of selling them into the secondary market. They found that major flow is sent to the secondary market because of more profit into the secondary market compared to revenues either from recycling or external remanufacturing. This shows that secondary market can play an important role in the success of RSC if explored properly. However, selling through secondary markets can be more complicated than marketing new product. Suppliers are often concerned about brand equity and hesitate to enter products into the secondary market (Rogers et al., 2012).

2.5 Methodology of literature review

In order to systematically review the literature and to clarify research methodology for the study, a step-by-step methodology, suggested by Mayring (2003) was adopted for the literature review. The methodology involves the material collection, followed by descriptive analysis of material collected. In next step category selection is made followed by the material evaluation. These steps are described in following section.

2.5.1 Material collection

Material collection methodology and unit of analysis is the first step of the literature review process. The unit of analysis has been defined as a single research article/book/report. The study was conducted in two stages. In first stage, pair of key words "reverse logistics" / "reverse supply chain" and "literature review" was used in title, abstract, and keywords to carry out review articles search. These keywords were used in Google-scholar search engine (www.scholar.google.com) and in Scopus (www.scopus.com) with options of searching for articles in English language excluding articles in other languages, and sorted by relevance. After reading and analyzing the literature review articles, further literature search were inductively attributed to the categorization of RSC i.e. adoption and implementation, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC. The terms "Forecasting product returns", "Implementation", "Disposition", "Outsourcing", and "performance" along with the key term "reverse logistics" / "reverse supply chain" were used in searching articles. The articles belong to the leading publishers including Elsevier (www.sciencedirect.com), Emerald (www.emeraldinsight.com), Springer (www.springerlink.com), Taylor and Francis (www.tandf.co.uk/journals/), Wiley (www.wiley.com), and Informs (http://journals.informs.org/). Most of the articles which were focused on the above mentioned issues were taken into consideration.

2.5.2. Descriptive analysis

To comprehend the multi perspective view of the concepts, articles were sorted out from more than fifty journals. It is observed that most of the articles have been published in reputed journals such as Resource, Conservation and Recycling, Omega, International Journal of Physical Distribution and Logistics Management, European Journal of Operational Research, International Journal of Production Research, journal of operations management, journal of cleaner production, and Journal of Production Economics.

2.5.3 Category selection

Categories of the study were selected based on the select issues of RSC. The literature on RSC has been classified into five categories. These five categories are (1) Adoption and implementation; (2) Forecasting product returns; (3) Disposition decisions; (4) Outsourcing; (5) Performance evaluation.

2.5.4 Material evaluation

Measures were taken to make sure a high level of inter-rater reliability. Rigor in validity is achieved by validation tests performed by three researchers using the deductive and inductive approaches simultaneously. Preliminary measures involved classification of articles by the researchers, and then comparing these articles to ensure consensus. To increase the reliability of the research, databanks and journals as well as the individual articles, materials were cross checked by three researchers with the help of spread sheets and intense discussion among themselves. The materials were crossed checked with other databases also, to ensure the accuracy and sufficiency of collected articles.

2.6 Select issues of RSC

Authors have reviewed literature on RSC in the past. Fleischmann et al. (1997) studied RSC from the perspectives of distribution planning, inventory management and production planning. Carter and Ellram (1998) focused on the environmental aspects of transportation, packaging and purchasing. Dowlatshahi (2000) developed a theory of RSC successful implementation considering various strategic and operational factors. Prahinski and Kocabasoglu (2006) identified ten research propositions to analyze current practices, critical issues, and managerial techniques. Akcali et al. (2009), Chanintrakul et al. (2009), Sheriff et al. (2012) reviewed the literature on RSC network design issues. These reviews provide insight to the RSC previous research on various issues. However, it was found that issues such as adoption and implementation, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC are not covered in depth and need to be reviewed. For example, Govindan et al. (2015) reviewed 382 articles covering whole area of RSC providing in depth insight from different perspectives but reviewed very few articles on forecasting product returns, performance evaluation, and outsourcing. Adoption and implementation and disposition decisions are also not covered. Phokharel and Mutha (2009) reviewed 164 articles on important RSC features including product acquisition, pricing, collection of used products, RSC network structure vis-à-vis the integration of manufacturing, and remanufacturing facilities location for inspection and consolidation activity. However, select issues for the research work are not reviewed in the article. Krapp et al. (2013a) observed that there are very few studies focusing on the issue of forecasting product returns. Rogers et al. (2012) and Hall et al. (2013) stated that disposition is one of the major RSC issues and need more attention. Brito et al. (2002), Linton et al. (2007), Meade et al. (2007), Rubio et al. (2008), Lambert et al. (2011) reviewed published literature on various aspects of RSC but select issues are either under-represented or not reviewed in their articles. The selected articles are discussed and

analyzed in this section to construct a holistic view of the recent and state-of-the-art studies in RSC on select issues. The results will clarify the current gaps in literature and will guide for the future research work**.**

2.6.1 Adoption and implementation

Adoption and implementation of RSC decisions involve several factors which are useful in decision making and RSC effectiveness. A critical analysis of the factors affecting RSC can provide valuable information for RSC implementation (Ravi, et al., 2005a). Rogers and Tibben-Lembke (1999) suggested that there are number of factors affecting RSC practices. The presence or absence of these factors can become drivers or barriers for RSC implementation.

Organizations may adopt RSC by choice because of inherent economic or competitive advantages or by force because of legislation or environmental reasons. Knowing the drivers influencing the RSC may be helpful in RSC implementation. Brito and Dekker (2002) categorized two types of drivers, internal and external. Carter and Ellram (1998) identified internal and external factors to examine, whether an organization is reactive, proactive, or value seeking in RSC implementation. Fleischmann et al. (1997) listed the economics, marketing, legislation as main drivers of RSC. Dowlatshahi (2010) developed a framework for an optimal design and RSC implementation considering strategic and operational factors based on cost-benefit analysis. There are number of drivers which have been discussed in the literature. The drivers were identified in a given region or country for a particular sector. These drivers are summarized in Table 2.2. It is evident from the Table 2.2 that these drivers are varying from sector to sector, and depending on region in which the study was carried out.

Table 2.2 Drivers of RSC implementation

Authors	Factors	Sector	Country
Fleischmann et al. (1997)	Economic factor, Marketing, Legislation	General	
Autry et al. (2001)	Sales volume, Organization size, Customers' satisfaction, Disposition	Electronics	
Brito and Dekker (2002)	Economic factor, Legislation, Extended producer's responsibility, Corporate citizenship		
Ravi et al. (2005a)	Economic factors, Environment and green issues, Corporate citizenship	End of life computers	India
Lau and Wang (2009)	Promotion of corporate image, Fulfillment of obligation for environment protection, Improvement of customer service	Electronics	China
Janse et al. (2010)	Top management awareness, Strategic partnerships, Performance visibility, Strategic focus in avoiding returns, Reclaiming value from returns, Put products swiftly back in the market	Electronics	USA
Rahman and Subramanian, (2012)	Legislation, Customers, Strategic cost, Environmental concerns, Volume and quality, Incentives, Resources, and integration, Coordination	EOL-Computers	Australia
Chiou et al. (2012)	Economic needs, Environmental needs, Social needs, Recycled volumes, Recycling costs, Increase of sales volume for new product	Electronics	Taiwan
Tyagi et al. (2012)	Facilities, Handling, Ease of access, Information	Hospitals	Canada
Jindal and Sangwan (2013a)	Economic, Environmental, and Social drivers	Indian Industry	India
Kapetanopoulou and Tagaras, (2011)	Legislation, Profitability, Green image, Customer service, Competition	Manufact.	Greek Industry
Mittal and Sangwan (2014)	Internal, Policy and Economic drivers	Manufact.	India
Kannan et al. (2014)	Extended producer, responsibility, codes of conduct, and resource scarcity	EOL tire Manuf.	India
Bouzon et al. (2015)	Legislation, Economic, Consumers	Manufact.	Brazil
Chileshe et al. (2016a)	Economic, Environmental, and Social drivers	Construction Industry	Australia

Carter and Ellram (1998) asserted customer preferences, regulations, resource constraints, and lack of stakeholder commitment as major barriers of RSC implementation. Rogers and Tibben-Lembke (1999) identified the attitude of top management and organization policies as two major barriers. Ravi and Shankar (2005), in a study of automobile sector in India added more barriers like problems with product quality, resistance to change to RSC, lack of appropriate performance metrics, and lack of training and education. There are number of barriers, which have been discussed in the literature. Major barriers for RSC, identified in different studies are summarized in Table 2.3. These barriers vary from sector to sector and country to country.

Table 2.3 Barriers of RSC implementation

Authors	Factors	Sector	Country
Carter and Ellram (1998)	Customer preferences, Regulation, Resource constraint, Lack of stakeholder commitment	General	
Rogers and Tibben-Lembke (1999)	Attitude of top management, Company policies	General	
Ravi and Shankar (2005)	Lack of awareness, Lack of commitment, Lack of strategic planning, Quality problems, Financial constraints	Automobile	India
Lau and Wang (2009)	Lack of laws and legislation, Economic policies, Underdevelopment of recycling technology, Lack of publicity and knowledge of RSC	Electronics	China
Janse et al. (2010)	Lack of clear return policies, Little recognition of strategic value, Poor performance measurement system, Inadequate IT support, Limited forecasting and planning, Insufficient tax know-how	Electronics	USA
Sharma et al. (2011)	Lack of awareness about RSC, Management inattention, Financial constraints, Legal issues	Industry	India
Rahman and Subramanian, (2012)	Lack of personnel resources, Management's low commitment, Lack of initial capital, Lack of enforceable laws, Regulations and directives, Lack of coordination	Manufacturing	China
Chiou et al. (2012)	Environmental regulations and directives, Consumer's environmental awareness, Pressures with stakeholders	Electronics	Taiwan
Gonza´ lez-Torre et al. (2010)	Reluctance on the part of government, Customer, and social actors, Lack of know-how, Lack of top management commitment, Lack of information Systems, High cost in financial and human resources	Automotive	Spain
	Legislation, Public pressure, Competitiveness, Customer demand, Top management commitment, Technology, Organizational resources		
Mittal and Sangwan (2013)	Lack of RSC experts, Low commitment, Lack of initial capital, Funds for return monitoring systems,	Indian Industry	India
Abdulrahman et al. (2014)	Lack of enforceable laws, Government supportive economic policies, Lack of systems for return monitoring	Manufacturing Industry	China
Prakash and Barua (2015)	Management, Organizational, Economic, Legal, Technological, Infrastructural, and Market related barriers	Electronics Industry	India
Bouzon et al. (2016)	Technology and infrastructure, Economic, Policy	Electrical and Electronics Industry	Brazil

2.6.2 Forecasting product returns

Planning for RSC is more difficult than forward supply chain because of more uncertainty in terms of quantity, time and quality of returned product (Flapper, 1995). The RSC starts with an end consumer returning products. It is important that when the consumer brings back products, and in what condition, and in how much quantity to the manufacturer. If this could

be predicted with reasonable accuracy, all the strategic, tactical and operational processes will be positively impacted (Potdar and Rogers, 2012). Forecasting for products available for collection, transportation, remanufacturing/recycling is important to achieve the optimum level of performance (Tibben-Lembke and Rogers, 2002; Ayvaz, 2014). Clottey et al. (2012) found that use of forecasting for sourcing cores yields significant cost savings in comparison to sourcing without forecasting. According to Xiaofeng and Tijun (2009), forecasting product returns is important for designing the RSC network, layout planning of the recovery facilities as well as the planning and control of recovery processes. Toktay et al. (2004) stated that there are few documented business examples of forecasting product returns. Krapp et al. (2013a) also observed that there are very few studies focusing on the issue of forecasting product returns. The literature has been reviewed comprehensively and some of the previous studies on forecasting product returns are summarized in table 2.4. The forecasting methods include both quantitative and qualitative methods as mentioned in the table 2.4. The product return is supposed to be function of factors varying from sector to sector and type of disposition of returned product.

Table 2.4 Forecasting models for product returns

Authors	Method/model	Factors for forecasting	Sector	Disposition	Country
Goh and Varaprasad (1986)	Statistical Methodology	Trip-page, Trip duration, Loss rate, Expected useful life	Containers	Reuse	
Kelle and Silver (1989)	Simulation Model	Quantitative	Reusable Containers	Reuse	USA
Toktay et al. (2000)	Discrete-Time Distributed-Lag Model	Quantitative	Kodak Camera	Reuse	
Marx-Gomez et al. (2002)	A neuro-fuzzy system	Quantitative	Photo copiers	Remanuf., Recycling	
Srivastava and Srivastava (2006)	Decomposition methods and heuristics	Product ownership data, Life cycle of products, Sales, Forecasted demand, Environmental policy, Green Indexes	Electronic	General	India

Authors	Method/model	Factors for forecasting	Sector	Disposition	Country
Peralta and Fontanos (2006)	Mathematical equations	Number of devices in use, Current end-of-life, Serviceable years of the product, Disposal behavior of consumers	Electronic	Recycling	Philippines
Hanafi et al. (2007)	Petri Net Forecasting Model	Product life, Social and Sales factor, Marketing and advertising budget, Population density, Age	Mobile phone	General	Australia
Liu and Fang (2007)	Transfer Function Noise model	Quantitative	-	-	-
Xiaofeng and Tijun (2009)	Wave function	Quantitative	Electronic	General	China
Efendigil et al. (2009)	Artificial intelligence approaches	Demand with incomplete information	Durable consumer goods	Closed loop supply chain	Turkey
Hu and Hua (2010)	Simplex grey forecast model with time series model	Quantitative	House hold appliances	General	China
Yu et al. (2010)	Logistic and material flow analysis	Quantitative	Personal Computers	Recycling	Asia
Shih et al. (2012)	Analytic Network Process	Consumer behavior, Marketing mix	Printers	Recycling	Taiwan
Potdar and Rogers (2012)	Data Envelopment Analysis	Consumer behavior	Electronic	General	USA
Benedito and Corominas (2013)	Markov Decision Model	Product demand, Product life cycle, Return rate of end of life	-	Remanuf., Recycling	-
Clottey et al. (2012)	A generalized approach	Quantitative	-	Remanuf.	-
Krapp et al. (2013a)	Bayesian estimation techniques	Quantitative	-	Closed loop supply chain	-
Krapp et al. (2013b)	A generic framework	Quantitative	-	Closed-loop supply chain	
Temur et al.(2014)	Fuzzy Expert System	Quantitative	E-waste	Closed loop supply chain	
Kumar et al. (2014)	ANFIS	Quantitative	General	Closed loop supply chain	
Matsumoto and Ikeda (2015)	Time Series Analysis	Quantitative	Auto parts	Remanuf.	

2.6.3 Outsourcing

Outsourcing is defined as acquiring services from external service providers (Grover et al., 1994). Manufacturers may adopt RSC by choice or by force but they have to decide whether

performing the activities themselves and outsourcing to a third party service provider (Ferguson and Toktay, 2006; Martin et al., 2010). Manufactures have three choices including do nothing, develop own RSC system or find a third party service provider and partner with them (Meade and Sarkis, 2002). Daugherty and Droge (1997) observed that outsourcing decisions are based on a variety of qualitative as well as quantitative factors and the organizational structure has a significant effect on the outsourcing decisions of the RSC functions completely or partly.

In past, authors have examined number of reasons and scenarios in which outsourcing RSC activities may be considered. Insigna and Werle (2000) suggested that the organizations should outsource activities for which internal capability is weak and the potential for gaining competitive advantage is low. Boyson et al. (1999) mentioned that the decision to outsource is driven by profit growth and increased focus on core competencies. Arnold (2000) distinguishes among core activities, core-close activities, core-distinct activities, and disposable activities. The core activities have the highest degree of contribution to the competitiveness while disposable activities have minimal contribution. The outsourcing strategy changes with the degree of contribution to the competitiveness. Wu et al. (2005) stated that if RSC activities are not the part of its core functions, RSC activities might be outsourced. Serrato et al. (2007) found that the industry with high return variability and a short product life cycle must outsource RSC activities because of reduced economic feasibility of maintaining an organization's own RSC. Ko and Evans (2007) observed that specialized infrastructure needing special information systems for tracking and capturing data, dedicated equipment for the processing of returns, and specialist trained nonstandard manufacturing processes are major reasons for outsourcing. Pagell et al. (2007) predicted that manufacturers may initially adopt low cost strategies but they will consider other strategies like in-house disassembly to protect intellectual property at a later stage. Govindan et al., (2012) observed that RSC outsourcing may reduce costs as the third

party can get the advantage of the economies of scale. Also, by outsourcing RSC, organizations can reduce their asset base, and deploy the capital released for other productive usage. Other advantages include low costs, less uncertainty, lower capital investment, more focused on core competency, more flexibility, better customer responsiveness, and better excess to new technology (Kumari et al., 2015). Huscroft et al. (2013) also emphasized on use of information technology for RSC cost effectiveness. These studies explain the reasons and scenario in which a RSC functions may be considered for outsourcing. However, some organizations realized unexpected higher costs because of complexity, lack of flexibility, and other hidden problems with outsourced service providers (Tadelis, 2007). Therefore, it is important to make systematic analysis from various business perspectives before taking outsourcing decisions.

Once an organization considers for outsourcing some of the RSC activities, there are methodologies and models developed by the researchers for assisting in outsourcing decisions. Krumwiede and Sheu (2002) developed a decision making framework to explore the RSC business through evaluation of market, customers and competitors. Ordoobadi (2009) developed a multi phased decision model for strategic and economic analysis of outsourcing activities. Bernon et al. (2011) proposed a conceptual framework based on ground theory approach considering the qualitative factors like trust, power, quality, cost, avoidance techniques. Dat et al. (2012) formulated a mathematical programming model optimizing the total processing cost of e-waste. Mafakheri and Nasiri (2013) addressed the issue of revenue sharing and emphasized on horizontal collaboration among organizations sharing RSC activities and contributions. Govindan and Murugesan (2011) utilized fuzzy extent analysis for selection of best third party service provider in battery industry. Senthil et al. (2014) developed a hybrid approach using AHP and the Fuzzy-TOPSIS for the contractor's evaluation and selection of third party service providers. Tavana et al. (2016) considered the criteria and sub criteria based on SWOT

analysis and applied intuitionist Fuzzy AHP for the selection of best alternative between in-house or outsource RSC activities. Govindan et al. (2013) utilized triple bottom line approach along with fuzzy multi criteria decision-making model for outsourcing decisions. Tjader et al. (2014) combined the ANP with BSC to develop a decision model for determining organization level outsourcing strategies. Hernandez et al. (2010) used both AHP and ANP for the evaluation of corporate performance of RSC in Brazilian industry. They compared the results and reported that AHP is the very efficient because it requires a smaller number of judgments while ANP is much reliable because it considers attributes dependencies. Apart from the number of studies discussed above, there are number of studies focusing on selection of third party RSC service provider (Meade and Sarkis, 2002; Bottani and Rizzi, 2006; Efendigil et al., 2008; Cheng and Lee, 2010; Ravi and Shankar, 2012; Govindan et al., 2013b; Aguezzoul, 2014; Senthil et al., 2014; Guarnieri et al., 2015).

Fourth party logistics is also one of options of outsourcing. Its market grew considerably with the use of IT (Win, 2008). It functions as a control tower by taking responsibility of all the users' outsourced operations and serves as a single interface between the client and multiple logistic service providers (Buyukozkan et al., 2009). They provide administrative services while other operators perform the physical movement of goods (Selviaridis and Spring, 2007). Mukhopadhyay and Setaputra (2006) used the fourth party logistics provider as RSC integrator and used it as a return service provider. Hingley et al. (2011) investigated the collaboration and implementation through an exploratory study of retailers, suppliers, and fourth party logistics service providers. In fact, fourth party service providers work in a virtual supply chain and manages all the work through IT and communications tool.

2.6.4 Disposition decisions

A schematic flow diagram of RSC for product returns is shown in figure 2.1. The users through product acquisition process return the products and these products are transported for inspection and separation. Inspection/sorting are carried out for determining the action, which recovers the most value from the returned product, and products are disposition accordingly. The disposition decision of returned product for the selection of best disposition option depends on number of attributes. These attributes were identified with the help of previous literature and discussion with the experts during the industry visits. These attributes are explained in table 2.5 along with their explanation.

Table 2.5 Attributes for selection of best disposition option

Attribute	**Authors**	**Concluding Remarks**
Customer behavior (CBH)	Hazen et al., 2012, Jack et al. (2010), Amini et al. (2005), Inderfurth et al. (2004), Kara and Onut (2010), Geyer et al. (2007), Vorasayan and Ryan, 2006).	Customer behavior plays bigger role in RSC as compared to the forward supply chain. Quality, quantity and timing of returned products are uncertain and difficult to predict and dependent on the customer behavior. In addition, the demand for remanufactured products or recycled material largely depends on customer behavior and plays an important role in disposition decision making.
Market conditions, (MCD)	Richey et al. (2005), Lambert et al. (2011), Franke et al. (2006)	Here we define it from the competitive perspective. It is important to notice that what and how competitors are handling the returned products. Selling remanufactured products in the market may be utilized as green strategy at the same time it may affect the brand image of a product depending on the market conditions.
Existing regulation, (EXR)	Hazen et al. 2012, Subramanian et al. (2014)	Government rules and regulations, which may affect the disposition of returned products and may impose restrictions on some of the disposition decisions for example disposal of end of life products is not allowed in many countries.
Environmental impact (EVI)	Shih (2001), Dowlatshahi (2005), Wu and Dunn (1995), Hoek (1999)	It is defined as impact of RSC on environment and its contribution to reduce negative impact on environment. Environmental impacts of RSC have been considered in many studies.
Supply chain capabilities (SCC)	Hazen et al., 2012, Bell et al. (2013), Defee et al. (2009)	It is defined as an organizations supply chain capability to integrate RSC into existing system and making resources available to the RSC activities (Hazen et al., 2011).
Product Value (PRV)	Ferrer and Whybark (2000), Chung and Wee (2011), Sharma et al. (2016)	In general, rather low value product/module/components are recycled for material recovery (Blackburn et al., 2004). It may be expensive to remanufacture them and at the same time customers may like to buy new because of low value.

Attribute	Authors	Concluding Remarks
Processing Cost (PRC)	Jamal et al. (2004), Li et al. (2009), Kongar and Gupta (2001), Sabharwal and Garg (2014)	It is defined as cost involved in reuse / repair / remanufacture / recycle. It includes the transportation cost, operating cost, inventory cost, and recovery cost.
No. of Returned Products (NRP)	Savaskan et al. (2004), Rubio and Corominas (2008), Sabharwal and Garg (2013)	Numbers of returned products are highly uncertain and difficult to predict. Numbers of returned products available for disposition are at a particular point of time very important for disposition decision.
Quality of Returned Products (QRP)	Aras et al. (2004), Guide and Wassenhove (2001), Ardeshirilajimi and Azadivar (2015), Sabharwal and Garg (2013)	Quality of returned products is also important factor for disposition decision. A good quality returned product offers better value to the remanufacturer and a low quality may be a better candidate for recycling.
Recapturing Value (RCV)	Ravi et al. (2005), Gobbi (2011), Rogers and Tibben-Lemke (2001), Kumar and Saravanan (2014)	Recapturing value from used product may be the primary economic objective of most of RSC system and greatly affects the disposition decisions in RSC.

There are various methodologies and models, which have been developed for effective disposition decision making. Wee and Kumar (2006) developed a system dynamics model for disposition of products for remanufacturing or refurbishing. They found that part replacements from the suppliers are more profitable than refurbished computer parts. Skinner et al. (2008) empirically examined the different disposition strategies and found that "if adequate resource support for RSC is not available then choose to destroy the product because other disposition options like recycling or remanufacturing require significant resources for recapturing value". Gobbi (2011) considered product recovery value and found that low product recovery value is associated with recycling and energy recovery, and high product recovery value is associated with reprocessing and reuse. When the recovery option is recycling, time is not relevant; primary objective is cost reduction. When the recovery option is reprocessing, time is primarily relevant, trade-offs between costs and time efficiency are necessary. Guide et al. (2008) developed a model for the optimal disposition of returned products considering the time value of the return, the condition of the product and the congestion effect at the remanufacturing facility. This model is helpful in extracting value from product return processes. Hazen (2011)

identified seven RSC disposition decision components by utilizing a problem-driven content analysis methodology. This study considers wide range of disposition strategies ranging from corporate strategy to business level strategy along with external factors for disposition decision making. Karamouzian et al. (2014) worked on queuing theory based optimal disposition decision model, which utilizes an acquisition policy by grading the return products. The objective of the study was to maximize the product recovery value. Wadhwa et al. (2009) developed fuzzy-set theory based flexible decision model for the selection of best option of disposition strategy. Senthil et al. (2012) proposed a hybrid methodology model, based on AHP and TOPSIS under fuzzy environment for the selection and evaluation of options including manufacturer's operation, third party operation or joint operation. These studies provide a great insight of the disposition issues in RSC.

2.6.5 Performance evaluation of RSC

According to Cui and Zhang (2008), 'the performance measurement systems can provide organizations with relevant, appropriate, complete, and accurate information. The organizations have opportunities to monitor and reposition their management and operations to obtain highly competitive environment'. Performance evaluation framework provides a balanced view between external and internal activity (Daniel and Keegan et al., 1989), between results and its determinants (Brignall et al., 1991), between the four balanced scorecard (BSC) perspectives (Kaplan and Norton 1992), and the multiple perspective of the stakeholders of the performance prism (Kennerley and Neely, 2000). Researchers and practitioners frequently in defining goals and performance measures of RSC have utilized BSC. Yellepeddi et al. (2005) proposed a BSC approach and utilized ANP method for the development of effective RSC performance evaluation system. Ravi et al. (2005a) also used BSC in combination with ANP technique for the selection of alternatives for EOL computers. Shaik and Kader (2012) developed a RSC performance evaluation framework by using BSC approach and AHP. In

another study, they developed a RSC performance evaluation system by integrating BSC characteristics with performance prism (Shaik and Kader, 2014). Huang et al. (2012) proposed a RSC performance evaluation system for recycled computers from the financial, operational procedure, learning and growth, reverse relationship and flexibility perspectives. The balanced scorecard based performance evaluation systems allow managers to look at the business from four divergent important perspectives: customer, internal business, innovation and learning, and finance (Kaplan and Norton, 1992). The merits of the approach are to integrate strategic, operational, and financial measures to consider the balanced key perspectives of performance.

Apart from balanced scorecard approach, other approaches have been applied for the performance evaluation of RSC. Biehl et al. (2007) developed a performance evaluation system for carpet recycling by evaluating the system's economic and environmental performance. Paksoy et al. (2011) developed a mathematical model for investigating a number of operational and environmental performance measures including total transportation costs, total environmental costs, emission rates, customer demand. Huang et al. (2015) tested the relationship of government agencies, suppliers, and customers with economic, and environmental performance of RSC by using survey method and statistical analysis. They found that government agencies, suppliers, and customers are positively correlated with RSC performance. Bai and Sarkis (2013) introduced a performance evaluation framework by using AHP approach for evaluating the economic, environmental, and the operational performance. Kannan et al. (2009) proposed a fuzzy MCDM model for the selection of alternative environmental management practices in RSC. Most of the performance evaluation systems for RSC considered factors related to economic performance, and environmental performance (Harris and Towmey, 2014; Tsoulfas et al., 2002; Huang et al., 2012). It is evident that environmental and social factors are not given much attention. However, in last few years,

environmental and social factors have become an important part of the performance of organizations (Siegel, 2009).

Presley et al. (2007) introduced the relationships of RSC to sustainability by considering social aspect along with economic, and environmental aspects, and developed a strategic sustainability evaluation framework. These three aspects of sustainability performance, economic, environmental and social are known as triple bottom line (TBL) (Elkington, 1997). The economic aspects of sustainability helps in generating enough cash flow for handling returns persistently (Vachon and Mao, 2008), and the environmental aspects of sustainability helps in protecting the environments (Bansal, 2002) while the social aspects of sustainability support the conception and improvement of skills, along with health and support fairly and equitably to everyone (McKenzie, 2004). In other words, organizations must adopt a long-term horizon and let economic growth sustain the social progress and the environment (Lamming and Hampson, 1996). According to Hubbard (2009), seventy five per cent of large organizations within the wider business environment are reported as being under pressure to develop non-financial measures of performance in addition to traditional measures. They need to measure business success in terms of social and environmental performance along with economic performance. Recently, Nagalingam et al. (2013) developed a framework for evaluating performance in terms of estimated utilization value of a manufactured product optimizing recovery cost, landfill waste, and quality characteristics. There are very few studies evaluating economic, environmental, and social aspects of RSC. Govindan et al. (2013a) developed a fuzzy multi criteria decision-making model for evaluating sustainability performance of a supplier based on TBL approach. Darbari et al. (2015) incorporated TBL concept of sustainability into the RSC and designed a distribution network for computer manufacturing organization. Venkatesh et al. (2015) also developed a model for performance evaluation of third party service providers by using data envelopment analysis. Nikolaou et al.

(2013) developed a framework for evaluating RSC social responsibility, based on the TBL approach in which performance measures were selected using Global Reporting Initiative guidelines. Based on the literature review, various performance measures from triple bottom line aspects are categorized and explained in table 2.6.

Table 2.6 Performance criteria and sub-criteria

Criteria/Sub-Criteria	Authors	Remarks
Economic Performance		
Return On Investment	Carter (2005), Presley et al. (2007), Lee et al. (2009a), Jacobs et al. (2010), Darbari et al. (2015)	Positive "Return On Investment" may be a major driver for the stake holders to adopt RSC practices
Recapturing Value	Meade and Sarkis (2002), Ravi et al. (2005b), Kannan et al. (2009)	Recapturing Value from recovered products and it is important for sustaining the RSC operations
Logistics Cost Optimization	Hu et al. (2002), Wee et al. (2003), Lee et al. (2009b), Darbari et al. (2015)	It involves the optimization of cost of product acquisition, collection, inspection, and transportation
Recycle Efficiency	Olugu et al. (2011), Michelini and Razzoli (2011)	Recycling Efficiency refers to the recycling of used product back into the useful raw material
Annual Sales	Shaik and Kader (2012), Shaik and Kader (2014)	Annual amount of products sold to the customers that are remanufactured or refurbished
Disposal Costs	Knemeyer et al. (2002), Wee et al. (2003), Presley et al. (2007), Lai et al. (2013)	Cost of disposal of returned products ensuring safety and protecting environment which cannot be remanufactured or recycled
Environmental Performance		
Minimum Energy Consumption	Vachon and Mao (2008), Nikolaou et al. (2013), Bhattacharya et al. (2014), Liu et al. (2014a)	Minimization of the energy consumption for the product/material recovery
Optimum use of raw material	Johnson (1998), Hu et al. (2002), Meade and Sarkis (2002), Hervani et al. (2005), Clemens (2006)	Minimization of the raw material used which are not good for environment
Transport Optimization	Hervani et al. (2005), Clemens (2006), Vachon and Mao (2008), Krikke (2011)	Transport optimization refers to the minimization of fuel consumption vehicle fleet and reduction in emission
Reduced Packaging	Handfield et al. (2002), Carter and Easton (2011), Shen et al. (2013)	Minimum use of packaging material containing less toxic materials
Use of recycled material	Hervani et al. (2005), Field and Sroufe (2007), Sarkis et al. (2010a), Winkler (2011), Azevedo et al. (2011)	Materials reused from the product recovery or percent of product reclaimed
Waste Reduction	Rao and Holt (2005), Carter (2005), Presley et al. (2007), Vachon and Mao (2008), Azevedo et al. (2011), Lai et al. (2013)	Waste to landfill and recycling waste reduction for the reduction of negative environmental impact

Criteria/Sub-Criteria	Authors	Remarks
Social Performance		
Community complaints	Presley et al. (2007), Garza, (2013), Bai and Sarkis (2014)	Number of complaints received and the number of complaints resolved to the satisfaction of the complainants
Customer Health and Safety	Nikolaou et al. (2013), Bhattacharya et al. (2014)	Lost time injury rate, sickness absence rate, number of incidents of non-compliance concerning health and safety impacts of products and services
Stake Holders Participitation	Presley et al. (2007), Nikolaou et al. (2013)	Stake holder engagement and empowerment
Employment Stability	Sarkis et al. (2010b), Hasan (2013)	Attrition rate of employees
Donations to Community	Jindal and Sangwan (2013b), Nikolaou and Evangelinos (2013)	Donations and in-kind support to community
Employee Benefits	Nikolou et al. (2013), Nikolaou and Evangelinos (2013)	Comparative wage levels

2.7 Research Gaps Analysis

Research gaps were analyzed based on the literature review carried out for the research work. The research gaps are enumerated and explained in the following section.

- It is evident from the literature review that RSC is in evolving phase and very few studies have been carried out in developing countries like India.
- It was found that select issues like adoption and implementation, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC are not covered in depth and need to be explored.
- Drivers and barriers play an important role in decision making of the RSC adoption and implementation effectively. Rogers and Tibben-Lembke (1999) suggested that there are number of factors affecting RSC practices. The presence or absence of these factors can become drivers or barriers to RSC implementation in an industry. It is evident from the literature review that these factors vary from sector to sector and are country specific. No study was found on identification and prioritization of critical success factors in Indian electronics industry.

- Forecasting product returns is one of the important issues for both short term and long term strategic and operational planning of RSC. Models developed for forecasting product returns for reuse, recycle, remanufacturing by considering different business scenarios are discussed in the literature. However, none of them considers the factors like consumer behaviour, customs and culture, demographics, rules and regulations collectively, which can make a very different scenario and may affect forecasting product returns substantially. No study was found to analyze the sufficiency of these factors for forecasting product returns.
- Outsourcing has been the key word for the corporate world in present business scenario. Organizations are more focused towards core competencies and outsourcing other activities. It is observed that RSC is not the part of core business of many organizations and it is a potential candidate for outsourcing. Outsourcing RSC activities and decision for selecting third party RSC service providers were discussed frequently in the literatures and various mathematical, analytical, and MCDM have been applied for decision making. Most of the studies provided the information on outsourcing part of RSC activities, mainly collection and transportation. No comprehensive frame work was found for decision making with respect to completely or partly outsourcing the RSC activities.
- Various operational and strategic decision making models and frameworks have been developed for the selection of best disposition options. Disposition options such as reuse, recycle, remanufacture, return to manufacturer/supplier, return to stock, resale, balance inventory, donate were discussed in the literature. Disposition options for particular industry in different business scenario are yet to be explored. There is a need of developing comprehensive strategic decision models and frameworks for identifying conditions under which each alternative must be selected. There are very few studies on disposition decisions and it offers a lot of potential for future research.

- Unlike forward supply chain, research on RSC performance evaluation system is fragmented and limited. Even after comprehensive literature review, it is difficult to identify key performance indicators of RSC and their performance evaluation. There is need of developing compehensive performance evaluation system for RSC based on borad perspectives of RSC.

2.8. Concluding remarks

The contemporary research in RSC is in evolving phase and a lot of work is being carried out on different issues of RSC in various sectors. It is evident that research is diversified across the sectors and no single sector has been explored in-depth particularly in developing country like India. Perusal of literature indicate that select issues of RSC such as adoption and implementation, forecasting product returns, disposition decisions, outsourcing, and performance evaluation of RSC are not explored in-depth. The research work explores and examines these issues in context of Indian electronics industry through survey method, case study, and development of models in subsequent chapters. The next chapter discusses the research methodology and framework to be utilized for the research work.

Chapter 3. Research Methodology

3.1 Introduction

This chapter deals with the research methodology, which is to be followed for the research work. Research methodology is defined as “an operational framework within which the facts are placed so that their meaning can be seen more clearly” (Leedy, 1989). It is a “procedural framework within which the research is conducted” (Remenyi and Williams, 1998). In this chapter, research objectives are established based on the research gap analysis and these objectives are enumerated in section 3.2. The research is based on the pragmatism research philosophy, which emphasizes on the research objectives as the primary component of research. A deductive research approach with mixed-method approach has been adopted for the research. Each research method has its own strength but also has its shortcomings. Mixed method allows one to overcome the shortcomings of other method and has several advantages including enhancement of validity and reliability of data coming from multiple sources (Bryman, 2007, Abowitz and Toole, 2009). It has been used by many authors such as Chileshe et al. (2016b); Dubey et al. (2015); Kwateng et al. (2014); and Sharif et al. (2012) in the area of supply chain management. The survey method and the case study method along with methodologies for the development of models and decision frameworks have been utilized for the research work. First, data were collected through survey of Indian electronics industry with the help of questionnaire, and hypotheses were tested and results are analyzed. In second phase, case study method was utilized which involves qualitative data collected through semi structured interviews, and the results from the survey were validated through in-depth analysis of the case study. The survey method and case study method are found to be dominant methodologies for exploring RSC issues (Rubio, 2008, Govindan et al., 2015). This chapter also discusses the various methodologies used for developing the models, and decision frameworks.

3.2 Research objectives

Based on the research gaps analysis discussed above following research objectives were established for the research work:

- To study and analyze Indian electronics industry in reference to reverse supply chain
- To analyze different issues of reverse supply chain through questionnaire based survey
- To Identify and study the critical success factors (drivers or barriers) for reverse supply chain implementation
- To study the strategic development issues for effective reverse supply chain
- To develop a forecasting model for product returns
- To develop a decision framework for disposition options
- To develop a decision framework for outsourcing
- To develop a framework for performance evaluation of reverse supply chain
- To validate the findings of research through case studies

To achieve these objectives, a research framework was developed as shown in figure 3.1. A questionnaire was developed and pilot testing was carried out to improve the quality and contents of the questionnaire. CSFs factors were identified with the help of literature review and discussion with the experts. A model has been developed for prioritization of CSFs for Indian electronics industry. These factors helped in understanding the electronics industry and development of questionnaire. A survey was conducted for collecting the information on various issues and strategic development RSC in Indian electronics industry. Select issues for the research work were examined through hypotheses testing of theoretical development of these issues. A case study was conducted subsequently for the validation of the findings related to these issues. Various models and decision frameworks have been developed for these select issues. The research methodology is discussed in detail in the following sections.

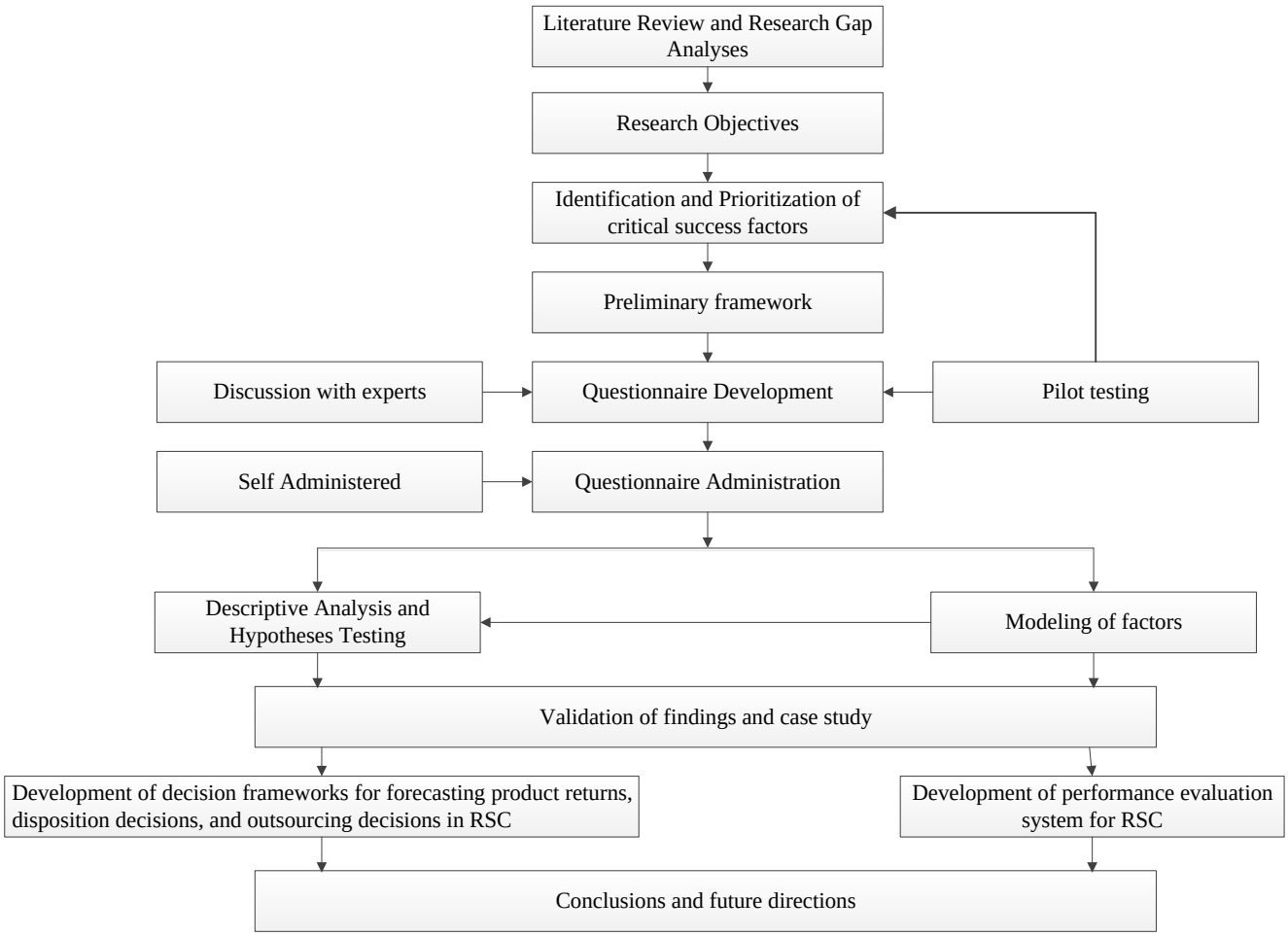

Figure 3.1 Research framework for the study

3.3 Research methodology

A comprehensive literature review was carried out and research gaps were identified. Research objectives were established based on research gap analysis. The research methodology is the procedural framework within which research work was proposed to be conducted to reach a set of conclusions about these objectives. The different stages of research work are explained as follows.

3.3.1 Research philosophy

A research philosophy includes underlying assumptions such as theories, facts and frameworks based upon which research is carried out. The adopted philosophy influences the interpretations made by the researchers. According to Roberts et al. (2003) and Saunders (2011), positivist, interpretivist, realist, and pragmatist are the widely used research philosophies in the area of supply chain management. The research work is based on the pragmatism research philosophy, which emphasizes on the research objectives as the primary component of research.

3.3.2 Research approach

There are two type of approaches discussed in the literature. One is deductive approach and another is inductive approach. The deductive approach involves the development of hypotheses based on existing theory, and designing research strategy to test the hypotheses (Robson, 2002; Nutt and Wilson, 2010). The Inductive approach involves the development of theories after the data collection, observations, and their analysis. The research work is more close to the deductive approach.

3.3.3 Data collection

The research work utilizes quantitative and qualitative data both on sequential basis. First, data was collected through survey of Indian electronics industry with the help of questionnaire, and results were analyzed and utilized for the case method. In second phase, case study method was utilized which involves qualitative data collected through semi structured interview. Both primary and secondary sources were used for the data collection and validation. The data collection and analysis are discussed in detail in respective chapters.

3.3.4 Time horizons

According to Saunders (2011), a cross-sectional study is concerned with the study on a particular phenomenon at a particular time while longitudinal study is concerned about change and development over a given period. Most of the research projects undertaken for academic courses are necessarily time constrained. Therefore, cross-sectional study has been utilized for the research work.

3.3.5 Research methods

There are number of research strategies suggested by Saunders (2011). The research work involves survey and case study methods along with various methodologies for the development of the models and frameworks. The survey method helped in quantitative assessment of the current RSC practices and issues related to RSC in Indian electronics industry. On the other hand, case study method helped in qualitative in-depth assessment of small set of cases (Ellram 1996). Although single case is recommended for the case method if the researchers are associated with the organization (Yin, 2003), the single case study may be used in conjunction with survey method to clarify some of the results of survey method more comprehensively (Flynn et al., 1990). Survey method along with single case study has been utilized for the research work.

3.3.5.1 Survey method

Survey method was utilized to explore the current RSC practices and issues in Indian electronics industry, and to test and validate the hypotheses through statistical analysis. The survey is most commonly used method in the area of RSC (Srivastava, 2008; Bernon et al., 2011; Lai et al., 2013, Ravi and Shankar, 2015). It relies on the factual data and allows the data collection of adequate size in a very economical way through questionnaires. A survey of

Indian electronics industry was carried out for the data collection with the help of the questionnaire. The questionnaire was developed and administered through google forms, and responses were collected in the google forms. Questionnaire validity and reliability was ensured by checking non-response bias, Cronbach's alpha and other statistical measures. Data was analyzed to explore the current RSC practices in Indian electronics industry, and select issues were analyzed through study of their relationship. Hypotheses were tested by using structural equation modelling after ensuring their fitness for test through measurement model analysis of different constructs. Partial Least Squares Path Modeling (PLSPM) was utilized for the research work because of small size and it combines the features of factor analysis and multiple regression. Although PLSPM is old techniques, its application in the area of supply chain management were found recently by researchers such as Abdullah and Quaddus (2012), Razak et al. (2016), Segarra-Oña et al. (2014), Parvadavardini et al. (2015), and Clauss and Spieth (2016). The detailed systematic approach and application of survey method for the research work are discussed in chapter 5.

3.3.5.2 Case study method

Robson (2002) defined the case study as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence". The case study is utilized to have a thoughtful context of the research and the processes being practiced (Morris and Wood, 1991). According to (Yin, 2003) "A case study is an empirical enquiry that (i) Investigates a contemporary phenomenon within its real life context, especially when, and (ii) The boundaries between phenomenon and context are not clearly evident". Case study is used as a research method if contextual factors are taken into account but at the same time limit the extent of the analysis (Eisenhardt, 1989; Voss et al., 2002). The case study method has been utilized frequently in the area of RSC (Brito

and Dekker, 2002; Lau and Wang, 2009; Dowlatshahi, 2010; Silva et al., 2013; Kinobe et al., 2015). The research methodology adopted for the case study is based on literature review and discussion with executives of the organization. A systematic approach was developed which includes the establishing objectives, instrument development, data collection, data analysis, and dissemination. A single case with embedded issues was considered in conjunction with survey method to access the findings comprehensively. The data for the case study were collected both from primary and secondary sources. Information and data collected from the field visits to the organization and other secondary sources were used to analyze the issues in RSC. The findings of the case study are discussed in the light of findings of survey of Indian electronics industry. The detailed systematic approach and application of case method for the research work are discussed in chapter 6.

3.3.5.3 Modelling based research methods

The research work has utilized various methodologies for the development of models, and decision frameworks. The methodologies, used in the research work are described in the following section.

3.3.5.3.1 Fuzzy-TOPSIS methodology

Fuzzy-TOPSIS methodology is utilized for prioritizing critical success factors in RSC. Multi-criteria decision-making (MCDM) is one of the powerful tools widely used for dealing with unstructured problems containing multiple and potentially conflicting objectives (Lee and Eom, 1990). A number of approaches have been developed for solving MCDM problems such as analytical hierarchy process (AHP), data envelopment analysis (DEA), and TOPSIS. These are traditional MCDM approaches which measures the alternative ratings and weights of the criteria's in crisp or precise numbers, which depends upon decision makers preferences (Wang

and Lee, 2009). The TOPSIS method by Hwang and Yoon (1981) was developed to provide solutions to the MCDM problems. Kim et al. (1997) stated the advantages of TOPSIS as follows.

- A sound logic that represents the rationale of human choice;
- A scalar value that accounts for both the best and worst alternatives simultaneously; and
- A simple computation process that can be easily programmed into a spreadsheet.

TOPSIS is useful particularly when there are large number of alternatives and criteria. In such cases, methods like AHP, which require pair wise comparison, are avoided. In addition, TOPSIS has the fewest rank changes reversals when an alternative is added or removed in comparison to other MCDM methodologies (Zanakis et al., 1998). The traditional TOPSIS method considers ratings and weights of criteria's in crisp numbers. However, crisp data are inadequate to represent the real life situation since human judgements are vague and they cannot estimate exact numeric values. In such situations, the fuzzy set theory is useful to capture the uncertainty of human judgments. Zadeh (1965) first introduced fuzzy set theory into MCDM including TOPSIS as an approach for effectively working with the vagueness and ambiguity of the human judgements. In fuzzy-TOPSIS, all the ratings and weights are defined by means of linguistic variables. There are following two main characteristics of fuzzy systems observed by Kahraman et al. (2007):

- Fuzzy systems are suitable for uncertain or approximate reasoning, especially for the system with a mathematical model that is difficult to derive; and
- Fuzzy logic allows decision-making with estimated values under incomplete or uncertain information.

Because of all these advantages, fuzzy logic has been combined with TOPSIS known as fuzzy-TOPSIS methodology. It has been applied in number of studies such as competitive advantage of shopping web-sites (Sun and Lin, 2009), e-sourcing problem (Singh and Benyoucef, 2011), traffic police centres performance (Sadi-Nezhad and Khalili-Damghani, 2010), an integrative sustainability performance assessment (Escrig-Olmedo et al., 2015), green supply chain evaluation (Kusi-Sarpong et al., 2015), and selection of green logistics service provider (Zhang et al., 2016). The detailed systematic approach and application of Fuzzy-TOPSIS methodology for the research work are discussed in chapter 4.

3.3.5.3.2 Graph Evaluation and Review Technique

Graph Evaluation and Review Technique (GERT) is utilized for forecasting product returns in RSC. GERT network is applied because of its ability to address the uncertainties, randomness, stochastic nature of the return process. One of its strengths is the graphical illustration, which is insightful and easy to understand. GERT not only provides the visual picture of the RSC system but also helps in determining the generating function for the expected time of product returns in a much easier way. According to Pritsker and Whitehou (1966), GERT is used for analyzing networks that contained activities that had a probability of occurrence associated with them, and treating the plausibility that the time to perform an activity was not constant but random variable. Because of all these advantages, GERT developed by Pritsker (1966) has been utilized for developing a model for forecasting product returns. It has been applied by many authors such as Wang et al. (2011); Samaranayake and Kiridena (2012); and Pandian and Rajan, 2015. The detailed systematic approach and application of GERT for the research work are discussed in chapter 7.

3.3.5.3.3 Graph Theory and Matrix Approach

Graph Theory and Matrix Approach (GTMA) has been utilized for the development of disposition decisions framework in RSC. Selection of the disposition option depends on the number of attributes and available options for the returned products disposition. Various MCDM approaches like TOPSIS, AHP, ANP, and DEA are available for providing solutions to such type of problems. TOPSIS and AHP can be utilized if the attributes are independent, which is not the case of proposed problem (Rao and Padmanabhan, 2006). While ANP does not represent hierarchical relationship among attributes, DEA requires more computation and if the number of attributes are large, then DEA may be a poor discriminator of good and poor performers (Rao and Padmanabhan, 2006). GTMA does not have such limitations. Therefore, research work has utilized GTMA for the selection of best disposition option. GTMA is a systematic and logical decision making approach. The advanced theory of graphs has been utilized for the modeling and analysis of various systems. It is proved beneficial for solving real life problems in the field of science and technology (Chen, 1997, Jense and Gutin, 2000). Faisal (2012), Sabharwal and Garg (2013), Gupta and Singh (2015) utilized GTMA for various supply chain studies. The detailed systematic approach and application of GTMA for the research work are discussed in chapter 7.

3.3.5.3.4 GTMA and Sustainable balanced scorecard

GTMA has been combined with sustainable balanced scorecard (SBSC) for developing an outsourcing decisions framework in RSC. Traditionally, the concept of balanced scorecard (BSC) has been primarily designed for the measurement of system performance, Authors have frequently utilized BSC perspectives as criteria for the selection of best outsourcing alternatives (Tjader et al., 2014; Ravi et al., 2005; Shaik and Kader, 2012). Merits of the BSC approach are to integrate strategic, operational, and financial attributes to consider the balanced key

perspectives of the decision-making. BSC approach allows managers to look at the business from four divergent important perspectives: customer, internal business, innovation and learning, and finance (Kaplan and Norton 1992). However, this approach does not consider the important sustainable development of the organizations such as TBL aspects of sustainability. TBL include economic, environment, and social dimensions of the sustainability. However, it does not provide the holistic view of an organization. In order to have advantages of both the approaches, TBL aspects of sustainability have been combined with BSC to develop SBSC for selecting the attributes and sub-attributes for outsourcing decisions framework in RSC. GTMA has been utilized for the selection of best outsourcing alternatives by determining the value of permanent function, referred as outsourcing index. Researchers such as Epstein and Wisner (2001) for effective sustainability management, and Nikolaou and Tsalis (2013) have developed SBSC by using Global Reporting Initiative indicators for geek organizations. The detailed systematic approach and application of GTMA and SBSC for the research work are discussed in chapter 7.

3.3.5.3.5 Fuzzy-AHP and Extent Analysis approach

Fuzzy-AHP and Extent Analysis has been combined with TBL aspects of sustainability for developing performance evaluation system of RSC. Saaty (1980) developed AHP approach to solve complex problems involving multiple criteria by considering number of criteria and sub criteria at different levels of hierarchy for prioritizing the alternatives. The basic procedure of AHP is to

- break down a complex, unstructured situation into its elements,
- arrange the elements into a hierarchy order,
- make pair-wise comparison and establish priorities among the elements in each level of the hierarchy, and

- Synthesize the judgments to obtain the overall priority of alternatives considering the priorities of the previous levels.

Applications of the approach have been reported in numerous fields such as project selection, budget allocation, transportation, healthcare, manufacturing, and supplier selection (Harker 1989; Wang et al. 2004; Avikal et al. 2014). The traditional AHP method considers ratings and weights of criteria's in crisp numbers. Because of advantages of fuzzy logic discussed above in fuzzy TOSIS methodology, fuzzy logic has been combined and used along with AHP, which is known as fuzzy AHP approach. Buckley et al. (1988) addressed the concept of consistency into fuzzy AHP (FAHP) model by using geometric mean method. Logarithmic least square method was developed to obtain triangular fuzzy weights from a triangular fuzzy comparison matrix (Weck et al. 1997). The direct fuzzification method by Csutora and Buckley (2001), fuzzy preference programming by Mikhailov (2003), two-stage logarithmic programming by Wang et al. (2005), and extent analysis method by Chang (1992) are some of the examples of fuzzy AHP. Among all of these approaches, the extent analysis method introduced by Chang (1992) has been employed in many applications due to its computational simplicity. Compared to eigenvectors, which are used to calculate the weight vectors in conventional AHP, FAHPEA is simple and easy to implement. Chang (1996) introduced triangular fuzzy numbers for handling FAHPEA. It has been applied by previous researchers such as Kaharaman et al. (2003); Chan and Kumar (2007); Lee et al. (2009), Shaw et al. (2012); and Yayla et al. (2015). The detailed systematic approach and application of FAHPEA methodology for the research work are discussed in chapter 8.

3.6 Concluding remarks

In this chapter, a research framework to achieve the research objectives has been developed. The research stages such as research philosophy, research approach, data collection, time horizon, and research methods have been justified and developed for the research work. The research work reviews the salient features of the mixed research comprised of the survey method and case method. A systematic approach for validation of the findings of the survey method through case study method and subsequent development of models and decision frameworks are also discussed. The chapter also discussed about the justification of various methodologies, used for the development of models and decision frameworks on select issues of RSC. Fuzzy-TOPSIS methodology will be utilized for the identification and prioritization of critical success factors in RSC. GERT, GTMA, GTMA & SBSC has been selected for the development of decision frameworks for forecasting product returns, disposition decisions, and outsourcing decisions respectively. The chapter also discussed about the FAHPEA for the development of performance evaluation system of RSC. The chapter justified the use of these methodologies for the development of decision frameworks along with their utilization in past research in the area of RSC. In next chapter, identification and prioritization of critical success factors for Indian electronics industry are discussed.

Chapter 4. Identification and Prioritization of Critical Success Factors for Reverse Supply Chain

4.1 Introduction

Adoption and implementation of RSC involves several factors, which are useful in decision-making and RSC effectiveness. A critical analysis of the factors affecting RSC can provide valuable information for RSC implementation (Ravi, et al., 2005a). Rogers and Tibben-Lembke (1999) suggested that there are number of factors affecting RSC practices. The presence or absence of these factors can become drivers or barriers to RSC implementation. A thorough study of CSFs and their ordered implementation is essential for successful RSC implementation. This chapter attempts to identify and prioritize various CSFs for RSC implementation in Indian electronics industry by using fuzzy TOPSIS methodology.

4.2 Identification of CSFs for RSC implementation

Several useful factors for RSC implementation are pointed out in the literature review discussed in chapter 2. Many CSFs are common to all of these studies and these factors can be utilized as base for discussion with expert from Indian electronics industry. Twelve CSFs were identified after pertinent literature review and discussion with the experts from Indian electronics industry. These factors are shown in figure 4.1. These factors are explained as follows.

4.2.1 Legislation

Legislation refers to the regulations or acts passed by the Government authorities to minimize the effect of end of life products on environment. Ravi et al. (2005a) defined legislation as one of the determinants of RSC. In fact, focusing on environmental concerns is partly enforced by

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government legislation (Prendergast and Pitt, 1996). Recently, the Goverment of India has instituted e-waste Management Rules 2011 & 2016 for electrical and electronics organization in the country. Experts were of the opinion that sooner or later Indian electronics manufacturers will have to comply with these e-waste management rules.

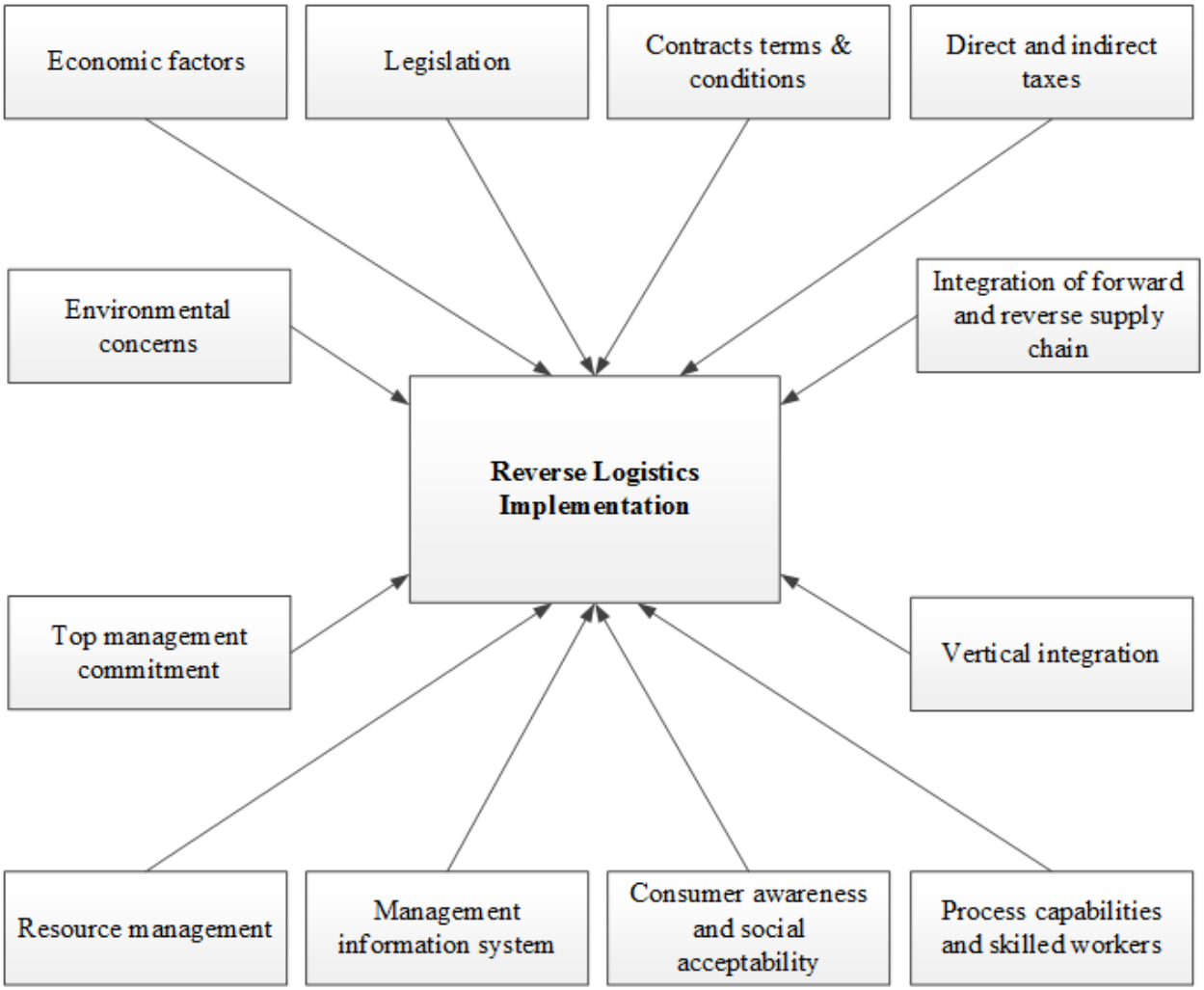

Figure 4.1 Identified CSFs for Indian electronics Industry

4.2.2 Economic factors

Economics is seen as one of the driving force to RSC related recovery options, where the organization receives both direct as well as indirect economic benefits (Ravi et al. 2005a). In a survey of mobile manufacturing organization in Hong Kong, Chan and Chan (2008) found that

majority of the returned products add extra value to the organization. The recovery of the products for remanufacturing, repair, reconfiguration, and recycling can lead to profitable business opportunities (Andel 1997). Guide and Wassenhove (2003) discussed an example of the US organization ReCellular, which had gained economic advantage by refurbishing of cell phones. Experts comment that RSC practices are assumed to be cost driven activity and the organizations in India are waiting for the response from each other for adopting these practices.

4.2.3 Environmental concerns

Environmental concerns are significant force reshaping the economy as well as one of the most important issues of great concern of the businesses (Murphy and Poist 2003). Many organizations have focused on RSC operations because of environmental reasons (Rogers and Tibben-Lembke, 1999). Many power projects and real state projects have been delayed because of environmental clearances from the Goverment of India. In last few years, the Goverment of india has taken several initiatives because of environmental concerns. This is an indication for other industries to focus on environmental concerns.

4.2.4 Top management awareness

Top management awareness is very crucial for the success of RSC implementation. A sincere and committed effort from the top management is essential for the successful deployment of RSC programs (Carter and Ellram, 1998). Mintzberg (1973) stated that top management awareness is the dominant factor of corporate endeavors. Top management awareness is needed to provide clear vision and value to RSC programs. Top management awareness motivates employees and ensures full support from seniors.

4.2.5 Resource management

Miller and Shamsie (1996) categorized the resources into property-based resources and knowledge-based resources. Property-based resources including the physical facility, automated machines and equipment, financial and human resource are regarded as critical indicators of the competitiveness (Das and Teng, 2000). Knowledge-based resources including managerial resources and technology are also critical for the success of RSC. Availability and effective utilization of both types of resources is essential for realizing the true value potential of RSC. Human resource is crucial for RSC implementation. Organizations encounter challenges while implementing RSC because of lack of knowledge of RSC among their employees. Organizations, willing to adopt RSC should develop their own expertise through various education and training programs for promoting the environmental awareness in their organization.

4.2.6 Management information system

Information support is one of the important factors for developing linkages to achieve efficient RSC operations (Daugherty et al., 2005). RSC information flows may be well managed by using the sophisticated information systems. Information and communication technologies assume tremendous importance in RSC, which are needed to process and transmit information (Brito and Dekker, 2002). IT enablement is necessary and one of important factors for effective communication (Kumar et al. 2013). Availability of prompt and accurate information may help managers in achieving operational efficiency in their RSC. This is an important tool but cost is a concern. Integration with the current management information system is also crucial for successful implementation.

4.2.7 Contracts terms & conditions

Contracts terms and conditions with suppliers are one of the most important factors for RSC implementation. Most of the parts and components are procured by the electronics organizations from the overseas suppliers. Legal terms and conditions with the contractors are important. Organizations may enforce regulatory requirements in the contacts to meet the criteria for parts and components from environmental perspectives. Contractor's ability to meet regulatory criteria's and corresponding costs are still to be analyzed.

4.2.8 Direct and Indirect taxes

According to Sharma et al. (2011), complex flows of goods as well as diverse bought-in services engrained in the RSC create a high degree of tax complexity and lead to unexpected tax exposures and costs. Direct and indirect taxes are very important factor for the financial consideratrion. Tax structure is very complex because of involvement of import-export, and no special consideration is given to the remanufactured products in India. In fact, direct and indirect taxes for remanufactured products need to be relooked for the promotion of environmental friendly practices.

4.2.9 Integration of forward and reverse supply chain

Integration of forward and RSC implies simultaneous management of material, information, and monetary flows as suggested by Fleischmann et al. (2001), and Tibben-Lembke and Rogers (2002). According Mehrbod et al. (2014) the integration of forward and RSC has attracted growing attention with the stringent pressures of customer expectations, environmental concerns, and economic factors. Greater resource utilization can be achieved through integration of forward and reverse supply chain. In general, responsibility of RSC is assigned to the supply chain department rather than having separate department. Therefore, integration

of forward and RSC plays an important role because same people work on both forward and RSC. One of the biggest concern is the impact of RSC on forward supply chain. Experts fear that integration may disturb the whole of the forward supply chain. Employee's awareness and motivation for the change is essential for successful integration.

4.2.10 Joint Consortium

Experts' opinion that joint consortium may be one of the options for handling returns just like telecommunication towers sharing in India. Earlier, organizations had their own telecommunication towers. Later on organizations started tower sharing and now one tower in a particular region is being used by many organizations reducing their investments and operational costs. There is need of exploring such kind of business model for example common collection center for all used cellular phones may reduce collection cost and economies of scale can be achieved. Joint consortium may be helpful, particularly in case of recycling where high investment in equipment is required and high product volume is necessity for operational efficiency.

4.2.11 Process capabilities and skilled workers

Experts state that process capabilities and skilled workers are very important for successful implementation. Workers must be skilled enough to work simultaneously both on manufacturing and re-manufacturing efficiently. Machines, equipment and tools must also be developed to perform both the operations simultaneously as much as possible. This is important for effective utilization of resources because of uncertainty of product returns.

4.2.12 Consumer awareness and social acceptability

Sharma et al. (2011) stated that the awareness of RSC could bring economic benefits by recovery of the returned product for use. Research suggests that there is an increasing customer demand for green products and organizations need to engage in environment friendly supply chain practices (New, 2000). Social acceptability of remanufactured products among the Indian consumers and society is crucial for the success of RSC. Most of the remanufactured products in India are sold in secondary market at lower prices because lower income group purchases these products. Consumer awareness and social acceptability will not only increase the product returns but also will motivate them to buy refurbished or remanufactured products at reasonable price.

4.3 Fuzzy-TOPSIS methodology

Fuzzy-TOPSIS methodology based on the technique introduced by Chen (1997) is selected for this study. The technique given by Chen (1997) is selected for prioritizing CSFs because this technique gives better result in comparison to other techniques. The following steps of fuzzy-TOPSIS are used for the proposed research.

Step 1

Collect the required data containing linguistics terms. A proper scale must be chosen to represent the data accurately and more precisely. Respondents must be asked to choose the best alternative among the linguistics terms for a given question. Linguistics terms must be converted into the fuzzy number. For example, triangular fuzzy numbers are used for the study and a 5-point scale having the linguistic terms low (L), fairly low (FL), medium (M), fairly

high (FH), and high (H); are selected as shown in figure 4.2. Triangular fuzzy numbers are used because it is intuitively easy for the respondents to use and calculate.

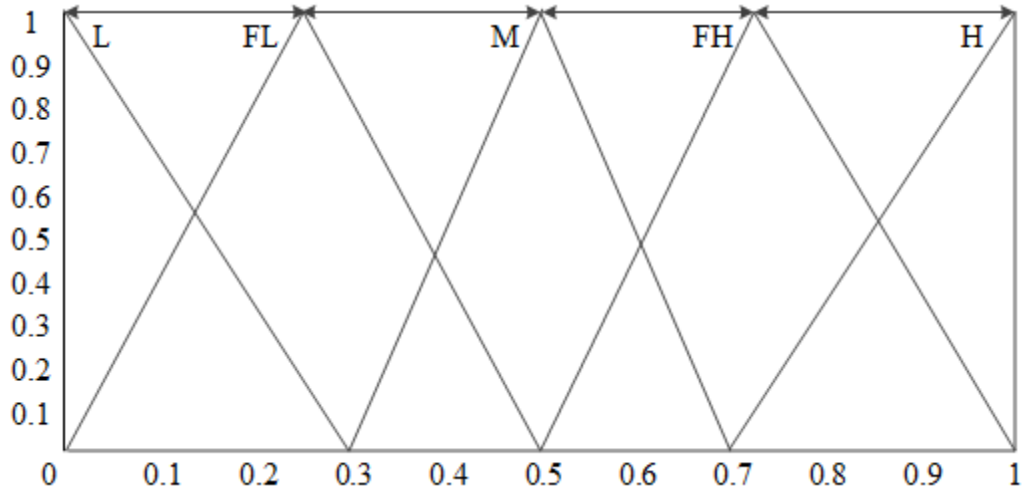

Figure 4.2 Linguistics scales and triangular fuzzy numbers

The fuzzy number of each linguistic term is determined with the help of the figure 4.2. Fuzzy numbers for the selected linguistics terms are presented in table 4.1.

Table 4.1 Linguistics terms and corresponding fuzzy number

Linguistic term	**Fuzzy Number**
Low	(0.0,0.1,0.3)
Fairly Low	(0.1,0.3,0.5)
Medium	(0.3,0.5,0.7)
Fairly High	(0.5,0.7,0.9)
High	(0.7,0.9,1.0)

Step 2

The TOPSIS method evaluates the following fuzzy decision matrix

$$D = \begin{matrix} x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mj} & \dots & x_{mn} \end{matrix} \quad (4.1)$$

Where $x_{ij}(=(a_{ij}, b_{ij}, c_{ij}))$ is a fuzzy number corresponding to the linguistic term assigned by the i^{th} Decision Maker (DM) to the j^{th} factor. $i = 1,2, \ldots \ldots \ldots, m$ are the number of DMs and $j = 1,2, \ldots \ldots \ldots, n$ are the number of factors (CSFs).

Step 3

This step includes neutralizing the weight of decision matrix and generating fuzzy un-weighted matrix (R).

To generate R, following relationship can be applied.

$$R = [r_{ij}]_{mXn}, r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad (4.2)$$

Where $c_j^* = \max_i c$

Step 4

Calculate the weighted normalized decision matrix.

$$V = [v_{ij}]_{mXn};\ i = 1,2,\ldots\ldots m;\ j = 1,2,\ldots\ldots n \quad (4.3)$$

The weighted normalized value v_{ij} is calculated as

$$v_{ij} = r_{ij} * w_j; \quad (4.4)$$

Where w_j is the weight given to each of the DMs, $w_j = (1,1,1,1,1) \forall\ j\ \epsilon\ n$, because all the DMs have been given same weight for this study

Step 5

Determine the ideal and negative-ideal solution for the CSFs.

$$A^* = \{v_1^*, v_2^*, \ldots \ldots . v_n^*\} \quad (4.5)$$

$$A^- = \{v_1^-, v_2^-, \ldots \ldots . v_n^-\} \quad (4.6)$$

Since the positive and negative ideal solutions introduced by Chen (1997) are used for the research. The following terms are used for ideal and negative ideal solution.

$$v_j^* = (1,1,1) \tag{4.7}$$

$$v_j^- = (0,0,0) \tag{4.8}$$

Step 6

Calculate the sum of distances from positive and negative ideal solution for each factor.

$$D_j^* = \frac{\sum_{i=1}^{m} d(v_{ij} - v_i^*)}{m},\ j = 1,2,.....n \tag{4.9}$$

$d(v_{ij} - v_i^*)$ is the distance between two fuzzy numbers which can be calculated by using the vector algebra. For example distance between two numbers $A1(a_1, b_1, c_1)\ and\ A2(a_2, b_2, c_2)$ can be calculated as

$$d(A1 - A2) = \sqrt{\frac{1}{3}[(a_2 - a_1)^2 + (b_2 - b_1)^2 + (c_2 - c_1)^2]}$$

Similarly, the separation from the negative ideal solution is given as

$$D_j^- = \frac{\sum_{i=1}^{m} d(v_{ij} - v_i^-)}{m},\ j = 1,2,.....n \tag{4.10}$$

Step 7

Calculate the relative closeness to the ideal solution. The relative closeness with respect to A* is defined as

$$C_j = D_j^- / (D_j^* + D_j^-),\ j = 1,2,.....n \tag{4.11}$$

Step 8

Prioritize the preference order based on the order of the values of C_j.

4.4 Case illustration of the fuzzy-TOPSIS methodology

The fuzzy-TOPSIS methodology has been utilized for the prioritization of CSFs in Indian electronics industry. Five decisions makers were selected from the five organizations of Indian electronics industry. The profile of the organizations are illustrated as follows.

4.4.1 Profile of the organizations

Five experts from electronic organizations participated in this study. Profiles of the decision makers and their respective organization are explained as follows:

First decision maker (DM1) is a supply chain manager in a mobile manufacturing organization, ABC-1 limited which is interested in RSC implementation. DM1 has responsibility of developing a RSC system for the organization. The organization is a pioneer in the manufacturing of mobile phones. The organization has received many awards for best quality and management practices. The organization has annual turnover of approximately $1.2 b in last financial year from its business in India. In India, the organization has a mobile handset manufacturing facility in Chennai. At present the organization has approximately 110,000 outlets including 50,000 stores selling organization`s product exclusively. The organization has outsourced its forward logistics to other computer manufacturing organizations for distributing products to different city warehouses. The local distribution to the dealers and retailers is carried out by the organization`s own employee. Recently, organization has decided to develop its own forward logistics system along with development of RSC system.

Second decision maker (DM2) is a logistics manager in an electronics manufacturing organization, ABC-2 limited. The organization manufactures, assembles and distributes a comprehensive range of electronic hardware including computer peripherals in India. The organization has annual turnover of approximately $ 2b in last financial year. The organization has manufacturing facilities in Chennai, Pondicherry, and Uttaranchal. It has strong chain of

distributors and dealers with 92,500 outlets in 8,700 towns in India. The organization has not given much attention to the EOL computers. Green awareness and implementation of e-waste management rules prompted them to think about implementing RSC system for handling product returns and EOL computers. This organization is also interested in working towards sustainability.

Third decision maker (DM3) is a logistics manager in an electronics manufacturing organization, ABC-3 limited. The organization assembles and distributes consumer electronics products in India including refrigerators, LCD, CTV, mobiles, washing machines and microwave ovens. The organization has annual turnover of approximately $1.2 b in last financial year. The organization has manufacturing facility in NCR Delhi having more than 1200 employees. The organization has mother warehouse in the NCR Delhi and four child warehouses in the cities Chennai, Ahmadabad, Kolkata, and Bangalore in India. The organization has its own well established distribution system and logistics facilities. The major challenge for the organization is to implement RSC without effecting the current operations. This organization has already taken several green initiatives including take back program for used products.

Fourth decision maker (DM4) is a marketing executive looking after north India region of an electronics manufacturing organization, ABC-4 limited. The organization manufactures, assembles and distributes color television sets in India. The organization has annual turnover of approximately USD 30 million. The organization has manufacturing facility in NCR Delhi having more than 350 employees. The organization has strong chain of distributors and dealers. The organization manufactures CTV mainly in rural markets in India. Growing demand for the LCDs and LEDs may hamper the demand of CTVs in future for the organization. The organization is willing to introduce new electronics product in the market for sustaining their business.

Fifth decision maker (DM5) is vice president of operations management of an electronics organization, ABC-5 limited engaged in manufacturing of consumer electronics products. The organization has annual turnover of approximately $1.5b in last financial year. The organization has manufacturing facilities in NCR Delhi and Bangalore in India. The organization has more than 1500 employees. The organization has strong supply chain for forward operations and willing to integrate it with its RSC.

4.5 Results and discussion based on the methodology

In order to prioritize the CSFs for RSC implementation in Indian electronics industry, twelve factors Legislation, Economic factors, Environmental concerns, Top management awareness, Resource management, Management information system, Contracts terms & conditions, Direct and Indirect taxes, Integration of forward and reverse supply chain, Joint Consortium, Process capabilities and skilled workers, and Consumer awareness and social acceptability were identified in section 4.3. These factors are considered for the prioritization. Five decision makers DM1, DM2, DM3, DM4, and DM5 were asked to rate the importance of the above mentioned each CSF on a 5-point scale having the linguistic terms low (L), fairly low (FL), medium (M), fairly high (FH), and high (H). The decision-makers used the linguistic variables shown in table 4.1 to assess the importance of the CSFs. A decision matrix was prepared based on the responses received from the DMs shown in the table 4.2.

Table 4.2 Decision matrix using linguistic variable

S.No.	CSFs for RSC implementation	DM1	DM2	DM3	DM4	DM5
1	Legislation	FH	FH	M	H	M
2	Economic factors	H	H	H	M	M
3	Environmental concerns	FH	M	M	M	M
4	Top management awareness	H	FH	H	H	H
5	Resource management	FH	FH	H	H	H
6	Management information system	M	L	M	M	M
7	Contracts terms & conditions	FH	FH	FH	FH	H
8	Direct and Indirect taxes	M	M	L	L	L
9	Integration of forward and reverse supply	FL	FL	M	M	M
10	Joint Consortium	FH	FH	M	M	FH
11	Process capabilities and skilled workers	FL	FL	L	L	L
12	Consumer awareness and social acceptability	FH	H	M	M	M

Low (L), Fairly Low (FL), Medium (M), Fairly High (FH), High (H)

As mentioned in the first step of fuzzy-TOPSIS methodology, triangular fuzzy numbers were used to convert linguistics variable into fuzzy numbers. By converting the fuzzy linguistic variables into triangular fuzzy numbers using table 4.1, the fuzzy decision matrix D was obtained. Fuzzy decision matrix for CSFs is shown in table 4.3.

Table 4.3 Fuzzy decision matrix

CSFs for reverse logistics implementation	**DM1**	**DM2**	**DM3**	**DM4**	**DM5**
CSF1: Legislation	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.7,0.9,1.0)	(0.3,0.5,0.7)
CSF2: Economic factors	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF3: Environmental concerns	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF4: Top management commitment	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
CSF5: Resource management	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
CSF6: Management information system	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF7: Contracts terms & conditions	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1.0)
CSF8: Direct and Indirect taxes	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.0,0.1,0.3)	(0.0,0.1,0.3)
CSF9: Integration of forward and reverse supply chain	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF10: Vertical integration	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.5,0.7,0.9)
CSF11: Process capabilities and skilled workers	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.0,0.1,0.3)	(0.0,0.1,0.3)
CSF12: Consumer awareness and social acceptability	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)

In the next step, un-weighted fuzzy decision matrix R was developed with the help of equation (4.2). Further steps were followed to obtain the weighted fuzzy normalized decision matrix by using equation (4.3)-(4.4). Since equal weightages are given to each DM, both weighted and unweighted matrix is same. Weighted fuzzy normalized decision matrix is shown in table 4.4.

Table 4.4 Weighted fuzzy normalized decision matrix

CSFs for reverse logistics implementation	**DM1**	**DM2**	**DM3**	**DM4**	**DM5**
CSF1: Legislation	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.7,0.9,1.0)	(0.3,0.5,0.7)
CSF2: Economic factors	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF3: Environmental concerns	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF4: Top management commitment	(0.7,0.9,1.0)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
CSF5: Resource management	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
CSF6: Management information system	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF7: Contracts terms & conditions	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1.0)
CSF8: Direct and Indirect taxes	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.0,0.1,0.3)	(0.0,0.1,0.3)	(0.0,0.1,0.3)
CSF9: Integration of forward and reverse supply chain	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
CSF10: Vertical integration	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.5,0.7,0.9)
CSF11: Process capabilities and skilled workers	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.0,0.1,0.3)	(0.0,0.1,0.3)	(0.0,0.1,0.3)
CSF12: Consumer awareness and social acceptability	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)

Equation (4.5)-(4.6) were used to find the ideal and negative-ideal solutions for the CSFs. The distance D^* and D^- of each CSF is derived, respectively, by using equations (4.7)-(4.10). The closeness coefficient C for each CSF is obtained by using equation (4.11). Values of D^-, D^* and closeness coefficient C for each CSF are shown in table 4.5. CSFs are prioritized based on values of these closeness coefficient for CSF. The prioritization of CSFs is shown in table 4.5.

Table 4.5 Closeness coefficient matrix and Priority

S.No.	**CSFs for RSC implementation**	D^*	D^-	**C**	**Priority**
1	Legislation	0.384	0.673	0.637	5
2	Economic factors	0.32	0.736	0.697	3
3	Environmental concerns	0.489	0.565	0.536	8
4	Top management awareness	0.214	0.844	0.797	1
5	Resource management	0.246	0.813	0.768	2
6	Management information system	0.562	0.541	0.491	9
7	Contracts terms & conditions	0.285	0.633	0.689	4
8	Direct and Indirect taxes	0.736	0.32	0.303	11
9	Integration of forward and reverse supply chain	0.603	0.452	0.429	10
10	Joint Consortium	0.415	0.642	0.607	6
11	Process capabilities and skilled workers	0.813	0.246	0.232	12
12	Consumer awareness and social acceptability	0.42	0.634	0.601	7

The overall prioritization of CSFs is

CSF4>CSF5>CSF2>CSF7>CSF1>CSF10>CSF12>CSF3>CSF6>CSF9>CSF8>CSF11

The most important CSF among the twelve CSFs is top management awareness and the least important CSF is process capabilities and skilled workers. Top management awareness has the highest value and is prioritized as top most factors. Top management initiates, guides, and motivates the organization for adoption and implementation of RSC implementation. Resource management is prioritized as 2nd most important CSF. Previous studies also support this result for example Richey et al. (2005) showed that resource commitment makes RSC more efficient and more effective. Economic factors are prioritized 3rd and are very crucial for RSC implementation. Recaptured value is the major source of direct revenue generation from RSC implementation. Ravi et al. (2005a) also found economic factor as important factor for RSC implementation. Contracts terms & conditions is prioritized 4th and are very important particularly, to meet environmental objectives. Most of the outsourced parts/components may be reprocessed by enforcing legal terms and conditions for reprocessing returned products. Contract terms and conditions are particularly important in cases where component/products are procured from other countries. Legislation is prioritized 5th and has become very important for Indian electronics industry after enforcement of e-waste management rules and regulations in 2011 & 2016. This finding is also supported by earlier research (Walker et al. 2008). Joint Consortium is ranked 6th and has great influence on the success of RSC implementation in Indian electronics industry. Joint Consortium is important to have co-operation with other organizations to minimize the e-waste and to recapture maximum value while satisfying regulatory requirements. Joint consortiun may help in achieving economies of scale and also, may help in reduced investment for a joint reprocessing / recycling facilities. Consumer awareness and social acceptability is prioritized 7th. This factor is very important to achieve a good volume and quality of returned products, and to gain profit through resale of remanufactured products. Ravi and Shankar (2005) also found lack of awareness as a chief barrier of RSC benefits in Indian automobile supply chain. Environmental concerns is ranked

8th and is mentioned by most of previous research on RSC implementation. Management information system is ranked 9th. Daugherty et al. (2005) also suggested that development of information technology capabilities might give better performance in reverse supply chain organizations. Integration of forward and reverse supply chain is ranked lower. This may be because organizations do not want to disturb forward supply chain and less importance is given to this integration. Direct and Indirect tax is ranked 11th and does not make much difference to implementation because of being part of the government policy, and industry does not have any control on this factor. Process capabilities and skilled workers are ranked 12th. This factor is important for the operational performance of RSC. However, it may require considerable investment in education and training of employees.

4.6 Concluding remarks

The study provides the valuable information on RSC implementation for Indian electronics Industry. The research identified twelve CSFs for RSC implementation in Indian electronics industry. The identified factors are somewhat similar to those identified by various researchers in other studies. Still, factors like contracts terms & conditions, direct and indirect taxes, joint consortium, process capabilities and skilled workers are rarely included in other studies. Analysis of the findings shows that top four prioritized factors top management awareness, resource management, economic factors, and contracts terms & conditions are the most important among all twelve factors. Briefly, the contributions of this study are summarized as follows.

- The study provides the insight of previous research on RSC implementation.
- Identifies the CSFs based on past literature review and experts opinion for successful RSC implementation.

- The research work proposes a framework for evaluating and prioritizing the CSFs by using Fuzzy-TOPSIS methodology for RSC implementation.

The findings of the research will help the managers and academicians in the development of RSC strategies and practices in Indian electronics industry. These CSFs can also be used for RSC implementation in other sectors of Indian industry. Like other studies, this study also has some limitations. This study is conducted using five experts from the Indian electronics industry. Future studies may consider larger sample size to assess the methodology and the effectiveness of the proposed solution to enable generalization. In future, Researchers may utilize other methodologies including other MCDM methodologies and may compare the results. Future studies may be carried out to identify organization specific or product specific RSC implementation.

Chapter 5. Descriptive Analysis and Hypotheses Testing

5.1 Introduction

It is evident from the literature review that RSC plays an important role in managing the commercial product returns and end of life products both effectively. This chapter explores the current practices of RSC activities in Indian electronics industry and examines the various issues in the industry. According to (Prahinski and Kocabascoglu, 2006), survey method is an appropriate tool for exploring an Industry and its RSC activities. The research work aimed at exploring the Indian electronics industry through survey of the industry. A survey was conducted in Indian electronics industry to explore the current trends, status, issues related to RSC. RSC issues related to forecasting product returns, disposition decisions, and outsourcing were explored and hypotheses were developed to test the association of these issues with economic, environmental, social performance of RSC. Hypotheses were tested after accessing the fitness of data through measurement model. Complexities of relationships were studied by using Partial Least Squares Path Modeling (PLSPM) approach of structural equation modelling which takes into account the causal relationship among latent variables. PLSPM was utilized for the research work because of small size and it combines the features of factor analysis and multiple regression. The hypotheses development, observations from the survey, hypotheses testing, and findings of the study are explained in the following sections.

5.2 Hypotheses development

In past, RSC has been considered as cost driven activity and focus was mainly on economic aspects of the performance. In a survey of Indian manufacturing industry, Ravi and Shankar (2015) found that organizations are adopting RSC practices because of economic reasons. Now, organizations are also addressing the environmental concerns through contribution of RSC (Xie & Breen, 2012). RSC can make significant contribution to the sustainable

development of an organization (Sarkis et al., 2010a). According to Govindan et al. (2013), there is need to explore the RSC planning and decision-making to improve the sustainability performance of an organization. However, there is little research on the social aspects of RSC (Devika et al., 2014). The research work considers the all three aspects of sustainability, and examines the impact of select issues on economic, environmental, and social performance of RSC. There are number of issues of RSC, which influences its performance. Research gap analysis indicates that forecasting product returns, disposition decisions, and outsourcing have not been explored much. Therefore, the research work developed the hypotheses on these issues in order to examine their impact on the economic, environmental, and social performances of RSC. Hypotheses are tested for relationship of these issues with economic, environmental, and social performance of RSC based on survey of Indian electronics industry. The hypotheses developments are explained in the following section.

5.2.1 Hypotheses related to forecasting product returns and RSC performance

Uncertainties in business environment can influence business decisions and influence the performance of an organization. Uncertainty is a fundamental issue in today's business and organizations need to combat them to be competitive in the market (Sutcliffe and Zaheer, 1998). Uncertainty in terms of quantity, quality, and timing of product returns significantly influences the RSC planning and performance both from strategic and operational perspectives. One of the effective methods to mitigate these uncertainties is forecasting product returns. Forecasting product returns is important for designing the RSC network, layout planning of the recovery facilities as well as the planning and control of recovery processes (Xiaofeng and Tijun, 2009; Ayvaz et al., 2014). Forecasting product returns consists of forecasting in terms of quality, quantity, and timing. These indicators, accuracy in forecasting quantity, quality, and timing of product returns are denoted by AF1, AF2, and AF3 respectively. Accuracy in

forecasting these components determines the overall accuracy in forecasting product returns. According to Toktay et al. (2000) consideration of explanatory factors could increase the accuracy in forecasting product returns. These explanatory factors vary from sector to sectors and changes with demographics. Therefore, it is important to understand the effect of explanatory factors for product returns in Indian electronics industry. The factors for the study, considered include FF1: Sales volume and price of product (Hess and Mayhew, 1997), FF2: Marketing and advertisement budget (Hanafi et al., 2007), FF3: Resistive return policy (Reda, 1998; Bernon et al., 2011), FF4: Product life cycle (Benedito and Corominas, 2013), FF5: Ease and cost of return (Toktay et al., 2000), and FF6: Environmental consciousness of consumers (Srivastava and Srivastava, 2006). Data for the forecasting indicators and factors were collected through responses of questions in section 5 of the questionnaire. In order to test whether these factors influence accuracy in forecasting, a hypothesis H_{1a} was developed. The hypothesis developed is as follows.

H_{1a}: Factors considered in forecasting product returns influences the accuracy in forecasting product returns.

Accuracy in forecasting for product returns in terms of quantity, quality and timing is important to achieve the optimum level of performance (Tibben-Lembke and Rogers, 2002). In order to test impact of accuracy in forecasting, three hypotheses have been developed to test whether accuracy in forecasting is positively associated with economic, environmental, and social performance of RSC. These hypotheses were tested in responses of questions in section 5 and section 10 of the questionnaire. The hypotheses developed are as follows.

H_{1b}: Accuracy in forecasting product returns is positively associated with economic performance of RSC.

H_{1c}: Accuracy in forecasting product returns is positively associated with environmental performance of RSC.

H_{1d}: Accuracy in forecasting product returns is positively associated with social performance of RSC.

5.2.2 Hypotheses related to disposition decisions and RSC performance

Products are returned by the users through product acquisition process, and are transported for inspection and separation. Inspection/sorting are carried out for determining the action which recovers the most value from the returned product, and products are disposition accordingly. Focus has been more on economic gains through recapturing value from the returned product. In an empirical study, Khor and Udin (2012) examined the impact of disposition decision on the economic and environmental performance of the organizations. They collected the data through survey of electronics industry in Malaysia and found that disposition decisions significantly influences the performances of the organizations. According to Attia (2015), returned product disposition decision effectiveness are positively correlated with the RSC performance. Disposition decisions are often industry or product-specific and its effectiveness depend upon number of factors such as price/value, cost to transport, shelf life of the product, and market demand patterns (Skinner et al., 2008). These factors are enumerated in table 2.5, and discussed in section 2.6.4 of chapter 2, literature review. These factors are classified into the external and internal factors. EF: External Factors include EF1: Economic factors, EF2: Environmental factors, EF3: Social factors, EF4: Customer behavior, EF5: Market conditions, and EF6: Government rules and regulations. IF: Internal Factors include IF1: Processing cost, IF2: Volume of returned products, IF3: Importance of quality of returned products, IF4:

Importance of supply chain capabilities, and IF5: Importance of product value. In order to examine the impact of these factors on the effectiveness of disposition decisions, the hypotheses are developed to test whether these factors influence the effectiveness of disposition decisions in RSC. These hypotheses were tested in responses of questions in section 9 of the questionnaire. The hypotheses developed are as follows.

H2a: External Factors considered in disposition decisions influences the effectiveness of disposition decisions.

H2b: Internal Factors considered in disposition decisions influences the effectiveness of disposition decisions.

Disposition decisions play an important role in the performance of RSC. Skinner et al. (2008) empirically examined the correlation between disposition decisions and RSC performance. They found that different disposition decisions are positively correlated with economic performance, operational responsiveness, and operational service quality. According to Khor and Udin (2012), the effectiveness of disposition returned products effectively positively influences the economic, and environmental performance. Although, RSC can make significant contribution to the sustainable development of an organization (Sarkis et al., 2010a), social dimension of sustainability is not given much attention (McWilliams et al., 2014). The research work considers the social performance evaluation also along with economic, and environmental performance to explore the sustainability aspect of RSC. The research work further test whether effectiveness of disposition decisions is positively associated with economic, environmental, and social performance of RSC in Indian electronics industry. These hypotheses were tested in responses of questions in section 9 and section 10 of the questionnaire. The hypotheses developed are as follows.

H2c: Effectiveness of disposition decisions is positively associated with economic performance of RSC.

H2d: Effectiveness of disposition decisions is positively associated with environmental performance of RSC.

H2e: Effectiveness of disposition decisions is positively associated with social performance of RSC.

5.2.3 Hypotheses related to outsourcing decisions in RSC

Outsourcing is a very common phenomenon in global business. The outsourcing in RSC is also very popular because of nature of business and several other advantages. Manufacturers may adopt RSC by choice or by force but they have to decide whether performing the activities themselves or outsourcing to a third party (Martin et al., 2010). Govindan et al., (2012) observed that RSC outsourcing might reduce costs as the third party can get the advantage of the economies of scale, which is otherwise not available to the organizations. In addition, by outsourcing RSC, organizations can reduce their asset base, and deploy the capital released for other productive usage. Other advantages include low costs, less uncertainty, lower capital investment, more focussed on core competency, more flexibility, better customer responsiveness, and better excess to new technology (Kumari et al., 2015). The research identified some of the key outsourcing benefits such as OB1: Focus on core activity of the organization, OB2: Economical to outsource RSC activities, OB3: Third party may provide sophisticated technology, system, and better services, OB4: Reduces investment in RSC facilities, OB5: More flexibility, OB6: Better customer satisfaction responsiveness, OB7: Third Party takes responsibility of entire product life cycle, and OB8: Third party may have better environment management. There is general perception that all these benefits directly or indirectly led to the economic performance of RSC. Recently, Govindan et al. (2013)

developed a model for evaluating the economic, environmental and social performance of a supplier. In the study, they reported that an organization could assure sustainability even if they are outsourcing RSC activities. The research work examined whether outsourcing contributed to the economic, environmental, and social performance of RSC. The hypotheses are developed to test whether the benefits are positively associated with economic, environmental, and social performance of RSC. These hypotheses were tested in responses of questions in section 8 and section 10 of the questionnaire. The hypotheses developed are as follows.

H3a: Benefits of outsourcing RSC are positively associated with economic performance of RSC.

H3b: Benefits of outsourcing RSC are positively associated with environmental performance of RSC.

H3c: Benefits of outsourcing RSC are positively associated with social performance of RSC.

5.3 Data collection

The following steps are followed for collecting the data through survey method.

5.3.1 Questionnaire development

A questionnaire was developed based on the comprehensive literature review and research gap analysis. Survey was divided into eleven sections aimed at gathering information in Indian electronics industry related to current practices, trends and their opinion to measure the theoretical constructs of RSC. The four experts from the academics and five RSC practitioners from Indian electronics industry as pilot testing reviewed the preliminary draft of questionnaire. Reviewers evaluated the survey draft and commented on the clarity, and on the contents of the representativeness of the questionnaire. Suggestions were incorporated and questionnaire was improved before the distribution for the the data collection.

Survey form was developed with the help of Google forms. The survey questionnaire is available in appendix 1A. The questionnaire mentioned that the individual responses and related information would be kept confidential.

5.3.2 Questionnaire administration

The questionnaire was self-administered, and the survey for the research work with target population of manufacturers in Indian electronics industry was conducted through Google form, Online. The survey link was sent on email addresses of the respondents with a cover letter. Some of the responses were collected through personal contacts during the industry visits. Now a days, web based survey are being used by many researchers because of less time required, ease of availability, real time data compilation, and lower cost than other surveys. The questionnaires were sent to the respondents in two phases. Initially, 300 forms were sent to different organizations through Google forms and responses were analyzed. Further, additional 400 more emails were sent to other organizations. Total 700 emails were sent to the electronics industry for the survey, 253 responses were received, and 45 were incomplete so discarded. An effective response rate of 29.73 % was achieved which is sufficient for the study. While higher response rate is better, response rates of more than 20% are desirable in operations management research (Malhotra and Grover, 1998).

5.3.3 Respondent's Profile and non-response bias

In two phases, total 700 emails were sent to the electronics industry for the survey. Overall, 208 responses were found suitable for the research work. The profile of the organizations and respondents are shown in figure 5.1, 5.2, and 5.3. Organizations, participated in the survey belong to low to medium to large size as evident from the turnover shown in figure 5.1 and number of employees shown in figure 5.2. Respondents who have participated in the survey

represent different levels of management as shown in figure 5.3 and mostly belong to logistics department, supply chain department, marketing & sales, corporate strategy, and human resource departments.

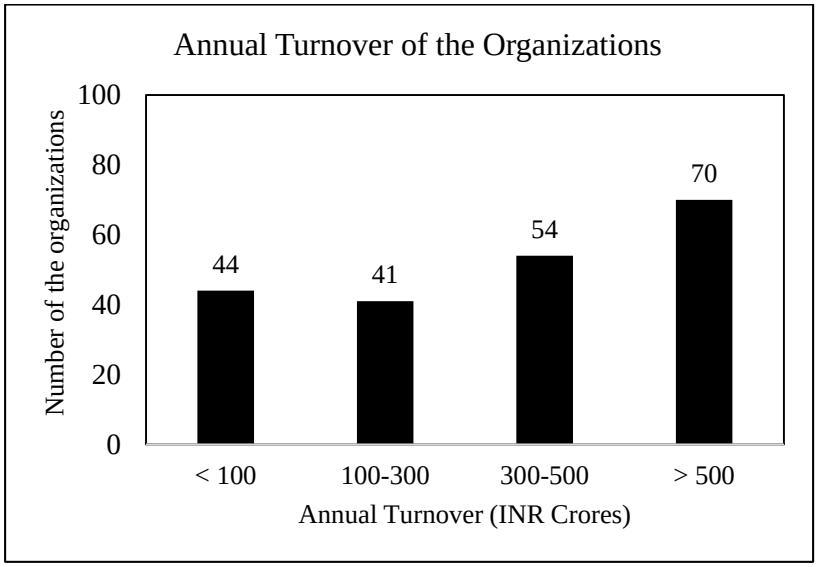

Figure 5.1 Annual turnover of the organizations

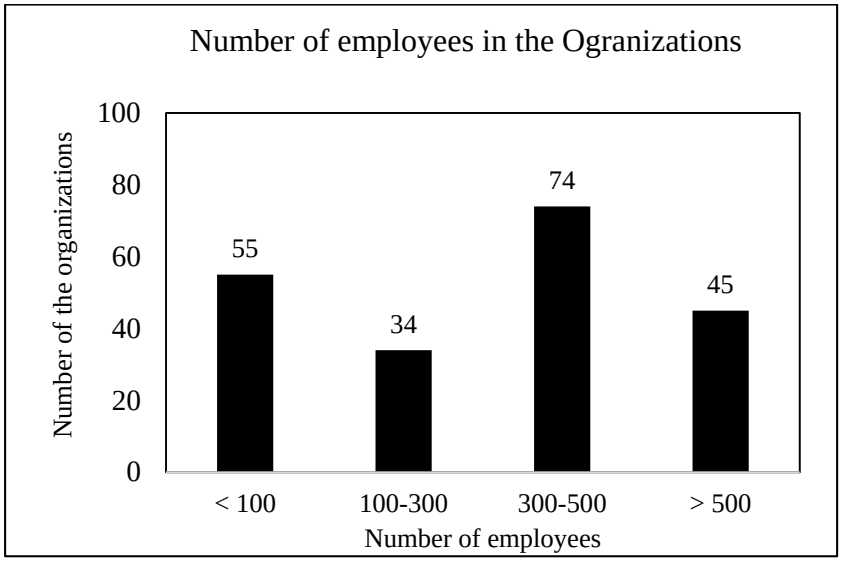

Figure 5.2 Number of organizations and employees

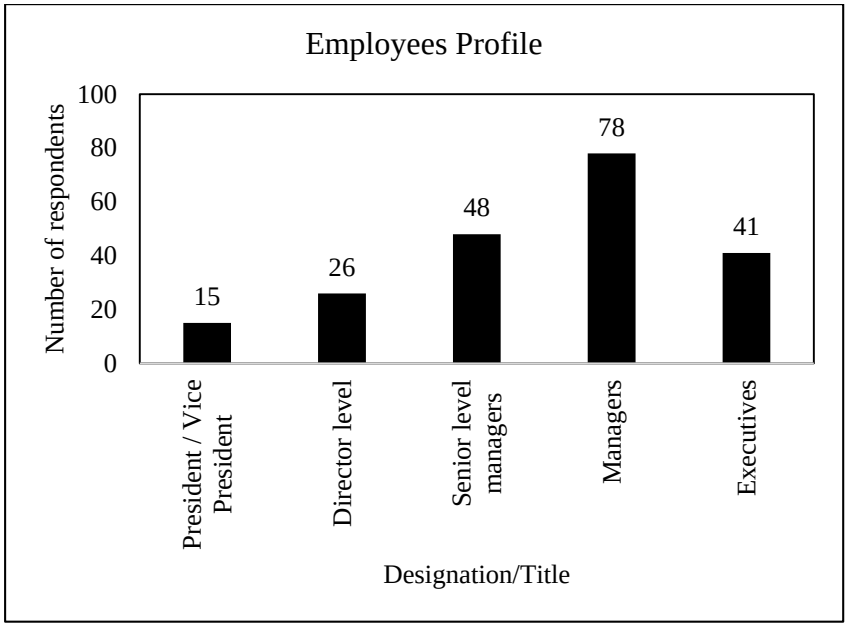

Figure 5.3 Number of organizations and respondent's designation

Non-response bias with web-based survey was accessed by splitting the sample into two groups based on receiving date of the responses. Early response group consisted of 102 responses and late response group consisted of 106 responses. The t-test was performed on the difference in early response group and late response group. It yielded no statistically significant difference between the mean of two groups ($p < 0.05$). In addition, statistical tests show that there are no significant difference among samples in terms of size of the organizations, number of employees, and their designations. A five point Likert scale with level of agreement of respondent as 5 for Very High, 4 for High, 3 for Medium, 2 for Low and 1 for Very Low; was utilized for the research work.

5.4 Observations from the survey

Observations from the Indian electronics industry were analyzed to understand the current practices, status, trends, and issues related to the RSC. Respondents were asked to express their opinion on a five point Likert scale with level of agreement of respondent as 5 for Very High, 4 for High, 3 for Medium, 2 for Low and 1 for Very Low. Observations from the survey are

analyzed, and explained in the following sections. The results were analyzed and Cronbach's alpha was determined for the constructs by using the software MINITAB version 17. The value of Cronbach's alpha ranges from 0.72 to 0.82, which are more than the minimum prescribed value of 0.5 for an exploratory study by Nunnally (1978). The values of mean and standard deviations are shown in the respective figures. The value of standard deviation is determined to have an understanding of diversification among opinions and for any further analysis, if needed.

5.4.1 Important trends in Indian Electronics Industry

Total nine number of factors were considered to analyze the trends in the Indian electronics industry. Factors were considered based on the orientation towards RSC. Mean values and standard deviations are shown in figure 5.4. It is observed from the results that increase in import of parts / components / products have the highest mean value (3.51) and standard deviation of 0.96. Saripalle (2015) also reported that Indian electronics industry is import intensive industry and import of parts / components are increasing with increase in products demand. The importance of consumer protection and service (mean = 3.30) is indicated second highest important trend because of growing importance of e-commerce (mean = 3.24) and increased competitiveness in the market (mean = 3.00). The growth of annual turnover of organizations (mean = 3.14) because of huge consumer demand and e-commerce also resulted in increased flow of product returns (mean = 3.17) (Prakash and Barua, 2016, Jena and Sarmah, 2015). Although the mean value (2.51) of shortening of product life cycle is between fairly low and high, manufacturers are under pressure to introduce new and innovative products because of the competitiveness in market which resulted in shorter product life cycle. Impact of pressure of corporate social responsibility (mean = 2.43) and e-waste management rules 2011 and environmental guidelines (mean = 2.32) is not much in comparison to other factors.

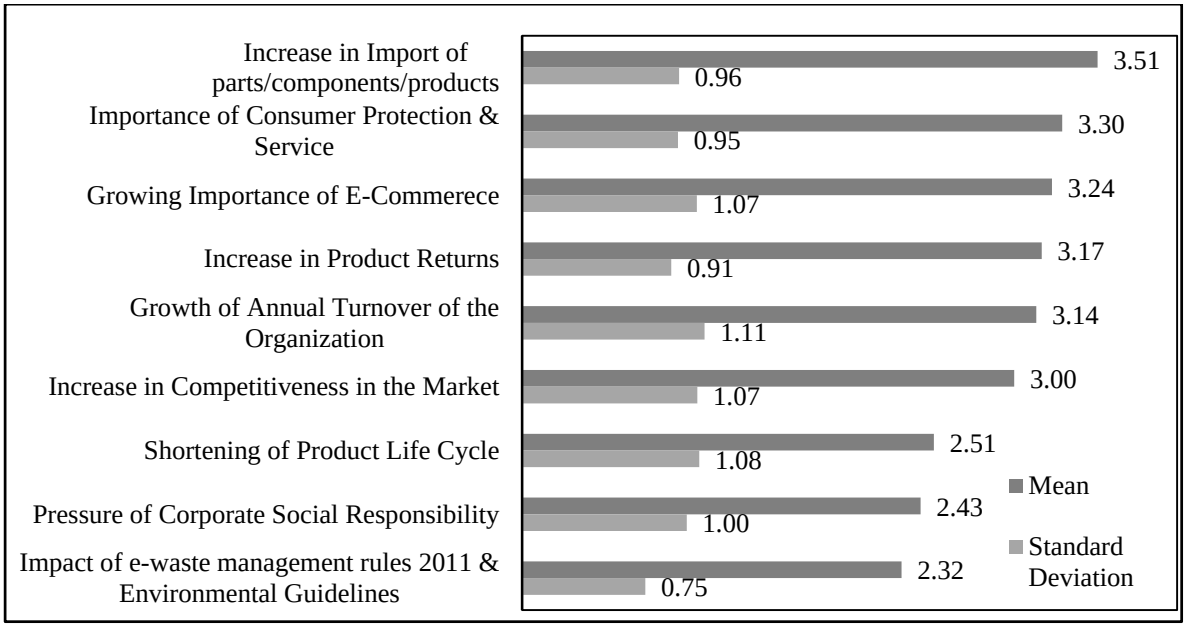

Figure 5.4 Important trends in Indian Electronics Industry

5.4.2 Important trends in RSC of Indian Electronics Industry

RSC has gained attention in Indian electronics industry because of increased flow of product returns, and concern for the e-waste management. The figure 5.5 shows the results of survey related to important trends in RSC of Indian electronics industry. It is clear that RSC has been given a lot of importance (mean = 3.91) and it has become a part of corporate strategy of the organizations (mean = 3.59). According to Saripalle (2015), RSC has been considered as major activity of core business of many organizations because of increased flow of product returns in Indian electronics industry. The availability of RSC experts in the market (mean = 3.02) is surprisingly higher against the general perception in the industry. The use of IT in RSC (mean = 2.93), and availability of third party service providers (mean = 2.88) are slightly lower than other trends. While other issues indicate fairly low importance in the industry, investment in RSC activities (mean = 1.94) and profit from RSC activities (mean = 1.93) are also trending low in comparison to other factors.

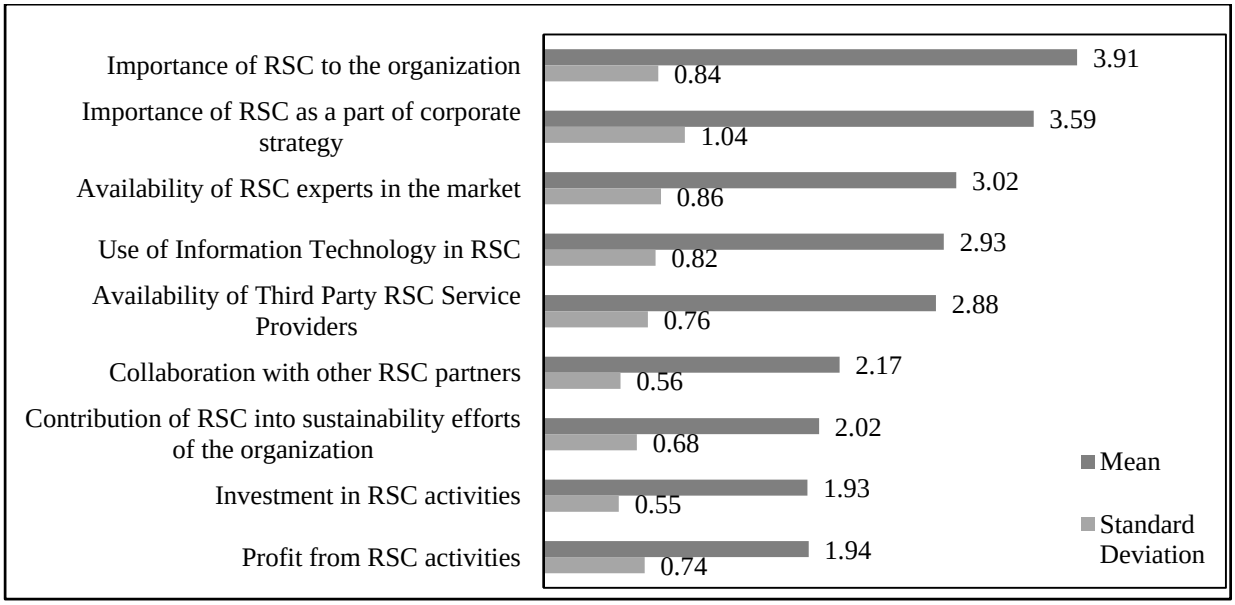

Figure 5.5 Important trends in RSC of Indian electronics industry

5.4.3 Motivation for RSC in Indian electronics industry

In recent years, organizations have realized that RSC is a necessity for managing the commercial and end of life product returns. RSC offers several benefits such as economic, environmental, and social benefits, and gives competitive advantages to the organizations. In order to understand the motivational factors, respondents were asked to indicate the level of motivation for adapting and implementing RSC practices in their organization. Results of the survey are shown in figure 5.6. The results indicate that better customer service (mean = 3.56), compliance with government rules and regulations (mean = 3.22), improving corporate image (mean = 3.21), and higher recapturing value (mean = 3.18) from RSC activities are the key motivational factors for attraction towards RSC. In a survey of Indian manufacturing industry, Ravi and Shankar (2015) also found that better customer service, increase in corporate image, increase in turnover are the major benefits perceived by the industry. Pressure of the stakeholders (mean = 2.38) and increase in profitability (mean = 2.94) have lower value than other factors and have not been given much importance.

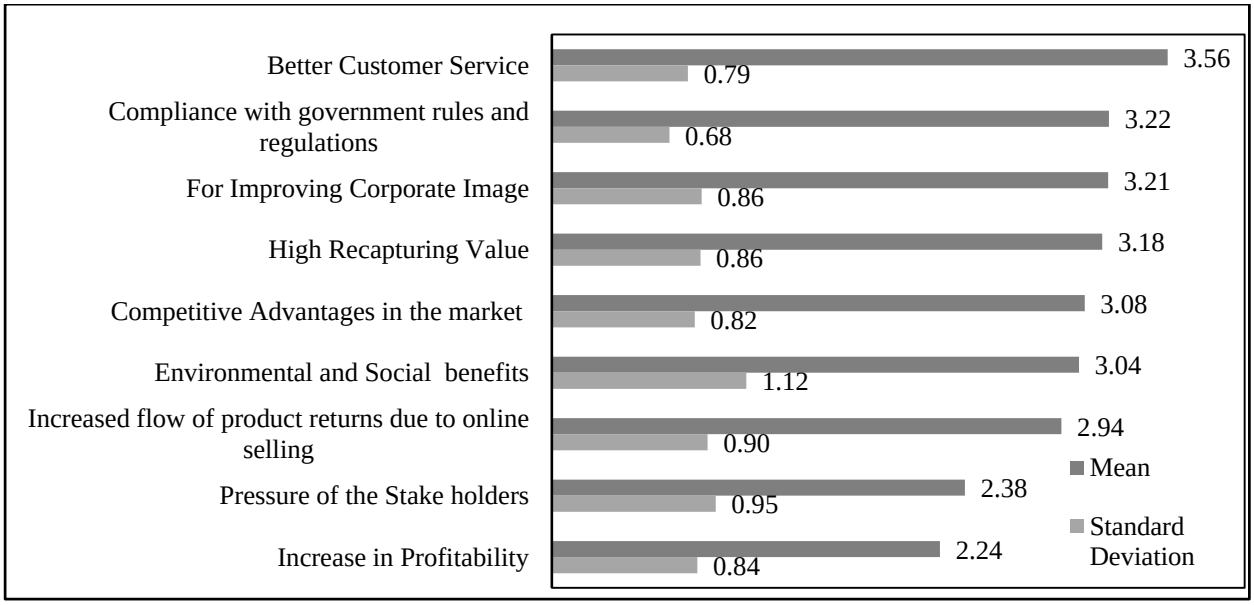

Figure 5.6 Motivation for RSC in Indian electronics industry

5.4.4 Important strategic issues in RSC

Strategic issues have long term importance with time line more than three years. Daniel et al. (2000) mentioned that success of an organization depends on the effective management of these issues. Allocation of financial resources (Daugherty et al., 2001; Lambert et al., 2011), risk of adopting RSC (Ferrer and Ketzenberg, 2004; Ketzenberg et al. 2006), disposition of returned products (Skinner et al., 2008; Hazen, 2011), outsourcing RSC activities (Meade and Sarkis, 2002), integration of forward and RSC (Yang and Wang, 2007), performance evaluation system (Biehl et al., 2007), IT infrastructure (Brito and Dekker, 2002), product return policy (Östlin et al., 2008) are some of major strategic issues which are discussed frequently in the literature. Total nine issues, based on literature review and expert's opinion have been considered for the survey. Respondents were asked to select the importance level of these strategic issues of RSC in the organization. These issues along with results of the survey are shown in figure 5.7. Allocation of financial resources (mean = 3.25) is a major issue and organizations are reluctant to allocate financial resources because of high risk of adopting RSC (mean = 3.22). Ho et al., 2012; and Mangla et al., 2016 also found resource constraints a major

issue because of financial implications of RSC activities to the organizations. Disposition decisions in RSC (mean = 3.21) is next most important issue of RSC. Although, many researchers considered it as operational issue, it has now become the part of strategy in many organizations and plays an important role in the success of RSC (Hazen, 2011). Absence of adequate performance evaluation system (mean = 3.02) is a big hurdle in RSC planning, benchmarking, and improving the performance of RSC. Another important issue is network design for collection and re-distribution of products (mean = 2.69). These findings are in tune with the findings of Indian manufacturing industry survey by Ravi and Shankar (2015).

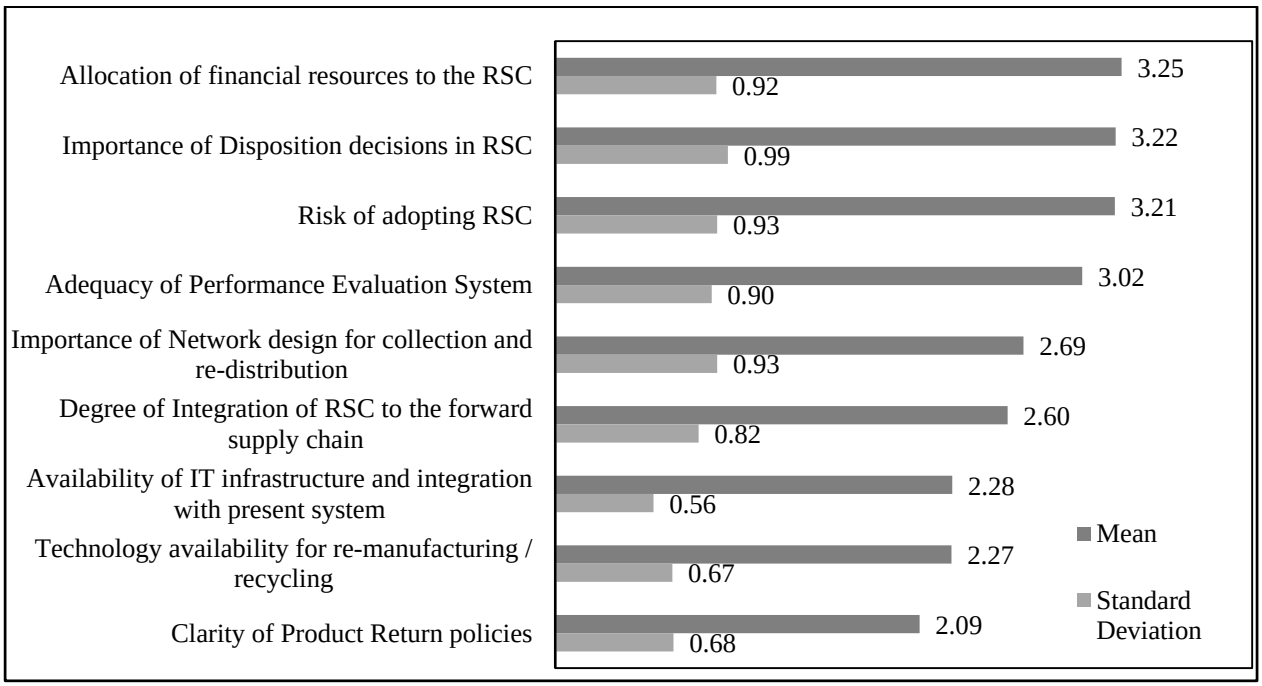

Figure 5.7 Important strategic issues in RSC

5.4.5 Critical success factors in RSC

Respondents were asked to indicate the level of importance of 12 CSFs for their organization. Top management commitment (mean = 3.47) is found to be most critical factor. Here also resource allocation (mean = 3.30) is indicated as very important factor for the success of RSC. Contract terms & conditions (mean = 3.22), Joint consortium (mean = 3.21), and economic

factors (mean = 3.21) are next three important critical success factors of RSC in Indian electronics industry. In a study of Indian electronics industry, Prakash and Barua (2015) also find these factors critical for the success of RSC. Only contract terms & conditions seem to be new and have not been considered in other studies to the best of our knowledge. These results are in line with the findings of the CSFs using fuzzy-TOPSIS methodology for Indian electronics industry in Chapter 4.

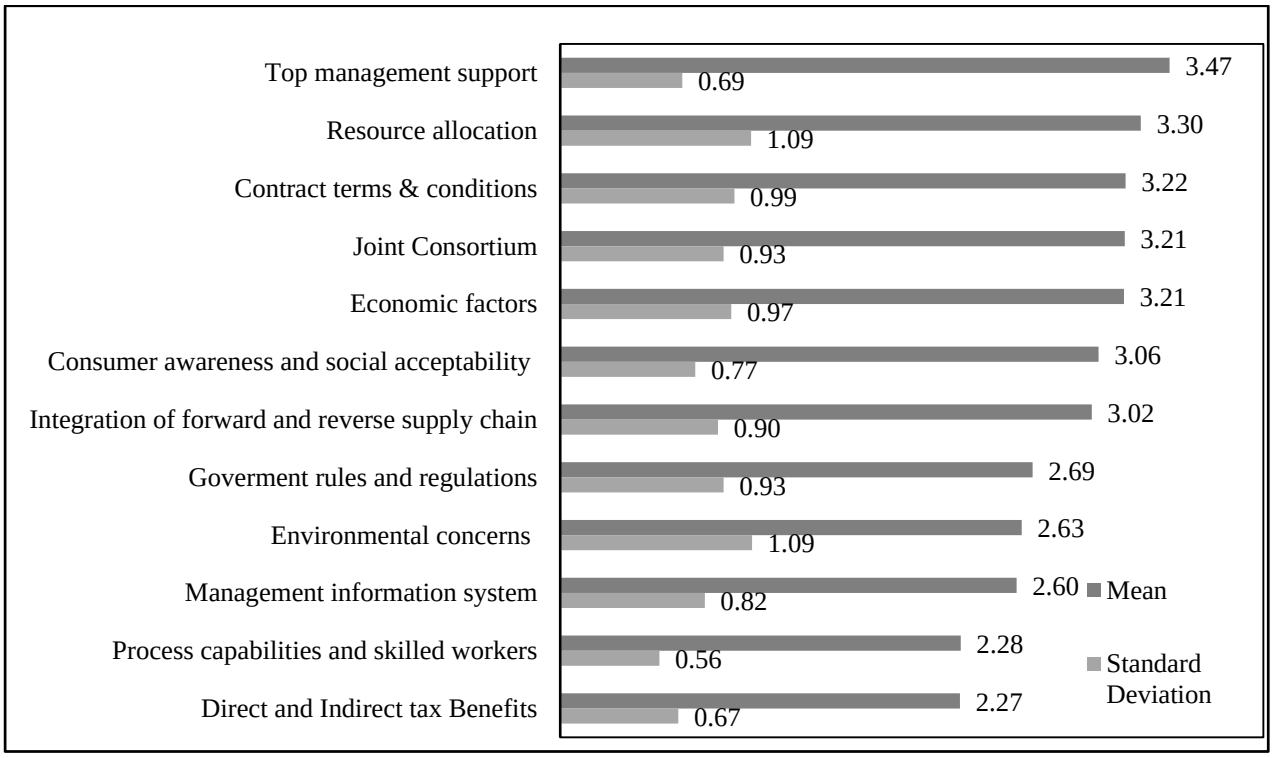

Figure 5.8 Critical success factors in RSC

5.4.6 Location for disposition decision in RSC

Products after inspections are sorted into different categories and disposition for further processing. Disposition decisions are important for the effective RSC. Location of disposition of products depends on the disposition policy of an organization and it may be chosen at any point of location in the RSC network (Hazen et al., 2012). Respondents were asked to indicate the disposition decision location; means the location where the disposition decisions of returned products are taken for further processing. Possible disposition locations considered

for the study and results of the survey are shown in figure 5.9. Disposition decisions are taken at collection centers in 21%, at inspection & testing centers in 20%, at retailers in 14%, at end user site in 11%, at manufacturing unit in 10%, and at third party location in 5% of the organizations. It is clear from the survey that disposition decision location is staggered from end user to the third party location, and not much attention has been given to the issue. There are very few studies available for the comparison of findings.

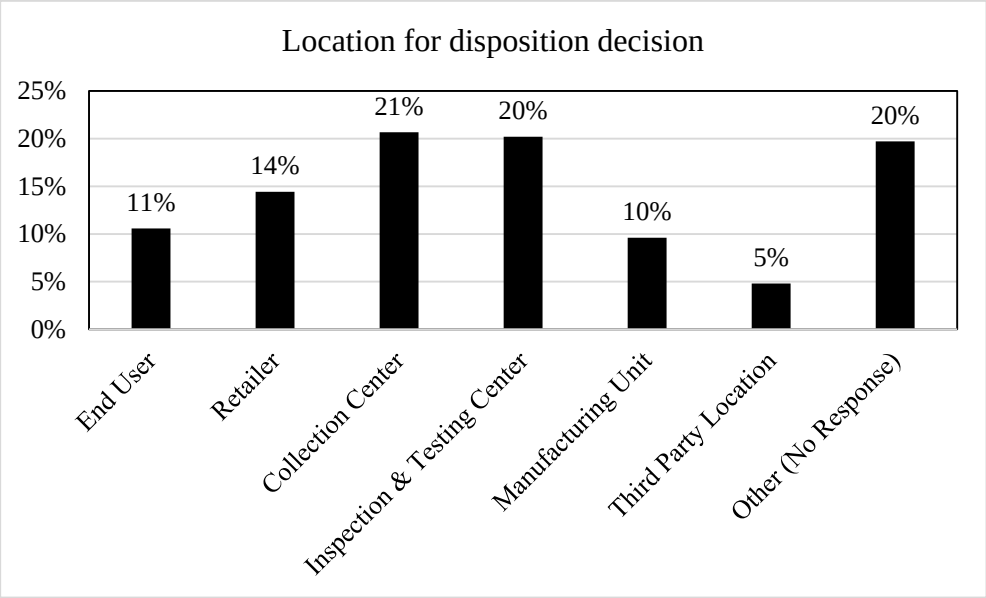

Figure 5.9 Location for disposition decision in RSC

5.4.7 Level of outsourced activities in RSC

Outsourcing is one of the major strategic issues in the RSC. An organization may outsource RSC activities partly or all the activities (Meade and Sarkis, 2002). Respondents were asked to indicate the activities, which they are practicing and have outsourced to the third party service providers. Outsourcing activities of RSC and results of the survey are shown in figure 5.10. Among the respondents who were involved in product collection, and transportation, more than 75% respondents have outsourced them to third party service providers. Recycling and disposal are also outsourced by more than 50% of the organizations. Inspection & sorting, repairing, remanufacturing are outsourced by less than 25% of the organizations.

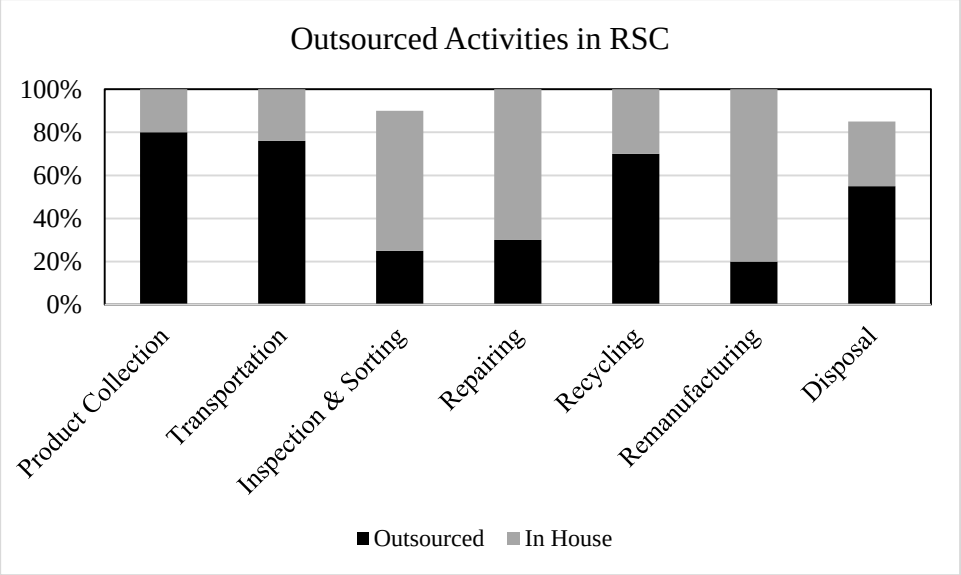

Figure 5.10 Level of outsourced activities in RSC

5.4.8 Importance of factors for forecasting product returns

As discussed in literature review and subsequently in hypotheses development, there are number of factors that may affect the accuracy in forecasting product returns. These factors and results of the survey are shown in figure 5.11. Survey results indicate that all the six factors have mean value more than 3 and are important for the accuracy in forecasting. Return policy has highest mean value of 3.29 and plays an important role in forecasting product returns (Bernon et al., 2011). Product life cycle (mean = 3.27) is next higher factor which influences the forecasting product returns. Shorter product life cycle adds to the uncertainty in product returns and affects the forecasting product returns (Benedito and Corominas, 2013). Another important factor was found to be environmental consciousness of consumers having mean value of 3.24. According to Toktay et al. (2000), environmental consciousness of consumers motivates them to return the products for recycling or reuse and increase the rate of product returns.

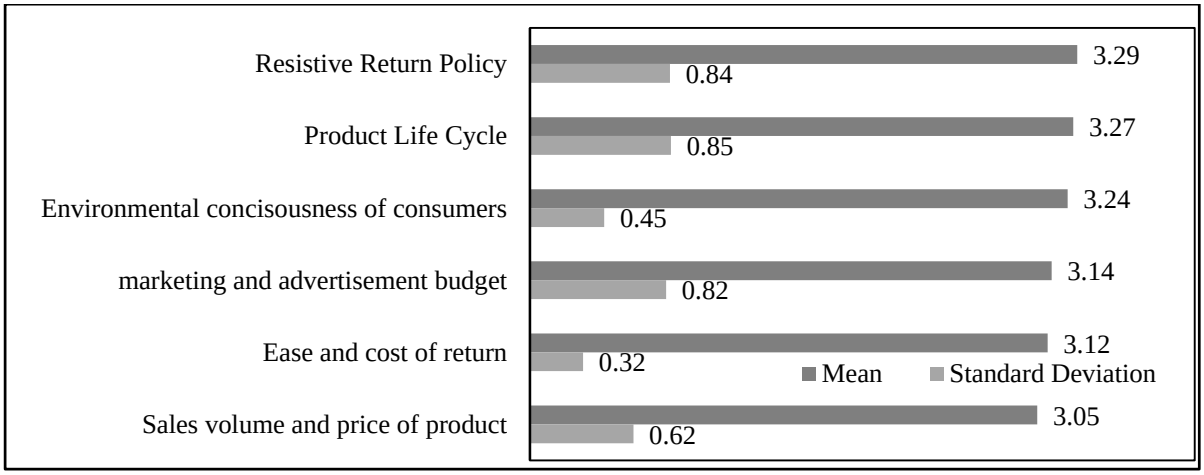

Figure 5.11 Importance of factors for forecasting product returns

5.5 Hypotheses Testing Methodology

The data collected was numerically coded in MS excel spreadsheet before it is transferred into the XLSTAT software for further analysis. The data was visually scanned for the errors and missing values for appropriate modification. Measurement models and structural models were analyzed by using structural equation modeling. Structural equation modeling has an ability to evaluate the measurement models with in same analysis (Gefen et al., 2000). It is a systematic approach for analyzing causal models using latent variables with their observed indicators (Kaplan, 2008). There are two types of approaches in structural equation modeling. First one is covariance based (CB) which involves linear structural relations (LISREL) and Analysis of Moment Structures (AMOS). Second, one is partial least square path modeling (PLSPM) approach. The research work utilized PLSPM to test the hypotheses developed among constructs because of its ability to deal with small sample size, and non-normal distribution data (Reinartz et al., 2009). It has features of both factor analysis and multi-regression analysis. In PLSPM, a single observed indicator for a latent variable can be treated efficiently unlike in AMOS and LISREL where numbers of observed indicators are restricted (Peng and Lai, 2012). The methodology involves two-step approach in which first measurement models are analyzed

and after that, structural equation models are analyzed. XLSTAT software analyzed the measurement models within PLSPM itself and provides the results both in graphical and tabular forms. These approaches are discussed in the following sections.

5.5.1 Analysis of measurement models

In order to test the hypothesis, validity and reliability of the constructs in the model are tested to ensure correct measurement by the observed variables. In a PLSPM analysis, the individual reliability of the item, the internal consistency and the convergent and discriminant validity are analyzed (Chin, 1998).

5.5.1.1 Individual Reliability

The individual reliability of items is examined to test whether a latent variable explains the substantial part of variance of its observed indicators. The individual reliability of each item for constructs with reflective indicators is evaluated by examining the loading of each indicator with the construct that it is intended to measure. The value of the standardized loadings must be equal to or greater than 0.5 (Falk and Miller, 1992).

5.5.1.2 Internal Consistency Reliability

The reliability of a construct tests the internal consistency of all the indicators while measuring the concept. It indicates that how rigorously the manifest variables are measuring the same latent variable. It can be measured in terms of Cronbach's alpha or composite reliability. Cronbach's alpha considers that all factor loadings are equally reliable and results in under estimation of internal consistency reliability (Chin, 1998). Composite reliability is preferred in PLSPM because it considers different factor loadings and provides better results (Werts et al., 1974; Henseler et al., 2009). Internal consistency of proposed models is measured in terms of

composite reliability. Nunnally (1978) suggested the minimum value of composite reliability as 0.7 for the acceptance.

5.5.1.3 Convergent Validity

Convergent validity is tested to ensure that construct represented by observed indicators has same underlying construct and has unidimensional characteristics. The convergent validity is analyzed by average variance extracted (AVE), which gives the amount of variance that a construct obtains from its indicators with respect to variance due to the measurement error. Fornell and Larcker (1981) recommend values higher than 0.5 for the measurement model to have convergent validity.

5.5.1.4 Discriminant Validity

Discriminant validity is the extent to which a latent variable accounts for the variance in observed indicators. To evaluate the discriminant validity, check if average variance extracted (AVE) of the construct is greater than the square of the correlations between that construct and other constructs of measurement model (Fornell and Larcker 1981). It indicates that one construct is different from any other constructs.

5.5.2 Analysis of structural model

After analyzing the measurement model, the structural model is analyzed before examining the hypotheses for drawing any conclusion. Structural model is utilized to predict the hypothesized relations among latent variables for different constructs. PLSPM approach is selected because of exploratory nature of the study (Leimeister et al., 2009). In addition, it does not require distribution restriction (normality) of the variables (Chin et al., 2000). PLSPM approach was

utilized and analyzed with the help of XLSTAT software. Important indexes for structural model path modeling are explained and discussed in the following section.

5.5.2.1 Structural model path coefficient

Hypothesized relationships among constructs are estimated in terms of structural model path coefficients. The path coefficient value represents the strength of relationship between two constructs (Vinzi et al., 2010). The standardized values of path coefficients vary between -1 and +1. The values close to +1 indicate the strong positive relationships among constructs and statistically significant. The values close to 0 indicate weaker relationships and usually non-significant. To test the significance of various relationships among constructs, the research work used 5% significance level for critical value. If empirical t-value is larger than the critical t-value, the hypothesis is accepted at this significance level.

5.5.2.2 Coefficient of determination (R^2 Value)

The predictive accuracy of the structural model is measured by explained variance (R^2) for the dependent latent variables. This is a squared correlation between the actual and predicted value of specified endogenous constructs. The standardized value of R^2 varies between 0 and +1 with higher values indicating higher predictive accuracy. According to Hair et al. (2006), independent variables having R^2 values more than 0.7 are described as strong coefficient determinant and variables having values less than 0.25 are described as weak coefficient determinant while 0.5 is considered as moderate. However, there is no thumb rule for acceptable R^2 value because these acceptable levels depend on the complexities of the model and the research area. In addition, the change in value of R^2 can be used to evaluate if an independent latent variable has substantial effect of the dependent latent variable. This change, known as effect size f^2 is examined by omitting an independent latent variable and determining

R^2 with and without independent latent variable (Cohen, 1988). The values of f^2 are 0.02, 0.15, and 0.35 respectively represent the weak, medium, and large effect of exogenous latent variable on the specified endogenous variable.

5.5.2.3 Predictive relevance (Q^2 Value)

To analyze the stability of the estimations offered, cross-validity redundancy (Q^2) developed by Stone (1974) and Geisser (1974) is utilized. The cross-validated redundancy approach considers both measurement model and structural path model of data prediction and fits perfectly for structural equation path modeling. It measures the goodness with which the observed values are reproduced by the model and its parameter estimates (Chin, 1998). According to Henseler et al. (2009), a model has good predictive relevance if the value of Q^2 is greater than zero. In addition, the relative impact of predictive relevance can be measured in terms of size effect q^2, which is similar to the effect size f^2. The values of q^2 are 0.02, 0.15, and 0.35 respectively represent the weak, medium, and large effect of exogenous latent variable on the specified endogenous variable.

5.6 Results

Three different structural models were analyzed by using PLSPM approach. The measurement models and structural models are explained as follows.

5.6.1 Measurement models

The measurement models were analyzed before the structural models analysis by using PLSPM. Three different measurement models developed for hypotheses testing were analyzed and results are represented in tables 5.1-5.6.

First model (Model 1) contained the relationship among factors influencing forecasting for product returns, accuracy in forecasting, and their relationship with economic, environmental, and social performance of RSC. Individual reliability of each item was accessed by standard factor loadings. As shown in table 5.1, factor loadings for all items ranges from 0.687 to 0.940, which are greater than the threshold value 0.5, suggested by Hair et al. (2006) and by Falk and Miller (1992). Individual reliability of each constructs is supported. Internal consistency reliability for each of the construct is accessed by composite reliability (CR), which must have minimum value of 0.7 for the acceptance (Nunnally, 1978). The CR value for all the constructs ranges from 0.899 to 0.935, which are greater than the minimum threshold value. AVE analyzed the convergent validity for all the constructs. The values for all constructs are higher than minimum threshold value 0.5 suggested by Falk and Miller (1992) which met the requirements of convergent validity. This indicates that all the latent variables explained more than 50% variance in their observed value. Correlation between the constructs and square root of AVE for each constructs were analyzed for accessing the discriminant validity of the model. The results, shown in table 5.2 indicates that square root of AVE values in all the cases are greater than corresponding off-diagonal values in the correlation matrix which support the discriminant validity of the model.

Table 5.1 Statistics results of measurement model for Model 1

Latent Variable (Cronbach's Alpha)	**Loadings**	**AVE**	**CR**
AIF: Accuracy in Forecasting (Cronbach's Alpha= 0.79)		0.753	0.925
FA1: Accuracy in prediction of quantity of product returns	0.912		
FA2: Accuracy in prediction of quality of product returns	0.789		
FA3: Accuracy in prediction of timing of product returns	0.869		
FIF: Factors Influencing Forecasting (Cronbach's Alpha= 0.89)		0.676	0.914
FF1: Sales volume and price of product	0.832		
FF2: Marketing and advertisement budget	0.806		
FF3: Resistive return policy	0.836		
FF4: Product life cycle	0.799		
FF5: Ease and cost of return	0.771		
FF6: Environmental consciousness of consumers	0.807		

Latent Variable (Cronbach's Alpha)	Loadings	AVE	CR
ECP: Economic Performance (Cronbach's Alpha= 0.85)		0.762	0.935
EC1: Return On Investment	0.839		
EC2: Recapturing Value	0.940		
EC3: Logistics Cost Optimization	0.776		
EC4: Recycle Efficiency	0.892		
EC5: Annual Sales of re-manufactured products	0.725		
EC6: Disposal Costs	0.817		
EVP: Environmental Performance (Cronbach's Alpha= 0.91)		0.701	0.927
EV1: Minimum Energy Consumption	0.823		
EV2: Optimum use of raw material	0.799		
EV3: Transport Optimization	0.828		
EV4: Reduced Packaging	0.803		
EV5: Use of recycled material	0.756		
EV6: Waste Reduction	0.827		
SCP: Social Performance (Cronbach's Alpha= 0.83)		0.683	0.899
SC1: Community complaints	0.847		
SC2: Customer Health and Safety	0.842		
SC3: Stake Holders Participation	0.701		
SC4: Employment Stability	0.687		
SC5: Donations to Community	0.852		
SC6: Employee Benefits	0.767		

Table 5.2 Constructs correlation and AVE for Model 1

Constructs	AVE	ECP	EVP	SCP	AIF	FIF
AIF	0.753	**0.868**	0	0	0	0
FIF	0.676	0.608	**0.822**	0	0	0
ECP	0.762	0.346	0.456	**0.873**	0	0
EVP	0.701	0.692	0.528	0.692	**0.837**	0
SCP	0.683	0.594	0.623	0.633	0.586	**0.826**

Second model (Model 2) contained the relationship among external factors, and internal factors, and their impact on effectiveness of disposition decisions, and their relationship with economic, environmental, and social performance of RSC. Individual reliability of each item was accessed by standard factor loadings. As shown in table 5.3, factor loadings for all items ranges from 0.618 to 0.931, which are greater than the threshold value 0.5, suggested by Hair et al. (2006) and by Falk and Miller (1992) except 6th external factor, EF6: Government rules and regulations. The value of this factor is 0.24, which is less than the threshold value. Therefore, this factor was discarded from the study and again factor loadings were calculated. The values of final loadings are shown in the table 5.3 which satisfy the minimum threshold criteria for individual reliability of each constructs. Internal consistency reliability for each of

the constructs is accessed by CR Value, which must have minimum value of 0.7 for the acceptance (Nunnally, 1978). The CR Values for all constructs are greater than the minimum threshold value as shown in table 5.3. AVE analyzed the convergent validity for all the constructs. The values for all constructs are higher than minimum threshold value 0.5, which met the requirements of convergent validity. Correlation between the constructs and square root of AVE for each constructs were analyzed for accessing the discriminant validity of the model. The results, shown in table 5.4 indicates that square root of AVE values in all the cases are greater than corresponding off-diagonal values in the correlation matrix which support the discriminant validity of the model.

Table 5.3 Statistics results of measurement model for Model 2

Latent Variable (Cronbach's Alpha)	**Initial Loadings**	**Final Loadings**	**AVE**	**CR**
EDD: Effectiveness of Disposition Decisions				
EF: External Factors (Cronbach's Alpha= 0.86)			0.704	0.901
EF1: Economic factors	0.882	0.883		
EF2: Environmental factors	0.786	0.786		
EF3: Social factors	0.820	0.822		
EF4: Customer behavior	0.875	0.875		
EF5: Market conditions	0.791	0.789		
EF6: Government rules and regulations	0.24*	-		
IF: Internal Factors (Cronbach's Alpha= 0.84)			0.692	0.898
IF1: Processing cost	0.865	0.865		
IF2: Volume of returned products	0.852	0.852		
IF3: Importance of quality of returned products	0.769	0.769		
IF4: Importance of supply chain capabilities	0.849	0.849		
IF5: Importance of product value	0.761	0.761		
ECP: Economic Performance (Cronbach's Alpha= 0.85)			0.723	0.941
EC1: Return On Investment	0.896	0.896		
EC2: Recapturing Value	0.875	0.875		
EC3: Logistics Cost Optimization	0.931	0.931		
EC4: Recycle Efficiency	0.740	0.740		
EC5: Annual Sales of re-manufactured products	0.730	0.730		
EC6: Disposal Costs	0.887	0.887		
EVP: Environmental Performance (Cronbach's Alpha= 0.91)			0.667	0.908
EV1: Minimum Energy Consumption	0.827	0.827		
EV2: Optimum use of raw material	0.911	0.911		
EV3: Transport Optimization	0.810	0.810		
EV4: Reduced Packaging	0.729	0.729		
EV5: Use of recycled material	0.717	0.717		
EV6: Waste Reduction	0.837	0.837		

Latent Variable (Cronbach's Alpha)	Initial Loadings	Final Loadings	AVE	CR
SCP: Social Performance (Cronbach's Alpha= 0.83)			0.623	0.877
SC1: Community complaints	0.842	0.837		
SC2: Customer Health and Safety	0.829	0.838		
SC3: Stake Holders Participation	0.627	0.741		
SC4: Employment Stability	0.618	0.621		
SC5: Donations to Community	0.839	0.844		
SC6: Employee Benefits	0.739	0.844		

Table 5.4 Constructs correlation and AVE for Model 2

Constructs	AVE	EF	IF	ECP	EVP	SCP
EF	0.704	**0.839**	0	0	0	0
IF	0.692	0.560	**0.832**	0	0	0
ECP	0.723	0.346	0.456	**0.850**	0	0
EVP	0.667	0.692	0.450	0.692	**0.817**	0
SCP	0.623	0.594	0.623	0.453	0.536	**0.789**

Third model (Model 3) contained the relationship among benefits of outsourcing RSC and their relationship with economic, environmental, and social performance of RSC. Individual reliability, composite reliability, convergent validity, and discriminant validity met the criteria for supporting the model. The values of different parameters are shown in table 5.5, and table 5.6.

Table 5.5 Statistics results of measurement model for Model 3

Latent Variable (Cronbach's Alpha)	Loadings	AVE	CR
OBS: Outsourcing Benefits (Cronbach's Alpha= 0.79)		0.576	0.901
OB1: Focus on core activity of the organization	0.776		
OB2: Economical to outsource RSC activities	0.620		
OB3: Third party may provide sophisticated technology, system, and better services	0.830		
OB4: Reduces investment in RSC facilities	0.865		
OB5: More flexibility	0.783		
OB6: Better customer satisfaction responsiveness	0.681		
OB7: Third Party takes responsibility of entire product life cycle	0.837		
OB8: Third party may have better environment management	0.761		
ECP: Economic Performance (Cronbach's Alpha= 0.85)		0.743	0.945
EC1: Return On Investment	0.923		
EC2: Recapturing Value	0.940		
EC3: Logistics Cost Optimization	0.767		
EC4: Recycle Efficiency	0.838		
EC5: Annual Sales of re-manufactured products	0.713		
EC6: Disposal Costs	0.904		
EVP: Environmental Performance (Cronbach's Alpha= 0.91)		0.662	0.919

Latent Variable (Cronbach's Alpha)	Loadings	AVE	CR
EV1: Minimum Energy Consumption	0.813		
EV2: Optimum use of raw material	0.852		
EV3: Transport Optimization	0.812		
EV4: Reduced Packaging	0.829		
EV5: Use of recycled material	0.732		
EV6: Waste Reduction	0.816		
SCP: Social Performance (Cronbach's Alpha= 0.83)		0.613	0.889
SC1: Community complaints	0.854		
SC2: Customer Health and Safety	0.847		
SC3: Stake Holders Participation	0.734		
SC4: Employment Stability	0.629		
SC5: Donations to Community	0.842		
SC6: Employee Benefits	0.789		

Table 5.6 Constructs correlation and AVE for Model 3

Constructs	AVE	OBS	ECP	EVP	SCP
OBS	0.576	**0.759**	0	0	0
ECP	0.743	0.579	**0.862**	0	0
EVP	0.662	0.441	0.487	**0.814**	0
SCP	0.613	0.683	0.439	0.697	**0.783**

These findings fall within the acceptable limit prescribed by the researchers. The evidences of constructs validity represent the adequate fit of measurement models (Iacobucci, 2010), and indicate for evaluating second part of the analysis that is structural equation modeling analysis.

5.6.2 Structural equation models

In PLSPM technique of structural equation models, all the relationships among constructs related to hypotheses testing of models developed are analyzed. Three different structural models, model 1, model 2, and model 3 were analyzed by using PLSPM approach with the help of XLSTAT software.

The first model, Model 1 with direct relationship among constructs indicated the adequate structural model fit. Hypothesis (H1a) predicted the influences of factors on accuracy in forecasting product returns. The results obtained from the software XLSTAT are shown in table 5.7 and figure 5.12. The path coefficient, 0.486 is positive with corresponding t- value of 5.097, which is higher, that critical value. The hypothesis is supported that factors influences

the accuracy in forecasting. Hypothesis (H1b) predicted the accuracy in forecasting positively associated with economic performance of RSC. The path coefficient, 0.206 was also significant. Similarly third and fourth hypotheses (H1c) and (H1d) were also found to be significant and support the respective hypotheses. These results indicate that accuracy in forecasting is greatly influenced by the factors discussed above, and accuracy in forecasting is positively associated with economic, environmental, and social performance of RSC. Toktay et al. (2000) also found that explanatory factors influences the accuracy in forecasting product returns. Toktay et al. (2004) observed that accuracy in forecasting affects the various strategic and operational decisions in RSC. In a study of carpet industry, Biehl et al. (2007) found that reducing uncertainty through forecasting product returns improves the economic, and environmental performance of RSC system. R^2 and Q^2 values shown in figure 5.12 and respective f^2 and q^2 values shown in table 5.7 falls within limit as described in section 5.5 of this chapter.

Table 5.7 Structural model results for Model 1

Hypotheses	**Relationship**	**Path Coefficient**	***t*-value**	**f^2 Effect Size**	**q^2 Effect Size**	**Results**
H1a	FIF-AIF	0.486	5.097*	0.402	0.226	Accepted
H1b	AIF-ECP	0.206	2.702*	0.028	0.018	Accepted
H1c	AIF-EVP	0.223	1.948*	0.039	0.02	Accepted
H1d	AIF-SCP	0.201	2.952*	0.021	0.015	Accepted

Note: Significantly lower than moderate value at *$p \leq 0.05$

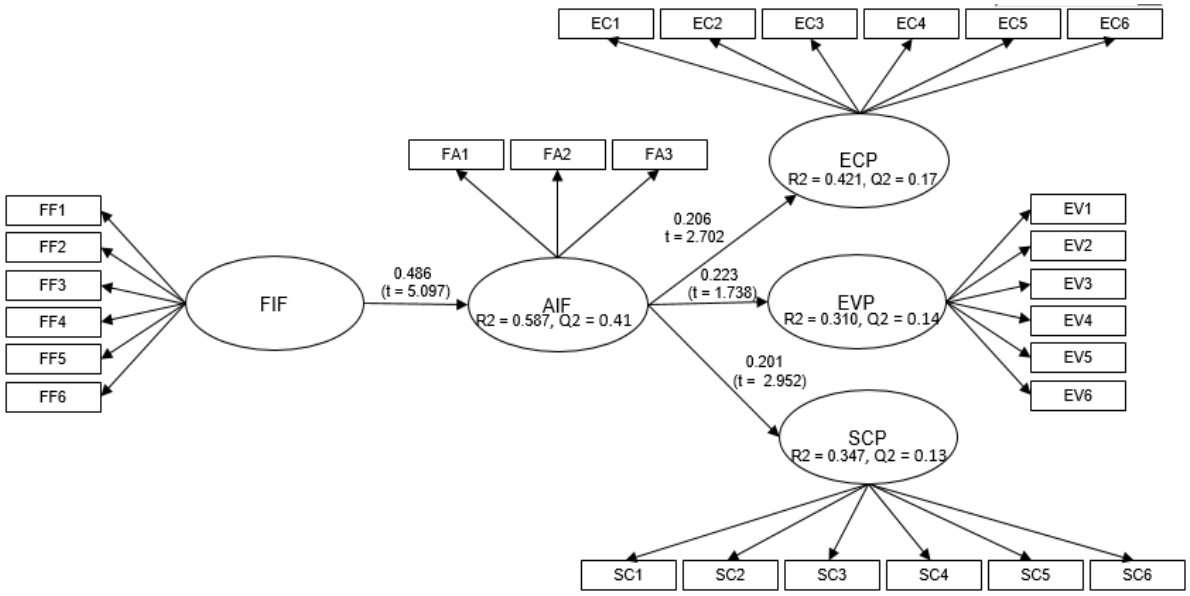

Figure 5.12 Structural equation model (Model 1) for forecasting product returns

The second model, Model 2 with direct relationship among constructs indicated the adequate structural model fit. Hypotheses (H2a & H2b) predicted that internal and external factors influence the effectiveness of disposition decisions in RSC. The results obtained from the software XLSTAT are shown in table 5.8 and figure 5.13. The path coefficients for external and internal factors are 0.52, 0.427 respectively and are positive which indicate the significance of hypotheses. The hypothesis is supported that external and internal factors influences the effectiveness of disposition decisions in RSC. Hypotheses (H2c & H2d & H2e) predicted that effectiveness of disposition decisions is positively associated with economic, environmental, and social performance of RSC. The values shown in table 5.8 indicate that these values are significant and support the respective hypotheses. These results indicate that effectiveness of disposition decisions is greatly influenced by the internal and external factors discussed above, and effectiveness of disposition decisions is positively associated with economic, environmental, and social performance of RSC. R^2 and Q^2 values shown in figure 5.13 and respective f^2 and q^2 values shown in table 5.8 falls within limit as described in section 5.5 of

this chapter. In an empirical study of Egyptian household appliance industry, Attia (2015) also found that disposition strategies are positively correlated with the organizational performance. According to Hazen et al. (2015), consumers have become more environmental conscious, want to ensure that products are disposition appropriately, and do not end up in landfills. Effectiveness of disposition decisions in RSC contributes not only in economic performance but also in environmental performance of RSC (Hazen, 2011). Disposition of products for social performance has been important specially in developing country like India where some of activities like recycling or disposal happens in hazardous environment (Wath et al., 2011).

Table 5.8 Structural model results for Model 2

Hypotheses	**Relationship**	**Path Coefficient**	***t*-value**	**f^2 Effect Size**	**q^2 Effect Size**	**Results**
H2a	IF-EDD	0.52	7.635*	0.412	0.252	Accepted
H2b	EF-EDD	0.427	6.239*	0.313	0.197	Accepted
H2c	EDD-ECP	0.478	6.704*	0.398	0.231	Accepted
H2d	EDD-EVP	0.262	2.53*	0.076	0.041	Accepted
H2e	EDD-SCP	0.483	5.333*	0.404	0.229	Accepted

Note: Significantly lower than moderate value at *$p \leq 0.05$

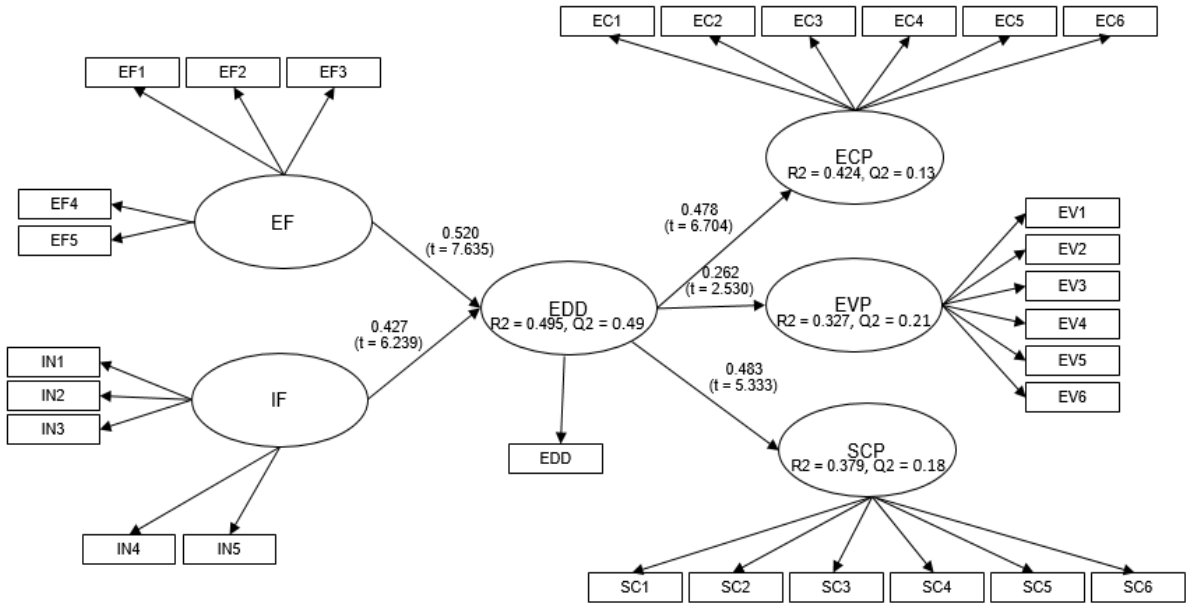

Figure 5.13 Structural equation model (Model 2) for disposition decisions

The third model, Model 3 with direct relationship among constructs indicated the adequate structural model fit. Hypotheses (H3a & H3b & H2c) predicted that RSC outsourcing benefits positively associated with economic, environmental, and social performance of RSC. The results obtained from the software XLSTAT are shown in table 5.8 and figure 5.14.The values shown in table 5.9 indicate that these values are significant and support the respective hypotheses. These results indicate that outsourcing benefits are positively associated with economic, environmental, and social performance of RSC. R^2 and Q^2 values are shown in figure 5.14 and respective f^2 and q^2 values, shown in table 5.9 falls within limit as described in section 5.5 of this chapter. According to Tavana et al. (2016), third party service provider's selection is critical for the economic and environmental performance of an organization. Govindan et al. (2013a) also found that outsourcing activities may also help in improving TBL performance and developed a model for supplier selection based on TBL for Indian industry.

Table 5.9 Structural model results for Model 3

Hypotheses	**Relationship**	**Path Coefficient**	***t*-value**	**f^2 Effect Size**	**q^2 Effect Size**	**Results**
H3a	OBS-ECP	0.535	9.087	0.439	0.265	Accepted
H3b	OBS-EVP	0.667	12.84	0.464	0.292	Accepted
H3c	OBS-SCP	0.531	9.004	0.432	0.294	Accepted

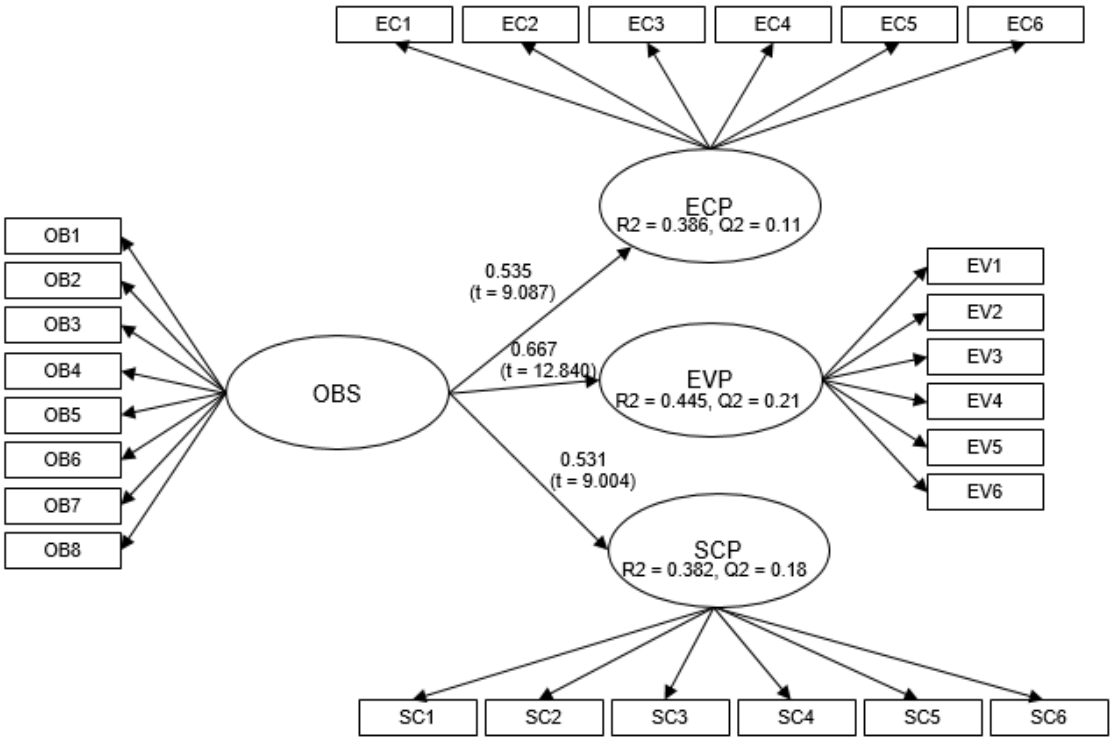

Figure 5.14 Structural equation model (Model 3) for outsourcing benefits

5.7 Discussion and Concluding remarks

Based on the survey of Indian electronics industry, the results of the research work remarkably shed light on the current practices of RSC followed, and explore the issues and their impact on the performance of RSC. A questionnaire-based survey was conducted and responses were analyzed after completing necessary statistical requirements. Product returns have increased considerably in last few years because of growth of e-commerce business along with overall growth of the industry. Higher growth, short product life cycle, and competitiveness in the market also led to the increased flow of product returns. There is pressure for handling end of life product returns because of government rules and regulations, environmental concerns, and corporate social responsibility. One of the ways to handle both type of returns is to adapt and implement RSC. Results of the survey indicate that a lot of importance is being given to the RSC and it has become a part of corporate strategy of many organizations. Better customer service, improved corporate image, higher recapturing value, competitive advantage in market

are some of the important motivational factors for many organizations to adopt RSC practices. However, there are number of issues such as allocation of financial resources, risk associated with adoption of RSC, disposition decisions, inadequate performance evaluation system, integration with forward supply chain, and so on. All these issues make the RSC implementation uncomfortable for some of the organizations.

The research work identified the critical success factors for adaptation and implementation of RSC. The most critical success factors were found to be top management awareness, resource allocation, and contract terms and conditions. Formation of joint consortium, economic factors, and consumer awareness & social acceptability are also some of the critical success factors for RSC implementation in the organizations. It was also observed from the survey that recycling and transportation are two major RSC activities outsourced by the organizations. The survey also examined the various factors affecting the accuracy in forecasting product returns, which plays an important role both in short term and long term planning of RSC. It was observed that disposition decisions location is fragmented and staggered among the organizations in the industry and not much attention has been given to it from strategic perspectives.

There are number of issues, which affect the performance of RSC. The research work examines the effect of forecasting product returns, disposition decisions, and outsourcing decisions on the economic, environmental, and social performance of RSC. Hypotheses were developed related to these three select issues of RSC. Three different structural models were developed and analyzed based on hypotheses developed. One structural model contained the issue related to forecasting in product returns, and other two were related to effectiveness of dispositions decisions, and outsourcing benefits. All three models were tested for their impact on economic, environmental, and social performance of RSC. The results show that accuracy in forecasting is influenced by number of factors, which makes a very different scenario

depending on the industry, and demographics. Accuracy in forecasting is important not only for the performance of RSC but also plays an important role in RSC planning. It affects the many strategic decisions, which depends on the expected volume of remanufacturing, recycling, repairing in future. The hypotheses results indicate that the number of external and internal factors influences effectiveness of disposition decisions. Disposition decisions are also very important for economic, environmental, and social performance of RSC. These decisions decide the future course of action in RSC. The outsourcing has been very popular in last few decades because of several advantages associated with it. The research work tested various outsourcing benefits and found that these benefits are associated with economic, environmental, and social performance of RSC. The research work tested three select issues for their contribution to economic, environmental, and social performance of RSC. Rather than developing these issues in single structural equation model, separate equation models have been developed for each select issue so that other issues may also be tested in future by following the proposed methodology. Another limitation of the study is that only economic, environmental, and social performance of RSC have been considered for the study. In future, other performances like responsiveness may also be considered. The research work was limited to Indian electronics industry but in future similar study may be carried out in other industry.

Chapter 6. Case Study

6.1 Introduction

This chapter deals with case study, which is aimed at exploring the current practices of reverse supply chain, and analyzing the key strategic issues and challenges faced by the Indian electronics industry through a real life case study. A case study of electronics manufacturing organization is considered for exploring the RSC strategic issues and key challenges in Indian context. Indian electronics industry has been selected for the study because of its high consumption volume, and major source of e-waste generation. In addition, this is one of the few sectors, which come under the e-waste management rules and regulations 2011, 2016 by the Government of India. The case study is developed based on the research processes discussed in past literature (Stuart et al., 2002; Yin, 2003; Eisenhardt, 1989). This method has been utilized for the case study in diversified areas in various organizations across the industries (Oke and Gopalakrishnan, 2009; Dubey et al., 2015; Jia et al., 2016).

6.2 Case Study Method

Organizations are adopting the RSC practices in order to comply with government rules and regulations, and to remain competitive while using green as marketing tool. These organizations come across several issues while performing RSC activities. Case research is one of the effective tools for in-depth understanding and analysis of these issues. According to (Yin, 2003) "A case study is an empirical enquiry that (i) Investigates a contemporary phenomenon within its real life context, especially when, and (ii) The boundaries between phenomenon and context are not clearly evident".

Case studies are used as a research method if contextual factors are taken into account and at the same time limit the extent of the analysis (Eisenhardt, 1989; Voss et al., 2002). Applying a flexible, sometimes even opportunistic research strategy is one of its major

strengths, but might also be a major weakness of case study research, in particular if the process is not well documented. The research methodology adopted for the study is based on literature review and discussion with executives of the organization. Discussions with executives provided real life scenario of RSC in Indian electronics industry including the select issues of RSC. A systematic approach for the present case study is developed based on the research processes discussed in past literature (Stuart et al., 2002; Yin, 2003; Eisenhardt, 1989). These steps are as followed.

Step 1: Definition of research question

The first step of case research methodology involves defining the research question. The research question is defined as "Study of select issues in reverse supply chain of Indian electronics industry". The case study will seek the answer of the following questions in context to case from an electronics organization i.e. ABC Limited.

- What are the major reverse supply chain activities performed by the organization?
- What are the critical success factors for reverse supply chain implementation?
- What are the major reverse supply chain activities outsourced by the organization?
- How the decisions for outsourcing are taken?
- How the future planning for reverse supply chain is done in the organization?
- How the returned products are disposition for further processing?
- How the organization measures the performance of the reverse supply chain?

Step 2: Instrument Development

The second step of case research methodology is the development of a research instrument and selection of the field site. A single case with embedded issues has been considered as representative case of a wider group of cases for the study. The organization for the study was

selected because of its size in terms of revenue and its office in NCR Delhi, India, which is local for the researchers.

Step 3: Data Collection

The next step is data collection for the case study. The data may be collected through open interview, semi-structured interview, structured interview, questionnaire, documents / websites / publications, direct observation, participant observations (Seuring, 2008). The data for the case study was collected both from primary and secondary sources through webpage and published material, and questionnaire followed by the semi-structured interviews with concerned people in the organization.

Step 4: Data Analysis

Information and data collected from the field visits to the organization and other secondary sources were used to analyze the issues in RSC.

Step 5: Dissemination

Case-based approaches to research are often subject to criticisms, some valid, some invalid. Yin (2003) made an effort by providing logical validity tests for judging the reliability and validity of the case research. Data for the study were also collected from the other sources like regulatory documents, web pages of the organization to ensure the construct validity and internal validity of the collected data. The organization executives from each stage were asked to answer questions according to the same interview guidelines. It helped in reaching the internal validity among different interviews.

6.3 Profile of the Organization, ABC Limited

ABC Limited is one of the leading consumers electronics organization headquartered at Gurgaon in National Capital Region, Delhi, India. The organization has approximately 900 employees and generated $2 b annual revenue in the last financial year. The revenue of this organization in last three financial years is shown in the figure 6.1. It is evident from the figure that this organization is growing very fast in the Indian mobile manufacturing market.

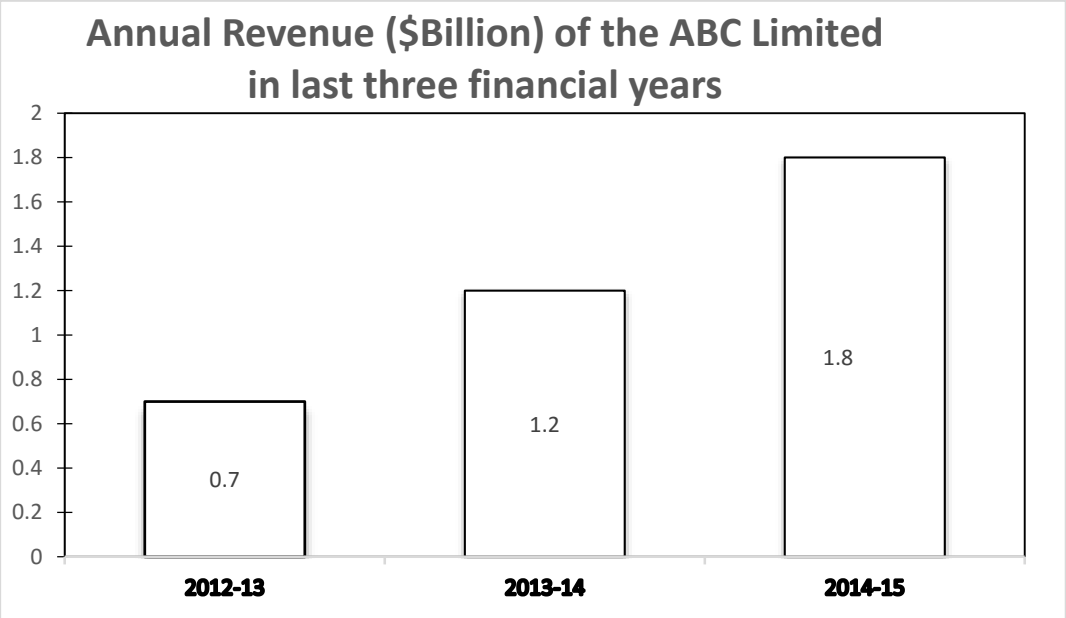

Figure 6.1 Revenue of the ABC Limited in last three financial years

The organization offers range of products including mobile phones, PC tablets, LED TV and data cards. The major business comes through the sale of mobile phones. The organization is the largest domestic mobile phone organization in low cost market segmentation. The organization is currently the 2nd largest mobile phone organization in India having 16% market share in smart phone market and 13 % market share in overall mobile phone segment. The organization is 2nd largest in Indian tablet PC segment also, with 11% market share. The organization initially started its business with model-based mobile phones sourcing from the organizations in Korea, China, and Taiwan to take full advantage of zero import duty on mobile

phones. Later on organization setup a manufacturing plant in Rudraprayag, UttraKhand, India where it manufactures PC tablets, and LED TV. Recently, the organization has started manufacturing mobile phone devices at this plant. The organization procures some of the components and parts from China and Taiwan, and assembles them at this facility. It has wide spread supply chain network in India particularly in rural areas and sells approximately 2.3 million handsets every month. It has started selling mobile phones in Russia also. Recently, Ministry of environment, forest, & climate change; the Government of India has enforced new waste management rules 2016 which includes e-waste management. These rules are based on the concept of extended producer responsibility. Organizations will have to manage their e-waste for complying with these rules.

6.4 Reverse supply chain of the ABC Limited

ABC Limited has vast network of super-distributors, distributors, and retailers throughout the country in 560 towns in India. As shown in figure 5.2, it has 70 super-distributors, also known as super-stockist, more than 1500 distributors, and 125,000 retailers along with more than 500 customer service center across the country. The organization has given a lot of attention to the supply chain and has developed innovative way of supply chain distribution. It introduced cash only model unlike other organizations offering 60 days credit line to the distributors. They offered higher margin (Approx. 15%, higher than the industry average of 6%) to the distributors in lieu of cash payment to the ABC Limited before delivery of products. Its strategy is to offer more margin and no credit to the distributors with advance payment to the organization. There are of the view that “If the distributor does not buy your handsets, there is no pressure on him to sell them,” and at the same time, it will offer more profit to the distributors. This strategy worked well for them. They not only managed to increase its sales but also managed cash flow very efficiently. The organization tracked the sales of products on daily bases to monitor the

success of the cash only model. The products are supplied to the distributors on regular basis so that they do not locked-in money in excess inventory. The products are sold through the online retailers and also, by its retailers (called merchants). The product returns have increased considerably due to online selling and their liberal policies like cash on delivery, 30 days replacement warranty, 1 year warranty etc on products. The product returns comprised of new products, products for repair, non-repairable products, and end of life products. The product acquisition from consumers is carried out through retailers or service centers or products are collected by the third party and dispatched to the service centers. Retailer resells new products, returned after repackaging by the service center, if required. Repair work is also performed at the service center and products after repair are given back to the consumers through respective retailers. The LED TV, and PC tablets, which are non-repairable, are returned to the manufacturing facility. The refurbishment or remanufacturing of these products is carried out at the manufacturing facility and products are resold through secondary markets. However, mobile phones are repaired or refurbished at the service center only. No remanufacturing of these products is considered because of higher logistics cost and non-availability of established remanufacturing. ABC Limited has authorized the third party recycler for collecting and recycling of the end of life mobile phones from the consumers, service centers, and from the manufacturing facility. Although recycling is not outsourced, in which the organization may have better control on the recycling operations. The organization has not given much attention to the reverse activities of the supply chain. Pursuant to newly updated e-waste management rules 2016 in India, increased flow of product returns, and recently established manufacturing facility, the organization has decided to explore the various recycling, remanufacturing options. Reverse supply chain of the ABC Limited is shown in figure 6.2 and processes are explained in the following sub-sections.

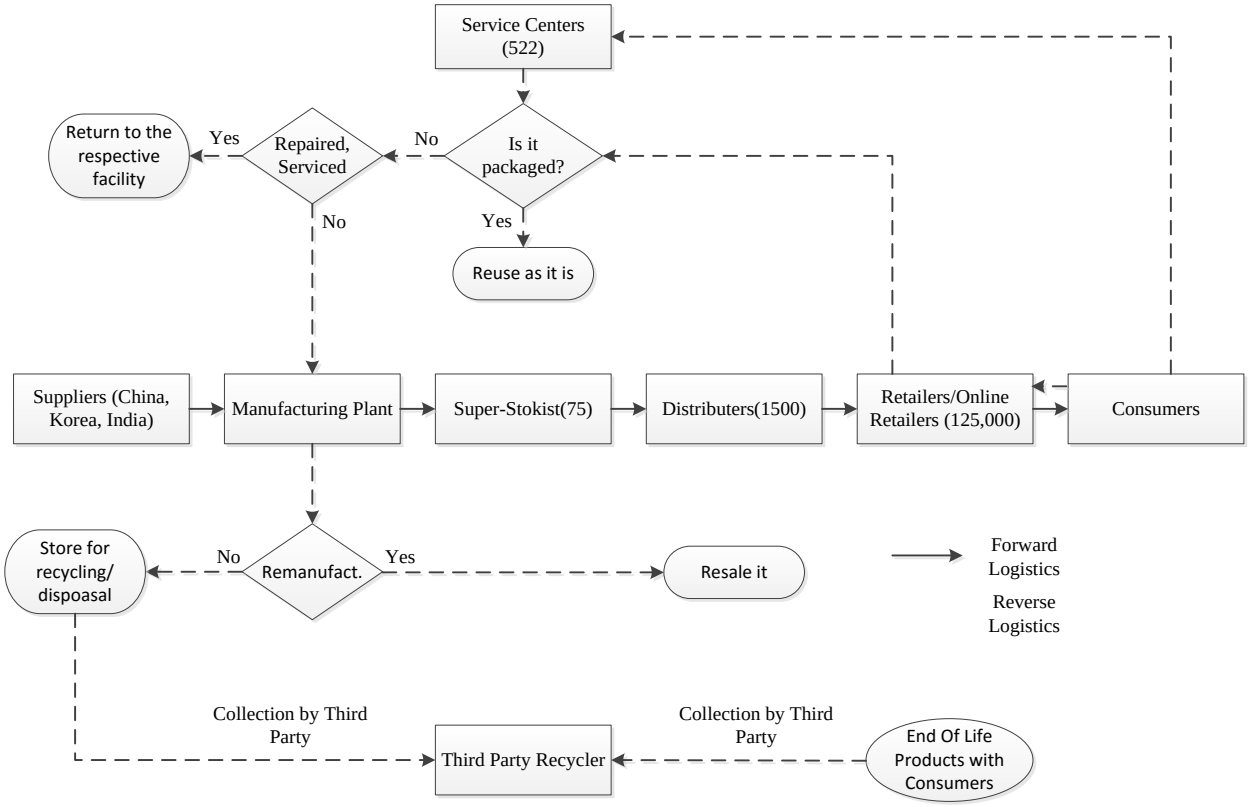

Figure 6.2 Reverse supply chain of the ABC Limited

6.4.1 Product acquisition/Gate keeping

The products are sold through retailers, e-retailers, and through own online portal of the ABC limited. The acquisition of returned products, sold online takes place at the site of consumer by the e-retailers through an outsourced service provider. The consumers either at the store or at the consumer service center return the products sold through retailers.

6.4.2 Collection

The returned products are collected by the e-retailers and sent it back to the point from where they were purchased during the monthly return policy. These products are mostly new and returned by the consumers due to price or change of mind for the products. After this one-

month time, the consumers return products to the service centers if they have any issue with the functioning of products. The product acquisition takes place at the service center. In case of sell through the retailers, the products are returned to the retailors during the one month period. Otherwise, consumers return those products to the service center.

6.4.3 Inspection and sorting

The products returned during the one month are mostly new and need little or no inspection. The engineers inspect the products at the service centers. The products are repaired and returned to the consumer. In case of LED TV, the products are inspected at the site of consumer and shipped to service center if not repaired at the site. If the products are not repaired at the service center, the products are transported to the manufacturing facility of the ABC Limited. If products are dead and there is no scope of any remanufacturing or further improvements, they are collected by the third party for the recycling.

6.4.4 Disposition

In recent years, the online sale of products through e-retailers and organization's own portal has increased considerably. At the same time, the organization is experiencing the returns even up to 30-40% due liberal policies like cash on delivery and competition in the market. The consumers return many products as new. These products after repackaging, if required are directly reused by the retailers and distributors of the organization, ABC. Repairing takes place at the consumer service centers, and products are returned to the consumers. In case of LED TV, the repairing may be carried out at the consumer site or shipped to the service center. If products cannot be repaired at the service center, they are shipped to the manufacturing facility.

ABC Limited performs the refurbishing or remanufacturing operations at the manufacturing facility. The LED TV are refurbished or remanufactured completely and after

remanufacturing, they are returned to the consumer or they are sold in the secondary market through online website like greendust.com and other local dealers. The mobiles are only refurbished and resold or returned to the consumer. ABC Limited has only assembly facility for mobiles and remanufacturing is not viable option. It has recently started manufacturing of mobiles in India and planning to go for 100% manufacturing of mobiles in India through local sourcing of components and parts. In case the products are not refurbished or remanufactured, they are disposition for recycling. ABC Limited has authorized a third party recycler to collect its product from consumer, service center and from the manufacturing facility, and recycle them. Although this authentication is formal in nature and ABC Limited may need to look into this pursuant to e-waste management rules and regulations in India. The recycler collects the products and there after the organization has no audit of these types of products. The recycler carries out disposal of products.

6.4.5 Redistribution

Products after refurbishment/remanufacturing are sold in the secondary market through online web portals and through local dealers. The new products returned by the consumers at service centers are resold in the market after repackaging, if required.

6.5 SWOT analysis of the ABC Limited

The organization needs to analyze its Strength, Weaknesses, Opportunities, and Threats (SWOT) for strategy formation to sustain and compete in the market. Therefore, SWOT analysis of the ABC Limited was carried out to get in-depth insight of the business model of the organization. SWOT findings are summarized in table 6.1. Low cost products, innovative products entering into the market at right time are the major strengths of the ABC Limited. The organization having strong wide spread network across the country has deep penetration into

the rural market segment of the country. ABC Limited has developed its own manufacturing facility in India. The organization has bundled its products with some of the key telecomm service providers and has better co-ordination with service providers. Consumer service centers with skilled capacities help in performing repairing work efficiently and reduce the remanufacturing need of the products. However, the low cost brand image of the ABC Limited makes it less competitive in the urban markets. This organization takes the advantages of global research of other organizations for introducing the new products in the market. This may prove to be disadvantageous in future because of entry of many Chinese organizations with similar low cost products. The profit margins on the products are reducing due to competition, online retailing, and higher margins to the distributors. The rapid change in technology is also a big challenge for the organization. For example, demand for 4G phone is growing very fast and 35% smart phone sold in India are 4G. According to International Data Corporation report, the ABC Limited is able to maintain second position with approximately 16.5 % market share. As discussed above, it has limited remanufacturing facility, which forces them for recycling of products. The recycling facility is authenticated to the third party by the organization. There is an opportunity to extract precious metals from the recycling of products. The organization has not given much attention to RSC and sustainability, which may become a threat in future with strict rules and regulations by the Government of India. There is opportunity of new emerging market for remanufactured products and better brand image by taking green initiative, which may be competitive advantages to the organization. Digital India, and Make in India initiative provide an opportunity for future market potential and other benefits offered by the Government for extension of manufacturing in India.

Table 6.1 SWOT Analysis of ABC Limited

Strengths	**Weaknesses**
Innovative Products and Features	Low cost brand image in urban markets
Low cost products	Image of low quality Chinese products
Introducing new product at right time in the market	New products similar to products available in global market
Strong supply chain of distribution	Reduced profit margins due to low price and higher margins to distributors
Strong supply network in rural markets	No control over recycling and disposal of EOL products
Effective cash flow management	Limited remanufacturing facility
Co-Ordination with telecomm service providers	Products are not designed for easy to dissemble
State of art manufacturing facility	Do not have robust reverse supply chain
Repairing facilities at Consumer Service centers	No Take back type initiative for promoting sustainability
Opportunities	**Threats**
Huge demand of mobile phones	Growing competition in domestic and International market
Penetration in urban market	Replication of business model by other Organizations
Profits from precious metal extracted through recycling	Strict e-waste management rules and regulations-2015
Exports to international markets	Entry of Chinese Organizations through online retailers
New Market Segment for remanufactured products	If Organization cannot take responsibility of e-waste management adequately, it may be forced to go out of business in future
Green Products can improve brand image and can be a competitive image	Price reduction due to online business offerings
Digital India Initiative	Reach of e-retailers to rural markets
Make in India Initiative	Establishment of other mobile manufacturing facilities in India

6.6 Key strategic issues and challenges: findings and discussion

After studying and going through the profile of ABC Ltd and business practices of its RSC, the case was analyzed based on case methodology to illustrate the various RSC issues in the organization. Different strategic issues were identified and are explained as follows.

6.6.1 Returned products acquisition and collection Issues

ABC Limited sells products to the consumers through multiple channels of distribution. As discussed above, the product acquisition takes places at multiple points in the channel. The collection of products through service centers provides an edge to the organization because of vast network of distributors and retailers. In case of end of life, there is an issue of collecting the products from the consumers. The organization has no visibility and control of products. In future, there may be problems of compliance with the e-waste management regulations. There is a lot of uncertainty in terms of quality, quantity, and timing of product returns particularly end of life products. The short term forecasting is managed by the organization through tracking of sales from the distributors. The organization has authorized the third party for end of life products from consumers directly but there is no audit of the recycling of these products. This is more a formal type arrangement for providing business to the recycler and cannot be considered as equivalent to outsourcing where the organization has better control and shares the business. Long term forecasting is important for the strategic decisions related to setting up of own facilities for recycling or out sourcing these activities. The future predictions may help in predicting future expected economic benefits of owning RSC by the organization.

6.6.2 Disposition related issues

Inspection and sorting is carried out at the service centers of the organization. These centers are equipped with modern facilities and trained engineers providing best service to the customers. In case of LED TV and tablets, the products after inspection are disposition for recycling or remanufacturing depending on their quality if they cannot be repaired. Mobile phones are repaired and returned to the customers. In most of the cases, the PCB is replaced with new one if it cannot be repaired. However, it was noticed that charges for the repairing phones, not covered under warranty or after warranty period are very high and consumers

mostly prefer to get them repair in local market. The organization may provide better service to the consumers by resolving this issue. The organization is used to disposition the mobile for recycling if they cannot be repaired. The reason was that the mobiles were sourced from the foreign country and they had no remanufacturing facilities in India. Since, low cost is the key for this organization, it perceived no potential to disposition them for remanufacturing. ABC Limited has established the manufacturing facilities within the country and also, the remanufacturing is recently being offered by some of the third party service providers. The organization is considering the remanufacturing operations of the mobile phones.

6.6.3 Critical success factors for RSC implementation

ABC Limited has established vast chain of network for the forward logistics and committed to manage RSC to provide better service to the consumer. However, it is under pressure to manage the e-waste generated because of government rules and regulations. Since, this organization has started manufacturing in India; it is looking for economic benefits by incorporating RSC practices into their business. In order to implement these practices, it is important to understand the CSFs for the ABC Limited. The CSFs, identified and prioritized in Chapter 4 were discussed with the management of the organization. It was observed that top management awareness is most important for complying with regulatory requirements and at the same time to invest money in the required resources. Another important factor observed was resource management including human resource, development of remanufacturing facility, and establishing recycling facility. The economic factor is also among one of the CSFs for the RSC of the organization. ABC Ltd offers the low cost products to the consumers and this is their unique selling point. Therefore, it is important to keep the economic benefits in consideration while implementing RSC. In order to comply with the government rules and regulations, and to achieve sustainable developments, it is important to have contract terms and conditions

incorporating these rules and regulations regarding components/parts supplied by them. Management information system is already in place in this organization and they are able to track their sales and stock status very well. However, information system does not track the end of life products. Since, products are sold and distributed through multiple channels, the integration of forward and RSC is not easy and economical for the organization. Joint consortium is important vertically but not significant horizontally because of competition in the market. Process capability will be important when organization will start full fledge manufacturing in house. Legislation, taxes, and environmental concerns are the part of discussion in this organization. These issues will gain importance with the effective implementation by the concerned regulatory bodies. In summary, the major top four critical success factors for the ABC Ltd have been identified as top management awareness, resource management, economic factors, and contracts terms and conditions which are in tune with the findings of fuzzy-TOPSIS methodology in chapter 4, and findings of survey in chapter 5.

6.6.4 Outsourcing decisions

Outsourcing is one of the important decisions for RSC. ABC Limited has vast distribution network for the forward supply chain. RSC is mainly confined to the warranty period returns and new products return through online retailers. It has established the consumer service centers and logistics facilities for collection, reuse, and repairing. However, remanufacturing is not explored due to model based sourcing from the foreign countries like Korea, China, and Taiwan. Since, the manufacturing facility has been established in India, ABC Limited can explore the option of remanufacturing. In addition, third party service providers are offering the remanufacturing of mobile phones. The organization can explore the option of outsourcing remanufacturing to these third party service providers. The organization has authorized the third party recycler for the collection and recycling of end of life products because it wants to

focus on core activities. The organization need to explore the option of outsourcing recycling as per regulatory requirements.

6.6.5 Performance evaluation system

ABC Limited has no established performance evaluation system for evaluating the performance of RSC. The key performance measures include the number of products returned, reasons of product returns, quality of product returns, and cost of product returns. The performance measures are mainly focused on the economic performance, internal process capabilities, learning and growth. The organization has not given much attention to the environmental and social factors. Govindan et al. (2014) have observed that for sustainable performance improvement and effective RSC, environmental and social factors should be part of performance framework. Now ABC Ltd sees the opportunity of utilizing corporate social responsibility funds for the management of product returns operations. The inclusion of some of the environmental and social factors and their measurements may provide opportunity to spend money on them for the improvements.

6.7 Concluding remarks

The researchers have explored several strategic issues and challenges in the past. Although, there are many studies on RSC but they have not explored strategic issues and challenges in context of developing countries such as India or other South Asian countries. The case study has provided an in-depth understanding of key strategic issues and challenges in the electronics industry by using a framework consisting of theoretical and real life practical approach. The strategic issues that were found to be crucial in RSC are critical success factors, outsourcing decisions, disposition decisions, forecasting product returns, and performance evaluation system. The study is summarized, and enumerated as follows.

- The electronics industry is coming across a new challenge of managing product returns because of changed business environment, and complying with e-waste management rules and regulations.
- Top management awareness, resource management, economic factors, and contracts terms & conditions with the supplier are the CSFs for the organization.
- The organization has authorized third party recycler for collection and recycling of end of products. They need to differentiate between outsourcing, and authorizing the third party for recycling. The organization has no control over the third party to whom they have authorized for the collection and recycling of end of life products. Pursuant to new e-waste management rules and regulations by the Government of India, the audit of the e-waste is not easy with this type of arrangement.
- This organization is able to manage inventory through tracking of products with the distributors online. However, long term forecasting product returns is important for the future planning and decision making in the RSC.
- Another important issue is disposition of products efficiently. This organization is yet to explore the remanufacturing options of disposition with in the manufacturing facility. Since, the industry is more dependent on the import of products, components, and parts; the remanufacturing has not been explored much. The initiative like Make in India may encourage the remanufacturing option while establishing new manufacturing facilities in the country.
- Another key observation is that the organization has not set up any formal performance evaluation system in reference to RSC. In long term, it may be important to establish comprehensive performance evaluation system for RSC so that it could be monitored and improved.

These observations and findings may help other organizations to improve their RSC performance. These observations and findings may also be useful for decision-making with

respect to RSC. Despite providing in depth analysis, the study is not without limitations. While study covered key strategic issues, the study does not consider all parts of the RSC due to lack of accessibility of all information. Furthermore, interviews may be biased and may not represent realistic picture. The organization may not be comfortable in talking about various issues openly because of regulatory requirements, and legal bindings. Therefore, more case studies and empirical study may be carried out to generalize the findings.

Chapter 7. Development of decision frameworks in Reverse Supply Chain

7.1 Introduction

Perusal of literature, Indian electronics industry survey, and case study concluded that there are number of issues such as forecasting product returns, disposition decisions, and outsourcing decisions are positively associated with the performance of RSC. The influences of decisions related to these issues will not only effect the organization but also other stakeholders. This chapter develops the decision frameworks for forecasting product returns, disposition decisions, and outsourcing decisions in RSC. The workflow of the chapter is shown in figure 7.1. Decisions frameworks have been developed with the help of various research methodologies and each framework has been validated through case illustration of Indian electronic organization. The decision frameworks have been developed and discussed in the following sections.

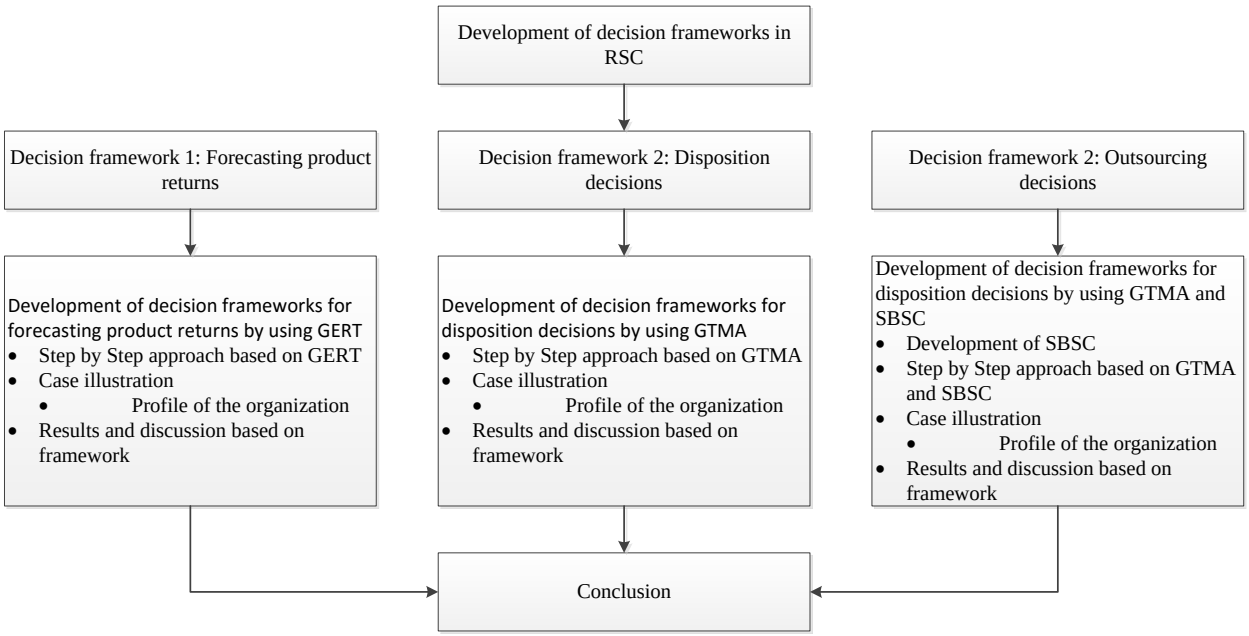

Figure 7.1 Workflow for the development of decision frame works

Part of this chapter has been published as* (i) "Forecasting product returns for recycling in Indian electronics industry", **Journal of Advances in Management Research, Vol. 11 No. 1, pp.102-114. 2014;
(ii) "Outsourcing decisions in reverse logistics: Sustainable balanced scorecard and graph theoretic approach", **Resources, Conservation and Recycling,** Vol. 108, pp.41-53, 2016.
(iii)"Disposition Decisions in Reverse Logistics: Graph Theory and Matrix Approach", **Journal of Cleaner Production,** Vol. 137, pp. 93-104, 2016.

7.2 Decision framework 1: Forecasting product returns

It is evident from the survey and case study that Indian electronics industry is mostly dependent upon the import of parts / components / products from other countries. The manufacturers have limited technology and facility for manufacturing or remanufacturing many components and products. It is very difficult and uneconomical for manufacturers to send them back to exporters for reprocessing of returned products. This results in the generation of e-waste and manufacturers need to develop the efficient and effective recycling system for handling these end of life products. As discussed in chapter 2, literature review, it requires high volume of product returns to be economically effective. Therefore, quantity, and timing of product returns is important for RSC planning to manage end of life products effectively. However, it is difficult to predict because of uncertainties involved in RSC. Forecasting product returns is one of the important decisions for managing these uncertainties. The forcasting will help in effective planning of RSC. Also, it will help in decision-making in reference to development of in-house facility of recycling. Percentage of product returns depends on several factors including consumer behaviour, customs and culture, demographics, rules and regulations. These factors vary from country to country. It is evident from the literature review that a lot of work has been done on forecasting product returns in developed countries but very little research has been done in developing countries like India. The forecasting model is developed in context of indian electronics industry. This model considers all possible flows of products in developing countries i.e. India from the point of sale to their recycling or landfilling.

7.2.1 Graphical Evaluation and Review Technique (GERT) for forecasting product returns

Product reaches their end of life at some point of time after being sold to the customer. Once product reaches end of life, the product returns are random and uncertain. Products may be

reused or land filled or recycled or may be stored by the end user. Reused or stored product may further go for either recycling or landfilled. Since both the traditional forward supply chain activities and additional RSC activities interact with each other under non-deterministic behavior, this forms a closed loop stochastic network. To address these uncertainties, randomness, stochastic nature of end of life product returns, GERT network has been developed for forecasting product returns. The following steps, based on the GERT developed by Pritsker (1966) have been proposed for forecasting product returns.

7.2.1.1 GERT network design and description

The GERT network for the flows of product starting with sale of products up to their recycling or land filling is shown in Figure 7.2, where each node represents a specific state as described below.

Node 0: Point of sale of products sold to the customer.

Node 1: Products reach their end of life

Node 2: Products stored

Node 3: Products reused

Node 4: Products recycled

Node 5: Products Land filled

An arrow on the GERT network indicates the transition from one node to the other node. Each arrow has a probability that the activity associated with it will be performed. The parameters P*ij* indicate the probability of occurrence of activity (*i, j*) means the probability of transition from node *i* to the node *j* and the parameter under each node indicates the operating time.

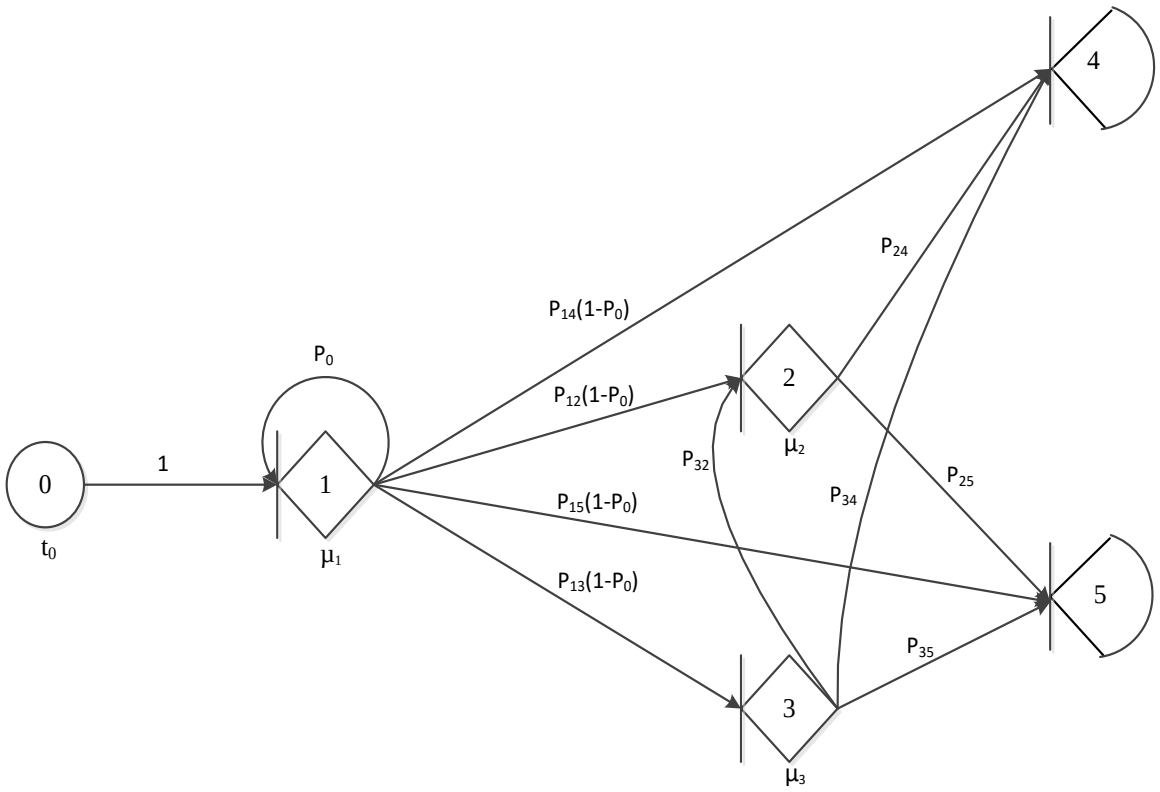

Figure 7.2 GERT network representing product flows from its point of sale to their recycling or land filling

GERT network can be explained as follows: Node 0 is the starting node indicating the state when the products were actually sold to the customers during period of t_0. Some of these products may return to the organization because of organization policy usually in the warranty period or because of some technical issues with probability P_0. Feedback loop on node 1 indicates these product returns. Arrow (0, 1) denotes the transition of products from "sold to the customer" (node 0) to the "products reach their end of life" (node 1) with probability one. It is assumed that μ_1 is the average life of the products. There are four possibilities when the products reach to their end of life. Let the products may either be stored or reused or recycled or may be landfilled with probabilities of P_{12}, P_{13}, P_{14} and P_{15} respectively. Arrows (1, 2), (1, 3), (1, 4) and (1, 5) indicate these four possibilities respectively as shown in the figure 7.2.

Since products which are returned to the organization will not go through any of these four possibilities at a given point of time. Probabilities of activities (1, 2), (1, 3), (1, 4) and (1, 5) have been multiplied by the factor (1- P_0). Node 2 indicates the number of products stored for the average time duration of μ_2 with P_{12} (1- P_0) probability of transition from node 1 to the node 2. These products may further go either for recycling (2, 4) with probability of transition P_{24} or for the land filling (2, 5) with probability of transition P_{25}. Node 3 indicates the number of products reused for their extended life time duration of μ_3 with P_{13} (1- P_0) probability of transition from node 1 to the node 3. These products may further go either for the storage (3, 2) or for the recycling (3, 4) or for the land- filling (3, 5) with probability of occurrence of P_{32}, P_{34}, P_{35} respectively.

7.2.1.2 Moment-Generating Function of the activities

In a GERT network, according to node logic, the arrow (*i*, *j*) can be implemented only if node *i* is realised. Assume the density function of node *i* with completion time t_i is *f*(t_i), then Moment-Generating Function (MGF) of the random variables t_i is the conditional MGF of the arc (*i*, *j*) shown as follows.

$$M_{ij}(s) = E\left(\exp st_i\right) = \int_{-\infty}^{+\infty} \exp st_i \,.\, f(t_i).\, dt_i \qquad (7.1)$$

Provided that if there is a positive number *h* such that the above integral (summation) exists and is finite for $-h < s < h$.

If the operating time t is constant then the equation for arrow (0, 1) becomes

$$M_{01}(s) = exp\, st_0 \qquad (7.1.1)$$

If t_i is assumed to be the negative exponential distribution, MGF for each activity are

$$M_{11}(s) = M_{12}(s) = M_{13}(s) = M_{14}(s) = M_{15}(s) = \frac{1}{1-\mu_1 s} \quad (7.1.2)$$

$$M_{24}(s) = M_{25}(s) = \frac{1}{1-\mu_2 s} \quad (7.1.3)$$

$$M_{32}(s) = M_{34}(s) = M_{35}(s) = \frac{1}{1-\mu_3 s} \quad (7.1.4)$$

7.2.1.3 Transfer function of the activity on network

The transfer function of each activity on the network (*i*, *j*) can be defined as the product of occurring probability and MGF as following:

$$w_{ij}(s) = P_{ij}(s) * M_{ij}(s) \quad (7.2)$$

By putting values from equations (7.1.1)-(7.1.4) in the above, equation (7.2) transfer function for each of activity can be expressed as:

$$w_{01}(s) = \exp st_0 \quad (7.2.1)$$

$$w_{11}(s) = \frac{P_0}{1-\mu_1 s} \quad (7.2.2)$$

$$w_{12}(s) = \frac{P_{12}(1-\mathrm{P}_0)}{1-\mu_1 s} \quad (7.2.3)$$

$$w_{13}(s) = \frac{P_{13}(1-\mathrm{P}_0)}{1-\mu_1 s} \quad (7.2.4)$$

$$w_{14}(s) = \frac{P_{14}(1-\mathrm{P}_0)}{1-\mu_1 s} \quad (7.2.5)$$

$$w_{24}(s) = \frac{P_{24}}{1-\mu_2 s} \quad (7.2.6)$$

$$w_{25}(s) = \frac{P_{25}}{1-\mu_2 s} \quad (7.2.7)$$

$$w_{32}(s) = \frac{P_{32}}{1-\mu_3 s} \quad (7.2.8)$$

$$w_{34}(s) = \frac{P_{34}}{1-\mu_3 s} \tag{7.2.9}$$

$$w_{35}(s) = \frac{P_{35}}{1-\mu_3 s} \tag{7.2.10}$$

7.2.1.4 Equivalent transfer functions

In the GERT network, non-touch loops represent that there is no common node between two loops; *n* order loops means *n* non-touch loops. According to Mason (1953), the equivalent transfer function from node x to node y is:

$W_{E_{xy}} = \frac{1}{\Delta} \sum_r \omega_r \Delta_r$, where Δ is a characteristics formula, $\Delta = 1 - \sum_{when\ r\ is\ even} \omega_r + \sum_{when\ r\ is\ odd} \omega_r$, ω_r is the transfer coefficient of the r[th] path from x to y. Δ_r is the characteristics formula when all spare nodes related to path r have been removed from Δ.

Equivalent transfer function can be determined from the start node (node 0) to the recycling node (node 4) by applying above mason`s rule. Equivalent transfer function is given by

$$W_{E_{04}}(s) = \frac{w_{01}}{(1-w_{11})}(w_{14} + w_{12}w_{24} + w_{13}w_{34}) \tag{7.3}$$

7.2.1.5 Equivalent probability

Let the probability from node x to node y is $P_{E_{xy}}$, MGF is $M_{E_{xy}}(s)$, then the transfer function is

$$W_{E_{xy}}(s) = P_{E_{xy}} * M_{E_{xy}}(s) \tag{7.4}$$

According to the characteristics of MGF, when s=0, the equation (7.4) can be expressed as

$$W_{E_{xy}}(0) = P_{E_{xy}} * M_{E_{xy}}(0) = P_{E_{xy}} * \int_{-\infty}^{+\infty} \exp st \,.\, f(t).\, dt \Big| s = 0$$

Hence

$$P_{E_{xy}} = W_{E_{xy}}(s)\,\big|_{s=0} \tag{7.4.1}$$

By using equations (7.2.1)-(7.2.10) and equation (7.3) in above equation (7.4.1);

Equivalent probability for recycling

$$P_{E_{04}} = W_{E_{04}}(s)\,\big|_{s=0}$$

$$= \left[\frac{w_{01}}{(1-w_{11})}(w_{14} + w_{12}w_{24} + w_{13}w_{34})\right]\big|\, s = 0$$

$$= \left[\frac{1}{(1-\mathrm{P}_0)}(\mathrm{P}_{14}(1-\mathrm{P}_0) + \mathrm{P}_{12}(1-\mathrm{P}_0)\mathrm{P}_{24} + \mathrm{P}_{13}(1-\mathrm{P}_0)\mathrm{P}_{34})\right]$$

$$= [\,\mathrm{P}_{14} + \mathrm{P}_{12}\mathrm{P}_{24} + \mathrm{P}_{13}\mathrm{P}_{34}] \tag{7.4.2}$$

7.2.1.6 Expected time of return

According to the characteristics of MGF,

Expected time from node *x* to *y* is

$$t_{E_{xy}} = E(t) = \frac{\partial}{\partial t}[M_{E_{xy}}(s)]\,\big|\, s = 0 = \frac{1}{P_{E_{xy}}} * \frac{\partial}{\partial t}[W_{E_{xy}}(s)]\,\big|\, s = 0 \tag{7.4.3}$$

By using equations (7.2.1)-(7.2.10), equation (7.4.2) and equation (7.3) in above equation (7.4.3),

The expected time of product returns

$$t = t_{E_{04}} = t_0 + \frac{\mu_1}{1-P_0} + \frac{\mu_2 \mathrm{P}_{12}\mathrm{P}_{24}}{(\mathrm{P}_{14}+\mathrm{P}_{12}\mathrm{P}_{24}+\mathrm{P}_{13}\mathrm{P}_{34})} + \frac{\mu_3 \mathrm{P}_{13}\mathrm{P}_{34}}{(\mathrm{P}_{14}+\mathrm{P}_{12}\mathrm{P}_{24}+\mathrm{P}_{13}\mathrm{P}_{34})} \tag{7.4.4}$$

7.2.2 Case illustration of GERT approach

Many organizations in India have started focusing on e-waste management especially after regulatory requirements by the Government of India. As discussed above forecasting product returns one of the important factors for developing an efficient and effective RSC system. A leading mobile phone manufacturing organization is selected for the demonstration of the proposed GERT based forecasting model.

7.2.2.1 Profile of the organization

The organization, XYZ limited is pioneer in the manufacturing of mobile phones. In 1992, XYZ limited introduced the first global system for mobile handsets. In 1994, XYZ limited completed the first satellite call. By 1998, XYZ limited became the world leader in the manufacturing and sales of mobile phones. The focus of XYZ limited was on growth through engineering design, supply chain management, high quality manufacturing and sales. This strategy helped the XYZ limited to become one of the best mobile manufacturing organizations in the world. At present XYZ, limited has fourteen manufacturing plant throughout the world including one in Chennai, India and has more than 50,000 employees.

The organization, XYZ Limited, a leading mobile phone manufacturer in the world has played pioneering role in growth of cellular technology in India. XYZ limited has grown from 450 employees in the starting to the 15000 employees at present in the country. XYZ limited has offices in almost all the metro cities in the India. The organization was awarded the ISO 14001 certification for its provision of sales, marketing and support services for mobile phones, network infrastructure, internet security and home communications businesses in the Asia Pacific region. XYZ limited has taken several sustainability initiatives including product design for environment, substance and material management. It has also started consumer education program focused on sustainable lifestyles.

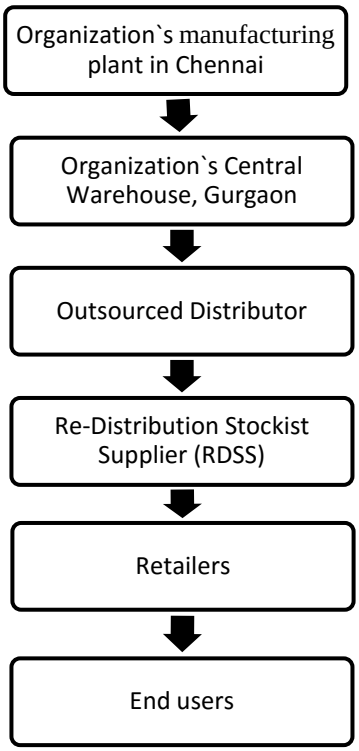

Figure 7.3 Distribution system of the organization XYZ limited

XYZ limited has developed a well-structured supply chain for the distribution of mobiles across the India. At present XYZ limited has approximately 110,000 outlets including 50,000 stores selling organization`s product exclusively. As shown in the figure 7.3, XYZ limited outsourced its supply chain partially and started distributing its mobile phones in partnership of a leading computer manufacturing organization in India which had already developed an extensive network for the distribution of its own products. This partner helped the organization in supplying the mobiles to the distributors and then products are supplied to the retailers through re-distribution stockist supplier. This multiple distribution system was developed to keep the business information confidential. But this system resulted in higher cost of distribution in comparison to peer organizations. Also, in last few years XYZ limited started take back program for the e-waste management of products in India. Since XYZ limited does not own the whole of the supply chain of products, it has been costly and in efficient for the organization to manage the RSC. So recently, the organization has decided to supplement the outsourced

supply chain with its own supply chain. XYZ limited believes that having own supply chain will reduce its operational cost and will also enable them to implement their sustainability efforts successfully in India.

7.2.3 Results and discussion based on model

XYZ limited plan is to develop a supply network by integrating both forward and RSC in a cost effective manner. In order to develop the RSC along with its own distribution network, XYZ limited conducted a survey. According to survey conducted by the XYZ limited only 3% (P_{14}) of the old devices are recycled and 4% (P_{15}) of the old devices are disposed in landfills. 44 % (P_{12}) of the devices are stored unused. Rest of the 49% (P_{13}) devices are sold in the secondary market or passed on to the friends and family. 10% (P_0) of the total products sold are returned to the organization as a part of the organization return policy or due to other technical issues. Average time of 3 months (t_0) is considered as planning period for this study. This is the time during which products are sold to the customer and the organization is interested in estimation of percentage and timing of these product returns for recycling. Here it is assumed that products are stored for average time duration of 30 months (μ_2) consistent with negative exponential distribution. 10% (P_{24}) of total stored devices go for recycling and rest of the 90% (P_{25}) landfills.

According to Srivastava and Srivastava (2006), average product life cycle of a cell phone is 36 months (μ_1) consistent with negative exponential distribution. This average life is increased by 0.6 months (μ_3) with negative exponential distribution during the reuse of device. Again 3% (P_{34}) of these devices are recycled, 4% (P_{35}) are disposed in landfills and 44 % (P_{32}) of the devices are stored unused.

By putting the values of $P_{14}, P_{12,}P_{24}, P_{13} and\ P_{34}$ for the organization XYZ in “equation (4.2)”

Equivalent probability$P_{E_{04}} = 9\%$

By putting the values of $t_0, \mu_1, \mu_2, \mu_3, P_{14}, P_{12}, P_{24}, P_{13}, P_{34}$ *and* P_0 for the organization, XYZ in equation (7.4.4),

The expected time of return $t = 53$ months

Equivalent probability represents the percentage of product returns that is 9% of total products sold during the planning period. This means that 9% of products sold by the organization in a specified period of 3 months are expected to return for the recycling in expected time of 53 months. This percentage return provides the status of expected product returns along with their timing in present scenario. The organization may need to increase this percentage in future because of legislation or other business reasons. These figures will provide a base for the planning of RSC and will help in future sustainability initiatives of the organization. Percentage of return will increase more and more with the consumer awareness and incentives offered by XYZ limited to the consumer for recycling. This will also change the expected time of product returns. In long run XYZ limited will have to take the responsibility of e-waste management because of regulatory requirements by the Government of India. All these factors must be considered by XYZ limited while designing their RSC. RSC planning will change with change in percentage of products returns to the organization over a period of time. Therefore, the organization for cost effective RSC, must adopt a flexible short term and long-term resource planning.

7.3 Decision framework 2: Disposition decisions

It is evident from the literature review, statistical analysis, and case study that disposition decisions is one of the important decisions to disposition returned products appropriately for better performance of RSC. According to Attia (2015), returned product disposition strategies are positively correlated with the RSC performance and hence with the performance of the organization. Perusal of previous literature indicates that there are very few studies on disposition of returned products in RSC. This chapter attempted to explore the disposition options and develop a decision framework for the selection of best disposition option using GTMA. A case of mobile manufacturing organization is discussed for the illustration of the approach. Various disposition options were explored and attributes were identified with the help of past literature review and discussion with the experts. Permanent function value, referred as “Disposition Index” was evaluated for each option with the help of C++ program and results are discussed based on these indices.

7.3.1 Selection of disposition attributes

Selection of the disposition option depends on the number of attributes. Most of the earlier selection attributes of disposition options were based on the operational requirements. Later on authors started considering disposition as strategic issues. Based on literature review, total eleven attributes were identified as important attributes for the study. these attributes are shown in table 2.4. Subsequently after the statistical analysis of responses from Indian electronics industry, one of the attributes was dropped from the 11 attributes and total 10 attributes were selected for the study. These attributes are shown in table 5.4. These attributes are discussed in next section.

7.3.2 Graph Theory and Matrix Approach

Selection of the disposition option depends on the number of attributes and available options for the returned products disposition. In GTMA, nodes and edges are two basic elements which are used for representing the (inter) relationship between nodes (different variables) in the form of directional graph (also known as digraph) and in the form of matrix. Relative weights can be assigned to the edges considering their individual importance to the system and their relative importance to each other to determine an overall index of a system for a given option. Overall index for different options may be calculated for the purpose of comparing them and selecting the best option.

7.3.2.1 Development of digraph and matrix

Disposition decision attribute is defined as a factor that influences the disposition decision for a given product. Once the attributes are decided, a diagraph showing these attributes and their interdependence is prepared. Numbers of nodes (M) in the diagraph are equal to the number of attributes considered for the study, and arrow or directed edge connecting two nodes represents their relative importance. As discussed by Rao and Padmanabhan (2006), the digraph consists of a set of nodes $N = \{n_i\}$ with $i = 1, 2, 3 \ldots\ldots\ldots M$ and a set of directed edge $E = \{a_{ij}\}$. A node n_i represents an i^{th} disposition selection attribute and edges represent the relative importance of the attributes. For example if node "i" has relative importance over other node "j" in the disposition option selection then arrow or edge is directed from node "i" to node "j". If node "j" has relative importance over other node "i" then arrow or edge is directed from node "j" to node "i". The digraph, graphical representation of the attributes makes it helpful in visualizing their relative importance easily and quickly. However, as number of attributes (nodes) increases, it becomes complicated and difficult to analyze visually. In such cases, the digraph is transformed into a matrix form.

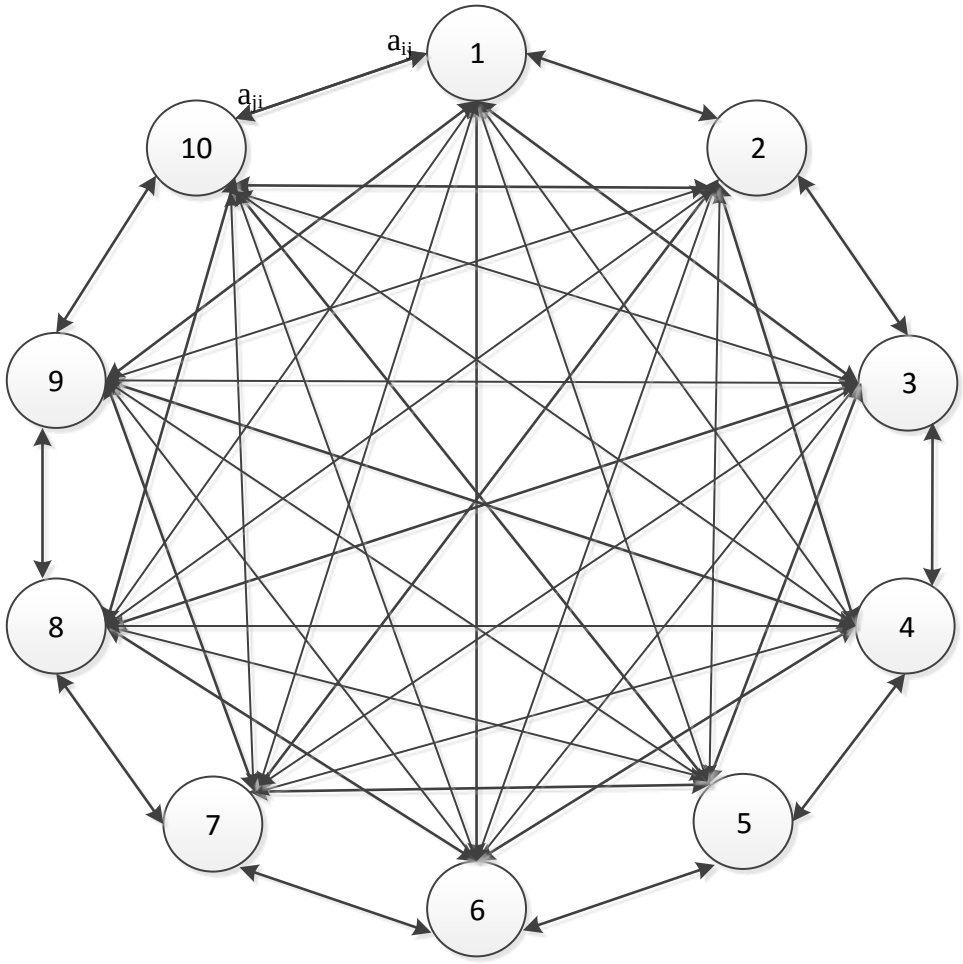

Figure 7.4 Digraph of disposition decision attributes

Diagraph is transformed into a square matrix, called relative importance matrix in which the off-diagonal elements represent the relative importance of one attribute over other. The diagonal elements represent the importance for disposition option. Since diagraph or matrix may change with change in number of attributes, a standard form of matrix function known as permanent function is computed rather than the determinant of the matrix. In case of determinant function of a matrix, some information may be lost due to the presence of negative signs. Therefore, researchers preferred to use the permanent function of a matrix in order to provide the complete information without any loss (Rao and Gandhi 2001, 2002, Rao and Padmanabhan 2006). The attributes, selected for the proposed study (discussed above) are Customer behavior (CBH), Market conditions, (MCD), Existing regulation, (EXR),

Environmental impact (EVI), Supply chain capabilities (SCC), Product Value (PRV), Processing Cost (PRC), No. of Returned Products (NRP), Quality of Returned Products (QRP), and Recapturing Value (RCV). Digraph for the 10 number of attributes is shown in figure 7.3. It is difficult to represent them on a digraph so a matrix, [A] is prepared as shown below. It is an M x M matrix which considers the importance of all the attributes (D_i, i = j), also known as inheritance for each disposition option and their relative importance (a_{ij}, $i \neq j$).

[A]=

	CBH	MCD	EXR	EVI	SCC	PRV	PRC	NRP	QRP	RCV
CBH	D_1	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	a_{19}	a_{110}
MCD	a_{21}	D_2	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}	a_{29}	a_{210}
EXR	a_{31}	a_{32}	D_3	a_{34}	a_{35}	a_{36}	a_{37}	a_{38}	a_{39}	a_{310}
EVI	a_{41}	a_{42}	a_{43}	D_4	a_{45}	a_{46}	a_{47}	a_{48}	a_{49}	a_{410}
SCC	a_{51}	a_{52}	a_{53}	a_{54}	D_5	a_{56}	a_{57}	a_{58}	a_{59}	a_{510}
PRV	a_{61}	a_{62}	a_{63}	a_{64}	a_{65}	D_6	a_{67}	a_{68}	a_{69}	a_{610}
PRC	a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}	D_7	a_{78}	a_{79}	a_{710}
NRP	a_{81}	a_{82}	a_{83}	a_{84}	a_{85}	a_{86}	a_{87}	D_8	a_{89}	a_{810}
QRP	a_{91}	a_{92}	a_{93}	a_{94}	a_{95}	a_{96}	a_{97}	a_{98}	D_9	a_{910}
RCV	a_{101}	a_{102}	a_{103}	a_{104}	a_{105}	a_{106}	a_{107}	a_{108}	a_{109}	D_{10}

7.3.2.2 Permanent function of matrix

The permanent function of this matrix [A] is classified as disposition decision attributes function. The permanent function is represented as follows:

$$\textbf{per(A)} = \prod_{i=1}^{M} D_i + \sum_{i=1}^{M-1} \sum_{j=i+1}^{M} \ldots\ldots \sum_{M=t+1}^{M} (a_{ij}a_{ji}) D_k D_1 D_m D_n D_o \ldots\ldots D_t D_M \ldots M \neq \text{pus}$$

$$+ \sum_{i=1}^{M-2} \sum_{j=i+1}^{M-1} \sum_{k=j+1}^{M} \ldots \sum_{M=t+1}^{M} (a_{ij}a_{jk}a_{ki} + a_{ik}a_{kj}a_{ji}) D_1 D_m D_n D_0 \ldots D_t D_M \quad k \ldots M \neq \text{pus}$$

$+\sum_{i=1}^{M-3}\sum_{j=i+1}^{M}\sum_{k=i+2}^{M-1}\sum_{l=i+2}^{M}\ldots.\sum_{M=t+1}^{M}(a_{ij}a_{ji})(a_{kl}a_{lk})D_mD_nD_o\ldots.D_tD_M$ k,l ….M≠ pus

$+\sum_{i=1}^{M-3}\sum_{j=i+1}^{M+1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\ldots\ldots..\sum_{M=t+1}^{M}(a_{ij}a_{jk}a_{kl}a_{li}+a_{il}a_{lk}a_{kj}a_{ji})D_mD_nD_o\ldots.D_tD_M$

k,l.….M≠ pus

$+\sum_{i=1}^{M-2}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M}\sum_{l=1}^{M-1}\sum_{m=l+1}^{M}\ldots.\sum_{M=t+1}^{M}(a_{ij}a_{jk}a_{ki}+a_{ik}a_{kj}a_{ji})(a_{lm}a_{ml})D_nD_o\ldots D_tD_M$

k,l,m…..M≠ pus

$+\sum_{i=1}^{M-4}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\sum_{m=j+1}^{M}\ldots.\sum_{M=t+1}^{M}(a_{ij}a_{jk}a_{kl}a_{lm}a_{mi}+a_{im}a_{ml}a_{lk}a_{kj}a_{ji})D_nD_o\ldots D_tD_M$

k,l,m…..M≠ pus

$+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M-1}\sum_{k=j+1}^{M}\sum_{l=1}^{M-2}\sum_{m=l+1}^{M-1}\sum_{n=m+1}^{M}\ldots\sum_{M=t+1}^{M}(a_{ij}a_{jk}a_{ki}+a_{ik}a_{kj}a_{ji})(a_{lm}\,a_{mn}a_{nl}+a_{lm}a_{nm}a_{ml})D_o\ldots.D_tD_M$ k,l,m,n…..M≠ pus

$+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M}\sum_{k=i+1}^{M-3}\sum_{l=i+2}^{M}\sum_{m=k+1}^{M-1}\sum_{n=k+2}^{M}\ldots.\sum_{M=t+1}^{M}(a_{ij}a_{ji})(a_{kl}a_{lk})(a_{mn}a_{nm})D_o\ldots..D_tD_M$

k,l,m,n…..M≠ pus

$+\sum_{i=1}^{M-5}\sum_{j=i+1}^{M-1}\sum_{k=i+1}^{M}\sum_{l=i+1}^{M}\sum_{m=i+1}^{M}\sum_{n=j+1}^{M}\ldots.\sum_{M=t+1}^{M}(a_{ij}a_{jk}a_{kl}a_{lm}a_{mn}a_{in}+a_{ni}a_{nm}a_{ml}a_{lk}a_{kj}a_{ji})D_o\ldots.D_tD_M$ k,l,m,n…..M≠ pus

In general, the permanent of an M×M matrix, [A] with attributes a_{ij} defined by Forbert and Marx (2003) as

$$Per\ (A) = \sum_{p}\prod_{i=1}^{M} a_i\ , P(i)$$

Where, the sum is overall permutations P. In order to calculate the permanent function value, a computer program in C++ language for M × M size of the matrix was utilized. The program takes few minutes to run the program and compute the value of permanent function. The value of permanent function is referred as "Disposition Index" for the disposition decisions. A systematic approach for applying GTMA is described as follows:

7.3.3 Development of decision framework

Step 1

Identify the disposition options and disposition options attributes for a given product.

Step 2

Find out the relative importance of disposition attributes on a suitable scale. The scale shown in table 7.1 is utilized for the study. These are the off-diagonal elements of the matrix.

Table 7.1 Scale for relative importance of attributes

Description	aij	1-aij
Two attributes are equally important	0.5	0.5
One attribute (i) is slightly more important over the other (j)	0.6	0.4
One attribute i) is strongly more important over the other (j)	0.7	0.3
One attribute (i) is very strongly important over the other (j)	0.8	0.2
One attribute is extremely important over the other	0.9	0.1
One attribute is exceptionally more important over the other	1	0

Step 3

Find out the individual importance or inheritance of the attributes for each of the disposition options on a suitable scale. The scale shown in table 7.2 is utilized for the study. These are the diagonal elements for the respective option.

Table 7.2 Scale for absolute importance of attributes

Qualitative measure of attributes	Assigned Value of Dij
Exceptionally low	0.0
Extremely low	0.1
Very low	0.2
Low	0.3
Below average	0.4
Average	0.5
Above average	0.6
High	0.7
Very high	0.8
Extremely high	0.9
Exceptionally high	1.0

Step 4

Develop the matrix for disposition option selection. This is an M x M matrix as shown in matrix [A]. The matrix must be developed for each option by entering the value of off-diagonal elements and by entering the value of diagonal elements for respective disposition option.

Step 5

Write the permanent function for disposition decision option for the matrix [A].

Step 6

Determine the value of permanent function, which is referred as disposition index for each of the disposition option. After the determination of disposition index (permanent function) for each of the options, the options may be compared and the best option may be selected based on these values.

7.3.4 A Case Illustration of GTMA

A case of mobile manufacturing organization has been considered for the illustration of GTMA methodology. The case is discussed in the following section.

7.3.4.1 Profile of the organization

The case study of the organization, ABC Limited, discussed in chapter 6 has been utilized for the illustration of the disposition decision framework. Since the organization is in the process of implementing various RSC activities, it has been well suited for the case illustration. In order to apply proposed approach, possible disposition options associated with mobile phone hand set for the ABC Ltd have been identified as repair or reuse and resell as new; repair or refurbish and resell in secondary market; re-manufacture and sell in the secondary market; recycle; and disposal. The last option, disposal is dropped because of regulatory restrictions by the government of India. The first option, repair or reuse and resell is concerned with those mobile phones, which are returned directly to the organization rather than customer going to the retailer or service center. These mobile phones are mostly sold through e-business or e-retailers and are almost new because only minor repair or reuse is required or customer returns them because of their choice. The second option, repair or refurbish and resell is concerned with mobile phones, which require major repair or refurbishment and cannot be sold as new. The ABC Ltd may sell them in secondary market. The third option, re-manufacture and sell are concerned with remanufacturing them through disassembly and use their parts and components. The fourth option is recycling them. In order to assign the values of diagonal and off-diagonal elements, total eleven experts participated in the study. The experts were chosen from the organization and electronics industry. The experts have an average experience of approximately 8 years in manufacturing, marketing, and finance department. In addition, one expert was selected from the academia involved in the research area of RSC. The experts are at the key responsible position in their respective organization and their knowledge is assumed to be sufficient for the proposed study.

7.3.5 Results and discussion based on the framework

In order to determine the disposition index for the selection of best disposition option, the steps of the methodology discussed above were carried out as follows:

Step 1

Disposition decision attribute is defined as a factor that influences the disposition decision for a given product or part. Following attributes have been selected for the study as discussed above in section 7.3.2.1 of this chapter.

Customer behavior (CBH), Market conditions, (MCD), Existing regulation, (EXR), Environmental impact (EVI), Supply chain capabilities (SCC), Product Value (PRV), Processing Cost (PRC), No. of Returned Products (NRP), Quality of Returned Products (QRP), and Recapturing Value (RCV). All these disposition decision attributes for the selection of best option are tabulated in table 7.3. These attributes will be used for the determination of Disposition Index for different disposition options by using GTMA.

The four options considered for the study are as follows:

Disposition Option 1 **(DOP-1):** Repair or reuse and resell as new;

Disposition Option 2 **(DOP-2):** Repair or refurbish and resell;

Disposition Option 3 **(DOP-3):** Re-manufacture and sell;

Disposition Option 4 **(DOP-4):** Recycle

Step 2

Quantitative values of relative importance were assigned by comparing them on scale shown in table 7.1. The experts were asked to choose values from the scale and highest mode value was selected. The values are shown in matrix [B]. The diagonal elements are concerned with values of respective disposition options.

$$[B] = \begin{array}{c} \\ \text{CBH} \\ \text{MCD} \\ \text{EXR} \\ \text{EVI} \\ \text{SCC} \\ \text{PRV} \\ \text{PRC} \\ \text{NRP} \\ \text{QRP} \\ \text{RCV} \end{array} \begin{array}{c} \begin{array}{cccccccccc} \text{CBH} & \text{MCD} & \text{EXR} & \text{EVI} & \text{SCC} & \text{PRV} & \text{PRC} & \text{NRP} & \text{QRP} & \text{RCV} \end{array} \\ \begin{bmatrix} D_{11} & 0.5 & 0.3 & 0.5 & 0.6 & 0.7 & 0.5 & 0.5 & 0.5 & 0.7 \\ 0.5 & D_{22} & 0.6 & 0.6 & 0.5 & 0.4 & 0.6 & 0.5 & 0.6 & 0.5 \\ 0.7 & 0.4 & D_{33} & 0.6 & 0.7 & 0.8 & 0.7 & 0.6 & 0.7 & 0.6 \\ 0.5 & 0.4 & 0.4 & D_{44} & 0.6 & 0.7 & 0.6 & 0.6 & 0.4 & 0.5 \\ 0.4 & 0.5 & 0.3 & 0.4 & D_{55} & 0.5 & 0.5 & 0.6 & 0.5 & 0.4 \\ 0.3 & 0.6 & 0.2 & 0.3 & 0.5 & D_{66} & 0.5 & 0.5 & 0.6 & 0.5 \\ 0.5 & 0.4 & 0.3 & 0.4 & 0.5 & 0.5 & D_{77} & 0.5 & 0.5 & 0.5 \\ 0.5 & 0.5 & 0.4 & 0.4 & 0.4 & 0.5 & 0.5 & D_{88} & 0.5 & 0.4 \\ 0.5 & 0.4 & 0.3 & 0.6 & 0.5 & 0.4 & 0.5 & 0.5 & D_{99} & 0.3 \\ 0.3 & 0.5 & 0.4 & 0.5 & 0.6 & 0.5 & 0.5 & 0.6 & 0.7 & D_{1010} \end{bmatrix} \end{array}$$

Step 3

The experts selected quantitative values of diagonal elements for selected disposition attributes by using scale shown in table 7.2. These values for all attributes were selected for each of the options respectively. Responses of the experts in terms assigned values are shown in table 7.3.

Table 7.3 Disposition options selection attributes

Attributes	**DOP-1**	**DOP-2**	**DOP-3**	**DOP-4**
Customer behavior (CBH)	0.6	0.5	0.3	0.7
Market conditions, (MCD)	0.7	0.5	0.2	0.6
Existing regulation, (EXR)	0.6	0.6	0.6	0.6
Environmental impact (EVI)	0.7	0.7	0.7	0.7
Supply chain capabilities (SCC)	0.9	0.8	0.6	0.9
Product Value (PRV)	0.7	0.7	0.6	0.4
Processing Cost (PRC)	0.8	0.7	0.4	0.6
No. of Returned Products (NRP)	0.4	0.6	0.3	0.7
Quality of Returned Products (QRP)	1	0.9	0.6	0.1
Recapturing Value (RCV)	0.9	0.8	0.5	0.4

Step 4

The matrix developed for all four options, DOP-1, DOP-2, DOP-3, and DOP-4 are shown in the following section.

[DOP-1] =

	CBH	MCD	EXR	EVI	SCC	PRV	PRC	NRP	QRP	RCV
CBH	0.6	0.5	0.3	0.5	0.6	0.7	0.5	0.5	0.5	0.7
MCD	0.5	0.7	0.6	0.6	0.5	0.4	0.6	0.5	0.6	0.5
EXR	0.7	0.4	0.6	0.6	0.7	0.8	0.7	0.6	0.7	0.6
EVI	0.5	0.4	0.4	0.7	0.6	0.7	0.6	0.6	0.4	0.5
SCC	0.4	0.5	0.3	0.4	0.9	0.5	0.5	0.6	0.5	0.4
PRV	0.3	0.6	0.2	0.3	0.5	0.7	0.5	0.5	0.6	0.5
PRC	0.5	0.4	0.3	0.4	0.5	0.5	0.8	0.5	0.5	0.5
NRP	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.4
QRP	0.5	0.4	0.3	0.6	0.5	0.4	0.5	0.5	1	0.3
RCV	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.6	0.7	0.9

[DOP-2] =

	CBH	MCD	EXR	EVI	SCC	PRV	PRC	NRP	QRP	RCV
CBH	0.5	0.5	0.3	0.5	0.6	0.7	0.5	0.5	0.5	0.7
MCD	0.5	0.5	0.6	0.6	0.5	0.4	0.6	0.5	0.6	0.5
EXR	0.7	0.4	0.6	0.6	0.7	0.8	0.7	0.6	0.7	0.6
EVI	0.5	0.4	0.4	0.7	0.6	0.7	0.6	0.6	0.4	0.5
SCC	0.4	0.5	0.3	0.4	0.8	0.5	0.5	0.6	0.5	0.4
PRV	0.3	0.6	0.2	0.3	0.5	0.7	0.5	0.5	0.6	0.5
PRC	0.5	0.4	0.3	0.4	0.5	0.5	0.7	0.5	0.5	0.5
NRP	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.6	0.5	0.4
QRP	0.5	0.4	0.3	0.6	0.5	0.4	0.5	0.5	0.9	0.3
RCV	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.6	0.7	0.8

[DOP-3] =

	CBH	MCD	EXR	EVI	SCC	PRV	PRC	NRP	QRP	RCV
CBH	0.3	0.5	0.3	0.5	0.6	0.7	0.5	0.5	0.5	0.7
MCD	0.5	0.2	0.6	0.6	0.5	0.4	0.6	0.5	0.6	0.5
EXR	0.7	0.4	0.6	0.6	0.7	0.8	0.7	0.6	0.7	0.6
EVI	0.5	0.4	0.4	0.6	0.6	0.7	0.6	0.6	0.4	0.5
SCC	0.4	0.5	0.3	0.4	0.7	0.5	0.5	0.6	0.5	0.4
PRV	0.3	0.6	0.2	0.3	0.5	0.6	0.5	0.5	0.6	0.5
PRC	0.5	0.4	0.3	0.4	0.5	0.5	0.4	0.5	0.5	0.5
NRP	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.3	0.5	0.4
QRP	0.5	0.4	0.3	0.6	0.5	0.4	0.5	0.5	0.6	0.3
RCV	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.6	0.7	0.5

[DOP-4] =

	CBH	MCD	EXR	EVI	SCC	PRV	PRC	NRP	QRP	RCV
CBH	0.7	0.5	0.3	0.5	0.6	0.7	0.5	0.5	0.5	0.7
MCD	0.5	0.6	0.6	0.6	0.5	0.4	0.6	0.5	0.6	0.5
EXR	0.7	0.4	0.6	0.6	0.7	0.8	0.7	0.6	0.7	0.6
EVI	0.5	0.4	0.4	0.7	0.6	0.7	0.6	0.6	0.4	0.5
SCC	0.4	0.5	0.3	0.4	0.9	0.5	0.5	0.6	0.5	0.4
PRV	0.3	0.6	0.2	0.3	0.5	0.4	0.5	0.5	0.6	0.5
PRC	0.5	0.4	0.3	0.4	0.5	0.5	0.6	0.5	0.5	0.5
NRP	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.7	0.5	0.4
QRP	0.5	0.4	0.3	0.6	0.5	0.4	0.5	0.5	0.1	0.3
RCV	0.3	0.5	0.4	0.5	0.6	0.5	0.5	0.6	0.7	0.4

Step 5

Permanent function for each disposition option was written with the help of matrix developed in step 4. Since, a computer program, written in C++ was used for calculating the permanent function value of this matrix, step 5 can be skipped.

Step 6

The permanent function value, decision index values for four options were calculated by using the computer program and are listed in descending order as follows:

Disposition Index for Disposition Option-1 (DOP-1) 5032.64

Disposition Index for Disposition Option-2 (DOP-2) 4568.91

Disposition Index for Disposition Option-4 (DOP-4) 3631.36

Disposition Index for Disposition Option-3 (DOP-3) 3057.34

From these values of Disposition Index, disposition option-1(repair or reuse and resell as new) is the best choice among all considered options for the ABC Limited. In a study of US and UK market, Geyer and Blass (2010) found that mobile phone reuse has healthier profit margin and recycling is the by-product. Increase in return of new or almost new mobile phones is also expected with the increase in e-business in India. Offers like payment on delivery and change in mind of customer during the delivery may increase these numbers. Second disposition option (repair or refurbish and resell) is the next best option. This option is related to returned mobiles, which require refurbishment or major repairing. The organization can reconditioned them without requiring dedicated remanufacturing facility. The fourth option (recycle) is preferred over third option (re-manufacture and sell). In a study of Indian mobile phone remanufacturing business, Rathore et al. (2011) stated that remanufacturing in Indian electronics industry is in learning stage and the organizations have not adopted the remanufacturing as a professional business activity. They also reported that the customers are not interested in second hand mobiles. Although remanufacturing is more viable option environmentally and economically because of reducing size and weight of mobile phones (Gehin et al., 2008; King et al., 2006), recycling is preferred over remanufacturing for the

organization in current market conditions because of customer attitude, remanufacturing capability, competitiveness, and lower cost model of the organization. Remanufactured products sales may influence both the new product sales (Atasu et al., 2010), and the price of new products.

7.4 Decision framework 3: Outsourcing decisions

It is evident from the literature review, statistical analysis, and case study that one of the important decisions is whether such activities must be outsourced partly, all must be outsourced, or nothing must be outsourced. The research work developed a framework for outsourcing decisions in RSC with the help of SBSC and GTMA. The ability of GTMA to consider interdependencies and maintaining hierarchical relationship among attributes and sub attributes makes it an attractive approach. The attributes and sub attributes were selected by combining four traditional BSC perspectives i.e. stakeholder, internal business process, learning and growth, and finance with TBL aspects of sustainability, known as SBSC. By considering, SBSC based attributes and sub attributes, organizations can ensure their contribution towards sustainability even after outsourcing the RSC activities. The framework is illustrated by case example of a mobile manufacturing organization. Scenario based alternatives were developed and "outsourcing index" were calculated for all the alternatives by evaluating permanent function using GTMA. The best alternative was selected based on the "outsourcing index".

7.4.1 Development of sustainable balanced scorecard

Traditionally, organizations have considered the economic criteria like cost, investment, economies of scale; processing parameters like flexibility, capacity, capability; resource

capacity; quality of service, core competency and other strategic, operational and tactical parameters for the outsourcing decisions. In recent years, growing concern for the environment, corporate social responsibility, and legislations in many countries are forcing organizations to think beyond business practices. Organizations worldwide realized the need of protecting the environment, and ensuring the health, safety and welfare of current and future generations along with economic benefits by incorporating sustainability into their practices (Gunasekaran and Spalanzani, 2012). Organizations with rising pressure by government agencies and increased social awareness of stakeholders are developing new approaches to incorporate sustainability into strategic decision-making (Gates and Germain, 2010). It is becoming obligatory to consider social and environmental aspect within the strategic decision making while developing a BSC (Jones, 2011). Environmental and social aspects can be integrated with conventional BSC to address the concerned issues along with the traditional measures (Elijido-Ten, 2010). Because of all these reasons, BSC has been combined with TBL aspects of sustainability known as SBSC.

Previous studies may help in understanding and developing the SBSC. Epstein and Wisner (2001) developed a SBSC framework highlighting factors that could enable organizations to practice more effective sustainability management. Hsu et al. (2011) provided a SBSC based performance evaluation system for the semiconductor industry. Nikolaou and Tsalis (2013) also developed the SBSC by using Global Reporting Initiative indicators for the Greek organizations. Kang et al. (2015) utilized the SBSC for exploring the relationship between corporate social responsibility and business performance. Rabbani et al. (2014) developed a performance evaluation framework based on ANP and SBSC. Figge et al. (2002) discussed the relationships between BSC and the sustainability, and enumerated the procedure to develop SBSC. The development of SBSC is related with its capability to identify the relationship between long-term environmental and social objectives and short-term economic

goals of organizations (Moller and Schaltegger, 2005). SBSC for the research work has been developed with the help of past literature review and experts. It considers the financial, internal process, learning and growth, and stakeholder's perspective along with environmental and social perspectives. The attributes and sub attributes of proposed SBSC are shown in the table 7.4.

Table 7.4 Attributes and sub attributes for the study

Attributes / Sub-Attributes	Description	Authors
Financial Perspective (FP)		
Total Capital Input (TCI)	Capital investment requirement for inspection/ remanufacturing/ recycling equipment, transport facility and Infrastructure including IT infrastructure	Presley et al. (2007); Lee et al. (2009a); Jacobs et al. (2010); Senthil et al. 2014
Logistics Cost Optimization (LCO)	It involves the optimization of cost of product acquisition, collection, inspection, and transportation	Hu et al. (2002); Wee et al. (2003); Lee et al. (2009)
Remanufactur'g /Recycling Cost (RRC)	Costs related to remanufacturing or recycling of a product	Senthil et al. (2014); Gunasekaran et al. (2009)
Recovery Value (RCV)	Recapturing Value from recovered products and it is important for sustaining the RL operations	Meade and Sarkis (2002); Ravi et al. (2005b); Kannan et al. (2009); Madaan et al. (2015)
Internal Process Perspective (IP)		
Core Focus (COF)	Organization's interest in focusing on its core business processes and RSC is not part of its core activities	Govindan et al. (2012); Arnold (2000); Wu and Cheng (2006)
Resource Capacity (RSP)	Level of advanced equipment, network capacity and infrastructure, transport capacity, human resource skills and training	Xiangru (2008); Chen and Chao (2012); Lee et al. (2009)
Communication Systems (CMS)	EDI capacity and IT level	Liu and Wang (2009); Chen (2011); Tyagi et al. (2012)
Agility (AGL)	Organization's responsiveness to change – new or changing demand	Liu and Wang (2009); Gunasekaran et al. (2004); Chang and Hung (2010)
Stakeholders Perspective (SP)		
Stakeholder Participation (SHP)	Stake holder engagement and empowerment	Nikolaou et al. (2013); Presley et al. (2007)
Customer Satisfaction (CSS)	Meeting the expectations of the customers	Rahman and Subramanian; (2012); Gonza´ lez-Torre et al. (2010); Mittal and Sangwan (2014); Shao et al. (2016)

Attributes / Sub-Attributes	Description	Authors
Regulatory Satisfaction (RGS)	Meeting the requirements of the government rules, regulations and legislations	Knemeyer et al. (2002); Rahman and Subramanian (2012)
Investors Satisfaction (INS)	Meeting the expectations of investors including financial and environmental requirements	Mittal and Sangwan (2014); Rahman and Subramanian (2012)
Learning and Growth (LG)		
Employee Competency (EMC)	The competency of the organization's employees pertaining to RSC functions	Nikolaou et al. (2013); Bai and Sarkis (2013)
Management Knowhow (MKH)	The management expertise and other knowhow to facilitate employee learning and innovation for the effective and efficient RSC system	Sharma et al. (2016); Gonza´ lez-Torre et al. (2010); Govindan et al. (2013)
Process Technology and Innovation Capability (PTI)	Automating physical, information and financial flows foster a seamless reverse chain. Use of technology streamlines processes and procedures of the RL to meet current and future demands	Liu and Wang (2009); Chen (2011); Khaleie et al. (2012); Wong et al. (2009)
Enterprise Alliances (ETA)	Sharing of benefits and risks, enterprise culture compatibility	Zhi-Hong and Qiang (2009); Janse et al. (2010); Senthil et al. (2014)
Environmental Perspective (EP)		
Resource Consumption (RSC)	Resource consumption in terms of raw material, energy, and water during the RSC processes	Knemeyer et al. (2002); Lai et al. (2013); Presley et al. (2007) Chen (2011); Gonza´ lez-Torre et al. (2010)
Disposal Capability (DSC)	Capability of ensuring safety and protecting environment through proper disposal of wastes	Wee et al. (2003); Knemeyer et al. (2002); Lai et al. (2013); Presley et al. (2007)
Environmental Management System (EMS)	Environmental certifications like ISO 14000, environmental policies, planning of environmental objectives, checking and control of environmental activities	Lau and Wang (2009); Tseng and Chiu; 2013; Govindan et al.; 2013
Pollution Production Control (PPC)	Average volume of air emission pollutant, waste water, solid wastes and harmful materials released per day during RSC performance	Kuo et al.; 2010; Buyukozkan and Berkol; 2011; Govindan et al. 2013
Social Perspective (SO)		
Corporate Image (CRI)	Market reputation of the enterprise and general image among the common public	Ravi et al. (2005a); Muller and Kolk (2009); Parast and Adams (2012)
Communities Influence (CMI)	Health, education, service infrastructure, housing, health and safety incidents, regulatory and public services, supporting educational institutions, security, cultural properties, economic welfare and growth, social pathologies, grants and donations, supporting community projects	Jindal and Sangwan (2013b); Nikolaou and Evangelinos (2013); Garza (2013); Bai and Sarkis (2014); Presley et al. (2007)
Employment Practices (EMP)	Disciplinary and security practices, employee contracts, equity labor sources, diversity, discrimination, flexible working arrangements, job opportunities, employment compensation, career development	Sarkis et al. (2010); Hasan (2013); Nikolaou et al. (2013); Nikolaou and Evangelinos (2013)

Attributes / Sub-Attributes	Description	Authors
Health and Safety (HAS)	Lost time injury rate, sickness absence rate, number of incidents of non-compliance concerning health and safety impacts of products and services	Nikolaou et al. (2013); Bhattacharya et al. (2014)

7.4.2 Development of framework for outsourcing decisions

Based on the GTMA methodology (Discussed in previous section 2.2) integrated with SBSC, a framework was developed for the study and is shown in figure 7.5. The systematic approach is explained in the following section.

Step 1 Identify the outsourcing RSC scenarios or alternatives.

Step 2 Select the outsourcing RSC attributes, which are to be considered for the decision-making. Also, identify the sub-attributes for each of the attributes. SBSC has been utilized for the selection of attributes and sub-attributes for proposed research.

Step 3 Plot the digraph of attributes for selected scenario and convert graph into the matrix.

Step 4 Seek responses from the experts for weights of inter-relationship or relative importance among sub-attributes by using suitable scale. For the proposed study, the scale is shown in table 7.1. It is utilized for the relative importance of attributes. These are the off-diagonal elements of the matrix.

Step 5 The diagonal elements or inheritance for the matrix may be obtained as follows.

Step 5.1 Select the each attribute one by one. For example, there are 6 attributes identified for the proposed research and each attribute has 4 sub-attributes. Select the first attribute and identify the respective sub-attribute.

Step 5.2 Plot the digraph for the sub-attributes and convert digraph into matrix where off-diagonal elements represent the inter-relationship among sub-attributes.

Step 5.3 Seek responses from the experts for weights of inheritance (diagonal elements) and inter-relationship on selected scale. For the proposed study, Scale shown in table 7.1 is used for the inter-relationship or relative importance and scale shown in table 7.2 is used for the absolute importance of attributes.

Step 5.4 Substitute the values of inheritance and inter-relationship in the matrix and evaluate the permanent function for the first attribute by using expression per(A). For the proposed study C++ Program may be used for evaluating permanent function of the first attribute.

Step 5.5 Repeat the steps from 4.2 to 4.4 for evaluating the permanent function of the rest of the 5 attributes.

Step 6 Substitute the values of inheritance in the matrix and evaluate the permanent function of the selected scenario by using the expression per(A) or C++ program.

Step 7 Evaluate the permanent function for each of the scenario by repeating the step 3 to step 6 for each of the scenario. This permanent function is referred as “Outsourcing Index”.

Step 8 Select the best scenario based on the RSC “Outsourcing Index” of all the scenarios.

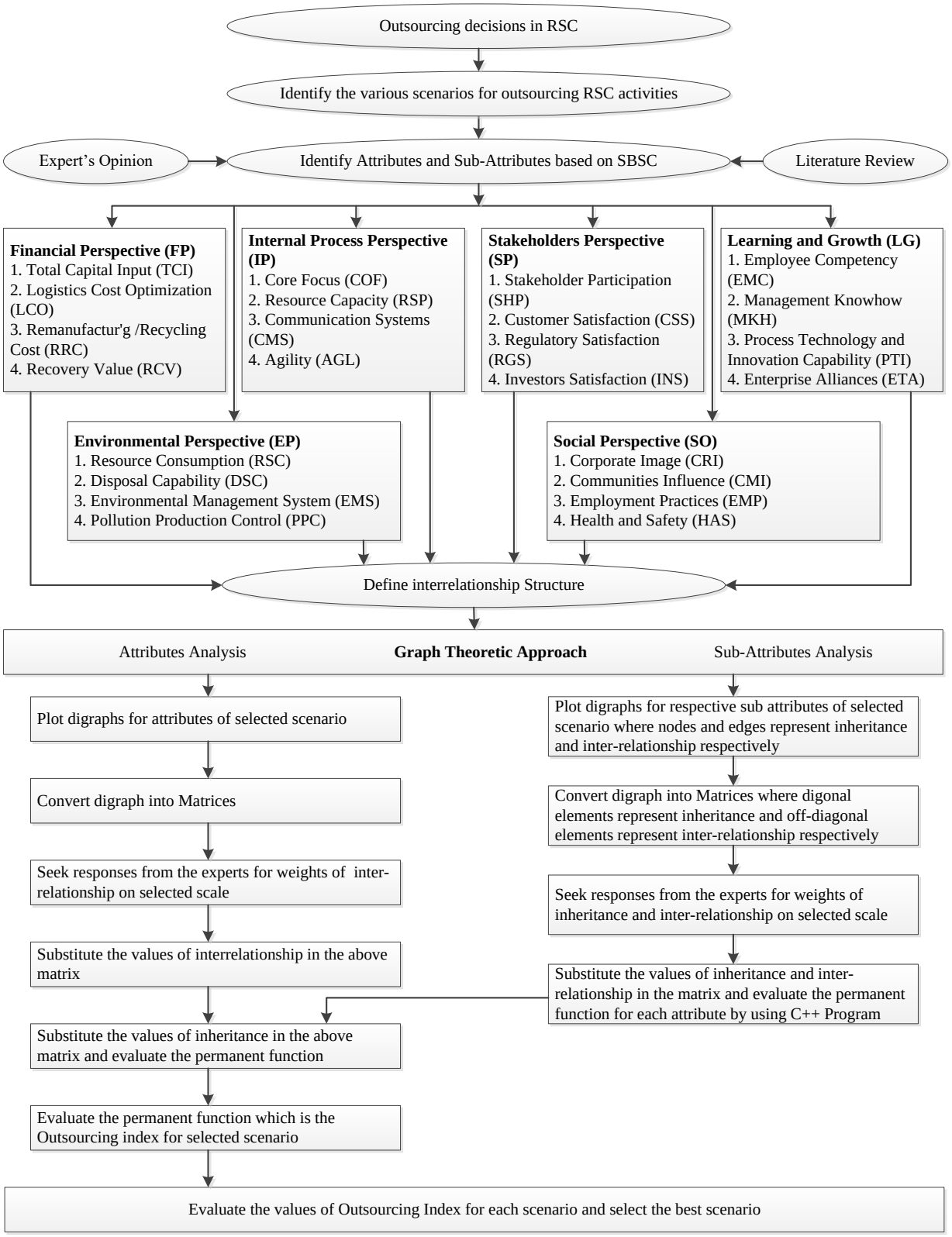

Figure 7.5 Framework for outsourcing RSC decisions

7.4.3 Case Illustration of GTMA and SBSC

To illustrate application of GTMA in outsourcing decision, a case of mobile manufacturing organization is considered.

7.4.3.1 Profile of the Organization

The case study of the organization, ABC Limited, discussed in chapter 6 has been utilized for the illustration of the outsourcing decision framework. Since the organization is in the process of implementing various RSC activities, it is well suited for the case illustration. The organization is looking for long-term solutions for handling these returns along with end of life products. Currently, the organization has no systematic practice of handling these returns and is willing to explore the RSC options for handling these returns. In order to develop scenario-based analysis, the experts were selected for the identification of attributes, sub-attributes, and their inter-relationship as discussed in step 1 and step 2 of the approach. Same group of experts as in previous framework with one additional third party service providers were selected for the research work. Total twelve experts participated in the study and helped in identifying attributes, sub-attributes, and their inter-relationship.

7.4.3.2 Development of scenarios

The product returns comprised of new mobile phone, mobile phones for repair, non-repairable mobile phones, and end of life mobile phones. The product acquisition is carried out either through the retailers or the service centers. Retailer resells new mobile phones, returned after repackaging by the service center, if required. Repair work is also performed at the service center and mobile phones after repair are given back to the customers. The mobile phones, which are non-repairable, are returned to the organization. This incurs loss to the organization because of logistics cost and non-availability of established remanufacturing. The mobile

phones, which are related to end of life, are directly sent to the local recyclers. The organization has not given much attention to these types mobile phone. Pursuant to e-waste management rules 2011 & 2016 in India and increased flow of product returns, the organization has decided to explore the options for returned products. Based on the discussion with the experts, the following scenario based options have been selected for the study.

Scenario-1: All RSC functions **(**Collection, Inspection & Sorting, transportation, remanufacturing, and recycling) are performed by the organization itself.

Scenario-2: Collection, Inspection & Sorting, transportation is outsourced; remanufacturing and recycling is carried out by the organization

Scenario-3: Collection, Inspection & Sorting, transportation, recycling are outsourced; remanufacturing is carried out by the organization

Scenario-4: All RSC functions **(**Collection, Inspection & Sorting, transportation, remanufacturing, and recycling) are outsourced by the organization.

This scenario-based approach provides a flexibility of developing the scenario according to the situation and need of an organization. The mobile phones, which are new or repairable, are not considered for the study because the organization wants to continue with the current practices. Four scenarios have been selected and one of the best scenarios is to be selected by using GTMA. The attributes and sub-attributes have been selected based on discussion with the experts and literature review. The six attributes were selected based on SBSC after consensus among the experts. Numbers of sub-attributes (six to nine) for each attribute were identified and finally four sub-attributes were selected for each attribute. The attributes and respective sub-attributes are discussed in table 7.4. These attributes are also shown the figure 7.5. After completing the step 1 and step 2 of the methodology, the remaining steps are as follows.

7.4.3.3 Development of digraph and matrices, and determination of permanent function

Step 3

Plot the digraph of attributes for selected scenario and convert graph into the matrix. Based on GTMA discussed above, the digraph for the outsourcing RSC contains six nodes corresponding to the six attributes from SBSC perspectives i.e, financial, internal process, learning and growth, environmental, and social perspective were developed which may directly affect the outsourcing decisions. The digraphs for the all six attributes are shown in Figure 7.6. Inter-relationship among attributes is shown by the directed edges. These diagraphs were translated into the matrices. The value of off-diagonal elements is taken from the table 7.1 based on the opinion of experts. The matrix is represented as matrix [OS 1]. Similar steps were followed for developing the matrix for rest of the three scenarios represented as [OS 2], [OS 3], and [OS 4]. Here, the values of diagonal elements, inheritance are not written. These values will be evaluated from the permanent functions of the sub-attributes matrices in the following steps.

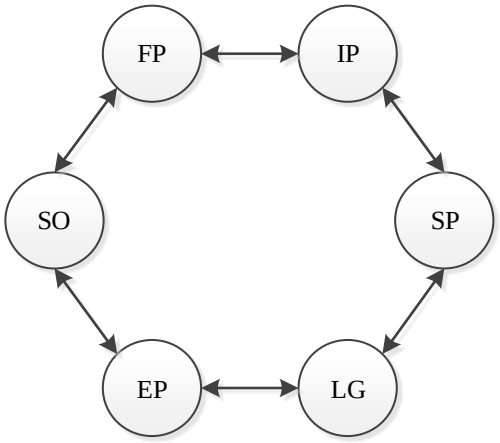

Figure 7.6 Digraph for the outsourcing RSC attributes

$$\text{Outsourcing Matrix for Scenario 1, [OS 1]} = \begin{matrix} - \\ \text{FP} \\ \text{PP} \\ \text{SP} \\ \text{LG} \\ \text{EP} \\ \text{SO} \end{matrix} \begin{matrix} \text{FP} & \text{IP} & \text{SP} & \text{LG} & \text{EP} & \text{SO} \end{matrix} \begin{bmatrix} D_{11} & 0.8 & 0.7 & 0.6 & 0.5 & 0.6 \\ 0.2 & D_{12} & 0.6 & 0.5 & 0.4 & 0.7 \\ 0.3 & 0.4 & D_{13} & 0.5 & 0.5 & 0.6 \\ 0.4 & 0.5 & 0.5 & D_{14} & 0.5 & 0.7 \\ 0.5 & 0.6 & 0.5 & 0.5 & D_{15} & 0.7 \\ 0.4 & 0.3 & 0.4 & 0.3 & 0.3 & D_{16} \end{bmatrix}$$

$$\text{Outsourcing Matrix for Scenario 2, [OS 2]} = \begin{matrix} - \\ \text{FP} \\ \text{IP} \\ \text{SP} \\ \text{LG} \\ \text{EP} \\ \text{SO} \end{matrix} \begin{matrix} \text{FP} & \text{IP} & \text{SP} & \text{LG} & \text{EP} & \text{SO} \end{matrix} \begin{bmatrix} D_{21} & 0.8 & 0.7 & 0.6 & 0.5 & 0.6 \\ 0.2 & D_{22} & 0.6 & 0.5 & 0.4 & 0.7 \\ 0.3 & 0.4 & D_{23} & 0.5 & 0.5 & 0.6 \\ 0.4 & 0.5 & 0.5 & D_{24} & 0.5 & 0.7 \\ 0.5 & 0.6 & 0.5 & 0.5 & D_{25} & 0.7 \\ 0.4 & 0.3 & 0.4 & 0.3 & 0.3 & D_{26} \end{bmatrix}$$

$$\text{Outsourcing Matrix for Scenario 3, [OS 3]} = \begin{matrix} - \\ \text{FP} \\ \text{IP} \\ \text{SP} \\ \text{LG} \\ \text{EP} \\ \text{SO} \end{matrix} \begin{matrix} \text{FP} & \text{IP} & \text{SP} & \text{LG} & \text{EP} & \text{SO} \end{matrix} \begin{bmatrix} D_{31} & 0.8 & 0.7 & 0.6 & 0.5 & 0.6 \\ 0.2 & D_{32} & 0.6 & 0.5 & 0.4 & 0.7 \\ 0.3 & 0.4 & D_{33} & 0.5 & 0.5 & 0.6 \\ 0.4 & 0.5 & 0.5 & D_{34} & 0.5 & 0.7 \\ 0.5 & 0.6 & 0.5 & 0.5 & D_{35} & 0.7 \\ 0.4 & 0.3 & 0.4 & 0.3 & 0.3 & D_{36} \end{bmatrix}$$

$$\text{Outsourcing Matrix for Scenario 4, [OS 4]} = \begin{matrix} - \\ \text{FP} \\ \text{IP} \\ \text{SP} \\ \text{LG} \\ \text{EP} \\ \text{SO} \end{matrix} \begin{matrix} \text{FP} & \text{IP} & \text{SP} & \text{LG} & \text{EP} & \text{SO} \end{matrix} \begin{bmatrix} D_{41} & 0.8 & 0.7 & 0.6 & 0.5 & 0.6 \\ 0.2 & D_{42} & 0.6 & 0.5 & 0.4 & 0.7 \\ 0.3 & 0.4 & D_{43} & 0.5 & 0.5 & 0.6 \\ 0.4 & 0.5 & 0.5 & D_{44} & 0.5 & 0.7 \\ 0.5 & 0.6 & 0.5 & 0.5 & D_{45} & 0.7 \\ 0.4 & 0.3 & 0.4 & 0.3 & 0.3 & D_{46} \end{bmatrix}$$

Step 5

Now the sub steps of step 5 are to be followed to get the diagonal elements values for each of the matrices [OS 1], [OS 2], [OS 3], and [OS 4]. The digraph for the sub-attributes will contain four nodes corresponding to the four sub-attributes of each respective attribute. The diagraphs for the respective sub attributes for all six SBSC perspectives are shown in the Figure 7.6. Inter-relationship among sub-attributes is shown by the directed edges.

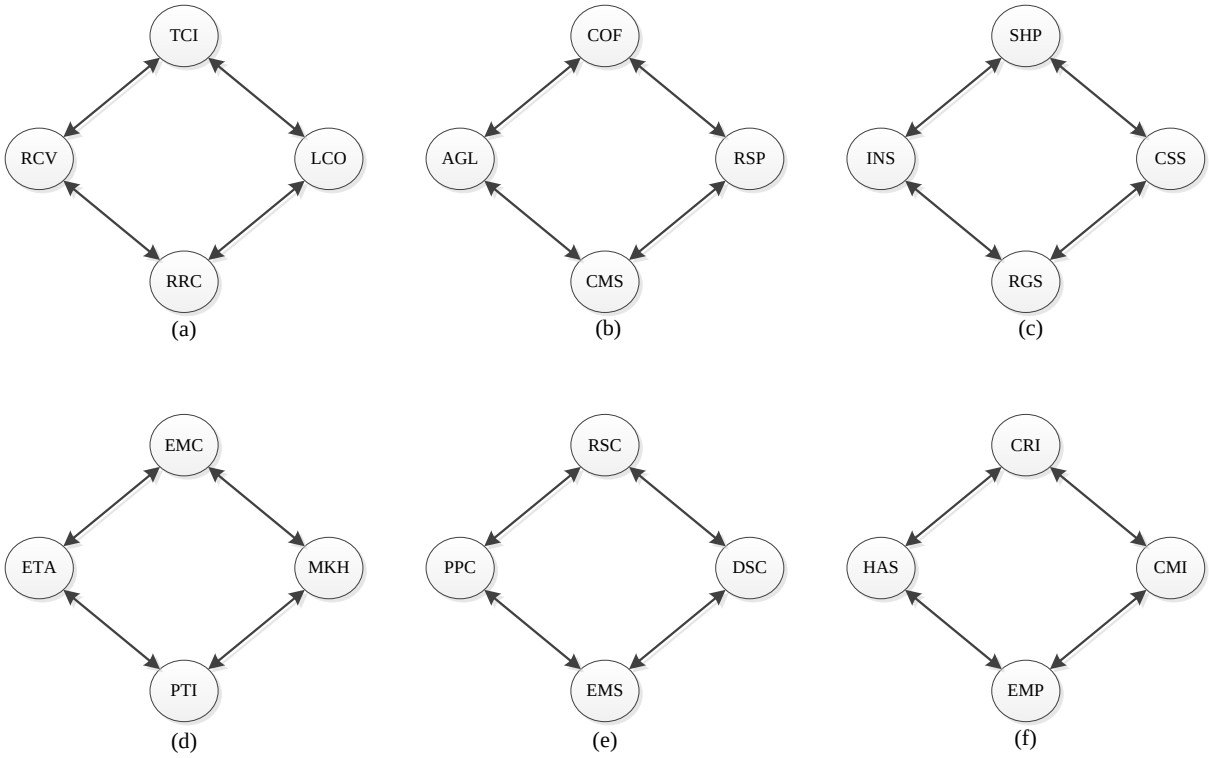

Figure 7.7 Digraphs for the sub attributes from all six SBSC perspectives i.e. (a) FP, (b) IP, (c) SP, (d) LG, (e) EP, (f) SO

These diagraphs are translated into the respective matrices. The value of off-diagonal elements is taken from the table 7.1 based on the opinion of group of experts. The values of diagonal elements for respective scenarios are taken from the table 7.5. The values shown in table 7.5 are based on the group of expert's opinion, selected from the table 7.2. The matrices are shown in the following steps along with computation of permanent function from all six perspectives for all four scenarios.

Table 7.5 Values of diagonal elements for the respective sub attributes

Attributes / Sub-Attributes	Scenario-1	Scenario-2	Scenario-3	Scenario-4
Financial Perspective (FP)				
Total Capital Input (TCI)	0.9	0.5	0.8	0.5
Logistics Cost Optimization (LCO)	0.6	0.6	0.4	0.4
Remanufactur'g /Recycling Cost (RRC)	0.7	0.5	0.7	0.4
Recovery Value (RCV)	0.5	0.3	0.5	0.4
Internal Process Perspective (IP)				
Core Focus (COF)	0.3	0.5	0.4	0.8
Resource Capacity (RSP)	0.5	0.6	0.7	0.6
Communication Systems (CMS)	0.5	0.6	0.7	0.8
Agility (AGL)	0.2	0.3	0.3	0.6
Stakeholders Perspective (SP)				
Stakeholder Participation (SHP)	0.7	0.7	0.5	0.5
Customer Satisfaction (CSS)	0.7	0.7	0.6	0.5
Regulatory Satisfaction (RGS)	0.9	0.7	0.8	0.5
Investors Satisfaction (INS)	0.4	0.6	0.6	0.6
Learning and Growth (LG)				
Employee Competency (EMC)	0.3	0.4	0.3	0.5
Management Knowhow (MKH)	0.4	0.4	0.4	0.6
Process Technology and Innovation Capability (PTI)	0.4	0.5	0.4	0.6
Enterprise Alliances (ETA)	0.2	0.5	0.5	0.7
Environmental Perspective (EP)				
Resource Consumption (RSC)	0.7	0.6	0.7	0.4
Disposal Capability (DSC)	0.5	0.4	0.6	0.6
Environmental Management System (EMS)	0.3	0.3	0.4	0.6
Pollution Production Control (PPC)	0.5	0.4	0.6	0.7
Social Perspective (SO)				
Corporate Image (CRI)	0.6	0.6	0.5	0.4
Communities Influence (CMI)	0.6	0.6	0.5	0.3
Employment Practices (EMP)	0.7	0.6	0.4	0.3
Health and Safety (HAS)	0.5	0.6	0.6	0.9

(i) From the financial perspective, the matrix obtained is as follows.

Matrix from the financial perspective, [FP]

$$\begin{array}{c} - \\ TCI \\ LCO \\ RRC \\ RCV \end{array} \begin{bmatrix} TCI & LCO & RRC & RCV \\ & 0.6 & 0.5 & 0.7 \\ 0.4 & & 0.4 & 0.6 \\ 0.5 & 0.6 & & 0.6 \\ 0.3 & 0.4 & 0.4 & \end{bmatrix}$$

Next step is to compute the permanent function values for each scenario. The value of permanent function for scenario 1 may be computed by entering the values of diagonal elements from table 4, that is (0.9, 0.6, 0.7, 0.5). By entering these values in matrix [FP] and subsequently this matrix into the C++ program, it gives the value of permanent function. This value is represented as D_{11} in matrix [OS 1].

D_{11} = 1.9614, similarly, for 2nd, 3rd and 4th scenario the values are D_{21} = 1.3054, D_{31} = 1.6784, D_{41} = 1.1924

(ii) From the Internal Process Perspective, the matrix is represented as [IP] and values obtained are D_{12} = 1.0315, D_{22} = 1.3359, D_{32} = 1.3885, D_{42} = 2.0443

Matrix from the Process perspective, [IP]

–	COF	RSP	CMS	AGL
COF		0.5	0.6	0.7
RSP	0.5		0.4	0.6
CMS	0.4	0.6		0.7
AGL	0.3	0.4	0.3	

(iii) From the Stakeholder Perspective, the matrix is represented as [SP] and values obtained are D_{13} = 2.0417, D_{23} = 2.0753, D_{33} = 1.8647, D_{43} = 1.5309

Matrix from the Process perspective, [SP]

–	SHP	CSS	RGS	INS
SHP		0.6	0.7	0.5
CSS	0.4		0.5	0.6
RGS	0.3	0.5		0.5
INS	0.5	0.4	0.5	

(iv) From the Learning and Growth Perspective, the matrix is represented as [LG] and values obtained are D_{14} = 1.0000, D_{24} = 1.2963, D_{34} = 1.1668, D_{44} = 1.7488

Matrix from the Learning and Growth perspective, [LG]

–	EMC	MKH	PTI	ETA
EMC		0.5	0.6	0.7
MKH	0.5		0.6	0.5
PTI	0.4	0.4		0.6
ETA	0.3	0.5	0.4	

(v) From the Environmental Perspective, the matrix is represented as [EP] and values obtained are D_{15} = 1.3809, D_{25} = 1.1933, D_{35} = 1.6199, D_{45} = 1.6263

Matrix from the Environmental Perspective, [EP]

–	RSC	DSC	EMS	PPC
RSC		0.6	0.5	0.6
DSC	0.4		0.3	0.5
EMS	0.5	0.7		0.6
PPC	0.4	0.5	0.4	

(vi) From the Social Perspective, the matrix is represented as [SO] and values obtained are $D_{16} = 1.7243$, $D_{26} = 1.7284$, $D_{36} = 1.404$, $D_{46} = 1.279$

Matrix from the Social Perspective, [SO]

–	CRI	CMI	EMP	HMS
CRI		0.7	0.6	0.5
CMI	0.3		0.4	0.4
EMP	0.4	0.6		0.6
HMS	0.5	0.6	0.4	

All the values of diagonal elements or inheritance for all four scenarios have been determined above. These values are represented in the form of radar chart as shown in figure 7.8. Scenario 1 has highest value for stakeholder's perspective, and the financial perspectives. Scenario 2 is favorable for financial perspective, and social perspective. Scenario 3 is more inclined towards environmental, and stakeholders perspective. Scenario 4 is more focused on internal process perspective, and learning & growth perspective. Every scenario has its own importance from different perspectives. Overall, with these values, it is difficult to decide which one is better for the organization. Therefore, the next step is followed for the final decision-making.

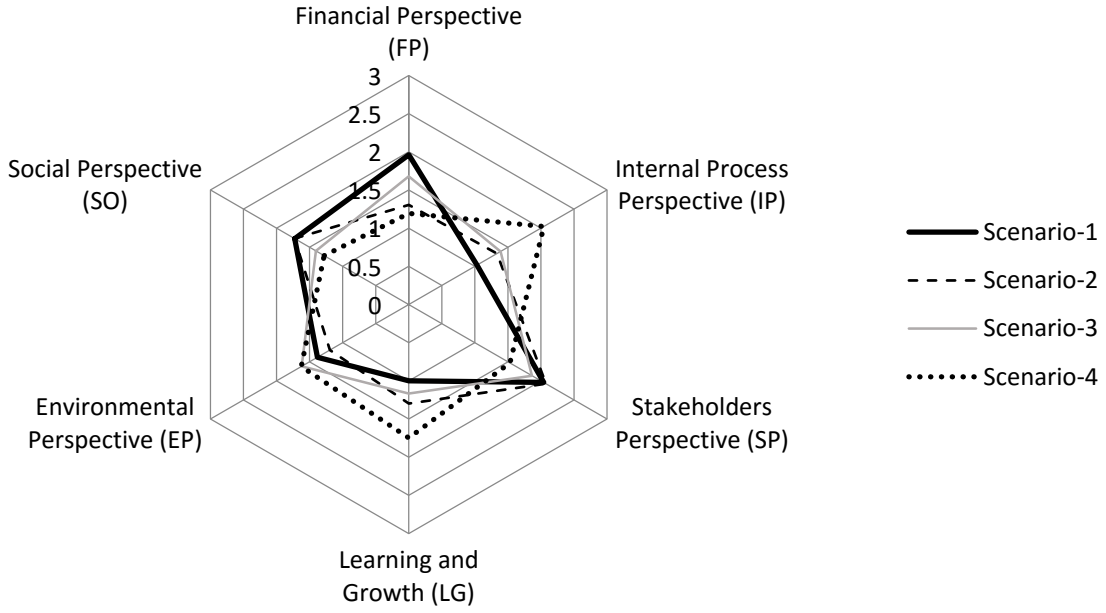

Figure 7.8 Radar chart of all four scenarios from all SBSC perspectives

7.4.4 Results and discussion based on framework

Substitute the values of diagonal elements or inheritance in the matrix [OS 1], the matrix is shown below.

$$[\text{OS 1}] = \begin{array}{c|cccccc} - & \text{FP} & \text{IP} & \text{SP} & \text{LG} & \text{EP} & \text{SO} \\ \text{FP} & 1.9614 & 0.8 & 0.7 & 0.6 & 0.5 & 0.6 \\ \text{IP} & 0.2 & 1.0315 & 0.6 & 0.5 & 0.4 & 0.7 \\ \text{SP} & 0.3 & 0.4 & 2.0417 & 0.5 & 0.5 & 0.6 \\ \text{LG} & 0.4 & 0.5 & 0.5 & 1.0000 & 0.5 & 0.7 \\ \text{EP} & 0.5 & 0.6 & 0.5 & 0.5 & 1.3809 & 0.7 \\ \text{SO} & 0.4 & 0.3 & 0.4 & 0.3 & 0.3 & 1.7243 \end{array}$$

Matrices for the scenario 2, 3, and 4 are not shown here. Now compute the value outsourcing index for scenario 1 by computing permanent function for [OS 1] and similarly for other three scenarios. Permanent function value may be computed either by using expression per(A) or by using the program C++. The values for all four scenarios were computed and shown below.

OS 1 Index = 74.2395,

OS 2 Index = 71.6052,

OS 3 Index = 77.3069,

OS 4 Index = 84.6152

Based on outsourcing index determined as above, the preferences of the outsourcing scenarios among all four scenarios i.e. **Scenario-1:** All RSC functions **(**Collection, Inspection & Sorting, transportation, remanufacturing, and recycling) are performed by the organization itself; **Scenario-2:** Collection, Inspection & Sorting, transportation are outsourced; remanufacturing and recycling is carried out by the organization; **Scenario-3:** Collection, Inspection & Sorting, transportation, recycling are outsourced; remanufacturing is carried out by the organization; &

Scenario-4: All RSC activities **(**Collection, Inspection & Sorting, transportation, remanufacturing, and recycling) are outsourced by the organization; are as follows.

Scenario 4 > Scenario 3 > Scenario 1 > Scenario 2

Therefore, we can conclude that scenario 4, i.e. outsourcing of all the RSC functions is the best choice among the considered alternative scenarios for the organization based on this analysis. If the index values are compared then it is clear that the organization may not opt for performing all RSC functions itself. The organization has one manufacturing plant while it has distribution all over the country, which may result in higher logistics cost. Uncertainty in terms of both quality and quantity also discourages the remanufacturing in the organization. Remanufacturing may not be good idea for the organization because of lower recapturing value of low cost mobile phones. Similar is the case with recycling which is economical only when the volume is large (Fleischmann et al., 1997). If these services are outsourced to the third party having good network of facilities in different cities, they can manage these operations in their local remanufacturing and recycling centers. In a case study of Indian mobile manufacturing organization, Jayant et al. (2014) also found that focus of the organization was more upon core competencies and outsourced the RSC activities to the third party logistic service providers. Third party RSC provider can take advantage of economies of scale and at the same can reduce the transportation cost because of local centers. Local remanufacturing facilities for mobile phones are very common in developing countries like India because of presence of huge secondary market for the mobile phones.

7.5 Concluding remarks

It may be concluded from the literature review, survey, and case study of Indian electonics industry that select issues such as forecasting product returns, disposition decisions, and outsourcing decisions play an important role in the performance of RSC. The research work focused on developing frameforks for these issues by using GERT, GTMA, and combination of GTMA and SBSC. The research frameworks were devlopeded by using methodologies and each framework was illustrated through case example of an electronics organization from Indian electronics industry. The results and discussion based on these frameworks were discussed for each of the frameworks. The conlusions of each of the frameworks are discussed as follows.

A framework for forecasting product returns, based on GERT network theory was developed. This frame work provides the percentage of product returns and also the time of product returns. The model has been validated through practical case example of a leading mobile phone manufacturing organization in India. Organizations can utilize these RSC estimates for the future RSC planning. This framework can be applied for other elctronics organizations and in other sectors also.

In second framework, GTMA has been utilized for the development of framework for the selection of best disposition option based on various disposition attributes. Attributes were selected based on past literature review and discussion with the experts. A case of mobile phone manufacturing organization was discussed for the illustration of the approach. The results indicate that recycling should be preferred to remanufacturing for the disposition of returned mobile hand set to the organization. The findings of the study will help in improving the overall RSC performance. The framework may help the managers and researchers in disposition decision making and further development on the disposition decisions while dealing with the

product returns in RSC. The study contributes to the very few studies available for the disposition decision making in RSC. In future, other methodologies may be applied and results may be compared with the study results. One of the limitations of the study is that the limited numbers of disposition options were examined. More disposition options like donation to community, selling in secondary markets may also be considered in future studies.

In third decision framework, a framework has been developed for outsourcing RSC decisions i.e. whether outsource RSC partly or fully. The study focuses not only on TBL aspects of sustainability but also integrates it with BSC and developed SBSC to have a holistic view of RSC. It enables the decision makers to make sure the sustainable development while taking outsourcing decisions. The study utilized SBSC for the selection of attributes and sub-attributes and GTMA as a decision making approach. A case of mobile manufacturing was considered for illustration of the approach. Various scenario based alternatives in terms of RSC activities were developed for the organization. A framework was developed after selecting various alternative scenarios, attributes and respective sub-attributes. The permanent function for each attribute was evaluated with the help of C++ program and subsequently outsourcing index for each alternative scenario was determined by evaluating the permanent function. The study is among very few studies available on decision making with respect to outsourcing RSC partly or fully. SBSC will help the managers to achieve the operational and financial efficiency and will help them to contribute to the sustainability efforts of an organization. The study will help managers in ensuring the sustainable development even when they are outsourcing the RSC activities. The attributes and sub-attributes selected in the study will guide the decision makers to visualize and analyze the impact of these attributes and sub-attributes on outsourcing decisions. Although framework suggested will be highly useful for taking appropriate outsourcing decisions but it has some limitations. One of limitations of the study is that the attributes and sub-attributes, and alternative scenarios are based on one organization. However,

methodology can easily be acclimatized to different scenarios, and can consider different kind of quantitative and qualitative attributes depending on the business need. In addition, a fuzzy based scale may be used to avoid any vagueness or subjective biasness.

Chapter 8. Reverse supply chain performance evaluation

8.1 Introduction

It is evident from the literature review and cast study that there is need of developing a compressive performance evaluation framework of RSC. This chapter deals with the development of reverse supply chain (RSC) performance evaluation system based TBL aspects of sustainability. Sustainability has become an important issue for all organizations due to growing awareness of environment, environmental legislations, and markets globalization. While addressing sustainability, organizations are more focused towards the forward supply chain activities and less attentive towards the reverse flows. This is also evident from the guidelines developed by the Global Reporting Initiative in which core indicators and additional indicators are generic and more inclined towards the forward flows. However, RSC can make significant contribution to the sustainable development of an organization (Sarkis et al. 2010a). It is evident from the literature review that most of the performance evaluation for RSC considers the factors related to economic performance and environmental performance. Devika et al. (2014) reported, "There is a gap in quantitatively modeling social impacts together with environmental and economic impacts". McWilliams et al. (2014) also find that there is little research focusing on social aspects of TBL. The research work attempts to bridge the existing gaps by developing a framework for performance evaluation of RSC from TBL aspects of sustainability.

8.2 Fuzzy-AHP and Extent Analysis approach

Let $X = \{x_1, x_2 \ldots x_n\}$ be an object set, and $U = \{u_1, u_2 \ldots u_m\}$ be a goal set. According to the method given by Chang (1992) on extent analysis, each object is taken and extent analysis for each goal g_i, is performed, respectively. Therefore, M-extent analysis values for each object can be obtained and are represented as follows:

Part of this chapter will be published as* "Triple Bottom Line Performance Evaluation of Reverse Logistics", **Competitiveness Review: An International Business Journal, Vol. 26 No. 3, 2016.

$$M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m, \quad i = 1,2, \dots, n, \tag{8.1}$$

Where, all the $M_{g_i}^j$ $(j = 1,2, \dots \dots m)$ are triangular fuzzy numbers represented by (l, m, u), l is the least possible value, m is the most likely value, and u is the largest possible value. The steps of the extent analysis AHP (Chang, 1996) are as follows:

Step 1 The value of fuzzy synthetic extent with respect to the i^{th} object is defined as

$$S_i = \sum_{j=1}^m M_{g_i}^j \otimes \left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} \tag{8.2}$$

To obtain $\sum_{j=1}^m M_{g_i}^j$ perform the fuzzy addition operation of M-extent analysis values for a particular matrix such that

$$\sum_{j=i}^m M_{g_i}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j\right) \tag{8.3}$$

and to obtain $[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^j$ $(j = 1,2, \dots \dots m)$ values such that

$$\sum_{i=1}^n \sum_{j=i}^m M_{g_i}^j = \left(\sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j\right) \tag{8.4}$$

the inverse of the vector in equation (8.2) can be computed as,

$$\left[\sum_{i=1}^n \sum_{j=1}^m M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{j=1}^m u_j}, \frac{1}{\sum_{j=1}^m m_j}, \frac{1}{\sum_{j=1}^m l_j}\right) \tag{8.5}$$

Step 2 The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_l, u_l)$ is defined as

$$V(M_2 \geq M_1) = \sup_{y \geq x}[\min(\mu_{M_1}(x), \mu_{M_2}(y))] \tag{8.6}$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \text{hgt}\,(M1 \cap M2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise,} \end{cases} \tag{8.7}$$

Where, d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_1}shown in figure 8.1.

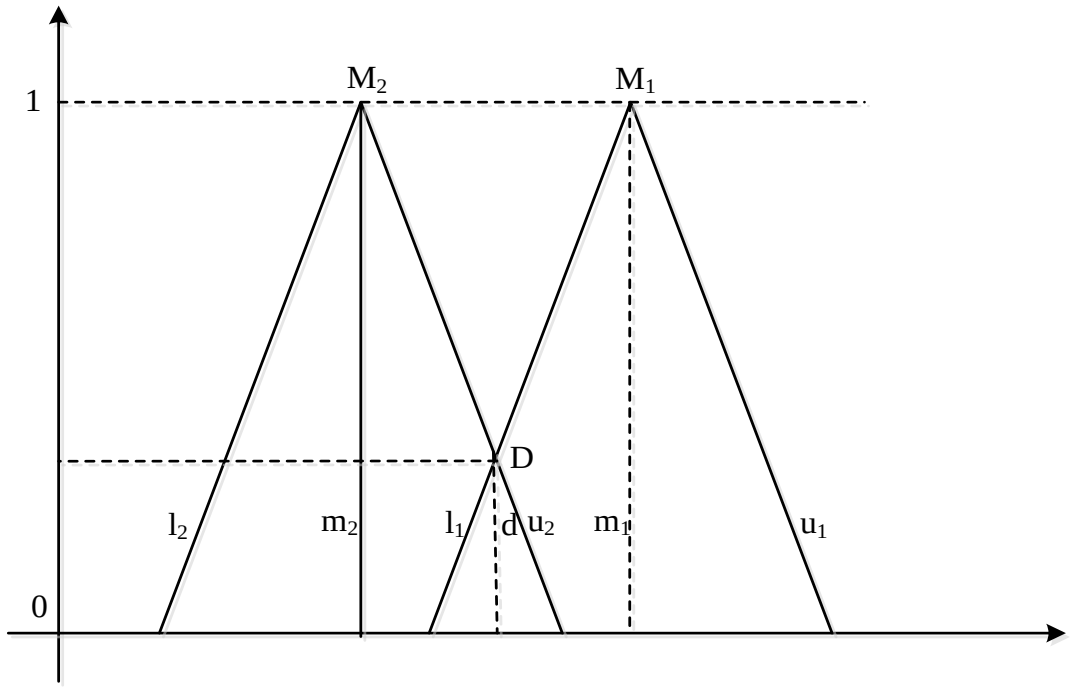

Figure 8.1 The Interaction between triangular fuzzy numbers, M1 and M2

To compare M_1 and M_2, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$

Step 3 The degree possibility for a convex fuzzy number to be greater than k, convex fuzzy numbers M_i (i=1, 2,….., k) can be defined as

$$V\ (M \geq M_1, M_2, \dots, M_k) = V\ [(M \geq M_1) and\ (M \geq M_2) and \dots and\ (M \geq M_k)]$$
$$= \min V\ (M \geq M_i)\,, i = 1,2,3, \dots, k \qquad (8.8)$$

Assume that, $d'(A_i) = \min V\ (S \geq S_k)$ (8.9)

for, k=1,2,…..,n and k≠1. Now the weight vector can be given by the following formulae,

$$W' = \{d'(A_1), d'(A_2), \dots, d'(A_n)\}^T, \qquad (8.10)$$

Where Ai (i=1, 2, 3….., n) are n elements.

Step 4 Via normalization, the normalized weight vectors are given as,

$$W' = \{d(A_1), d(A_2), \dots, d(A_n)\}^T,$$

Where "W" is a non- fuzzy number

Step 5 Integrate the opinions of decision makers and apply geometric average to combine the fuzzy weights of decision makers.

8.3 Development of AHP model for application of FAHPEA

The decision problem is structured into its important components as shown in figure 2. The relevant criteria and sub criteria are structured in the form of a control hierarchy where the criteria at the top level in the model have the highest value. The top-level criteria in the model are Economic Performance (ECP), Environmental Performance (EVP) and Social Performance (SCP). In the second level of hierarchy, sub criteria for each of top-level criteria are selected from all three perspectives of TBL top-level criteria shown in figure 8.2. Return On Investment (EC-1), Recapturing Value (EC-2), Logistics Cost Optimization (EC-3), Recycle Efficiency (EC-4), Annual Sales (EC-5) and Disposal Costs (EC-6) are selected from economic performance perspectives. Minimum Energy Consumption (EV-1), Optimum use of raw material (EV-2), Transport Optimization (EV-3), Reduced Packaging (EV-4), Use of recycled material (EV-5), and Waste Reduction (EV-6) are selected from the environmental performance perspective. Community complaints (SC-1), Customer Health and Safety (SC-2), Stake Holders Participation (SC-3), Employment Stability (SC-4), Donations to Community (SC-5) and Employee Benefits (SC-6) are selected from the social performance perspectives. Three organizations DEF-1, DEF-2 and DEF-3 are shown at the bottom level of the structure and are discussed later in the chapter. The criteria and sub-criteria were selected based on the

literature review and discussion with the experts. The criteria and sub-criteria are explained along with literature review in table 2.6 of chapter 2.

8.4 Estimation of weights and global weights for performance measures

The study comprised of open and semi-structured interviews with the senior executives and key functional managers of the electronic industry. The discussions were focused on selection of sub criteria for performance evaluation and pair-wise comparison of selected criteria / sub criteria. Nine decision makers were asked to make pair-wise comparison for each criteria/sub criteria by selecting one of nine linguistic variables (which are represented by positive triangular fuzzy numbers) listed in table 8.1.

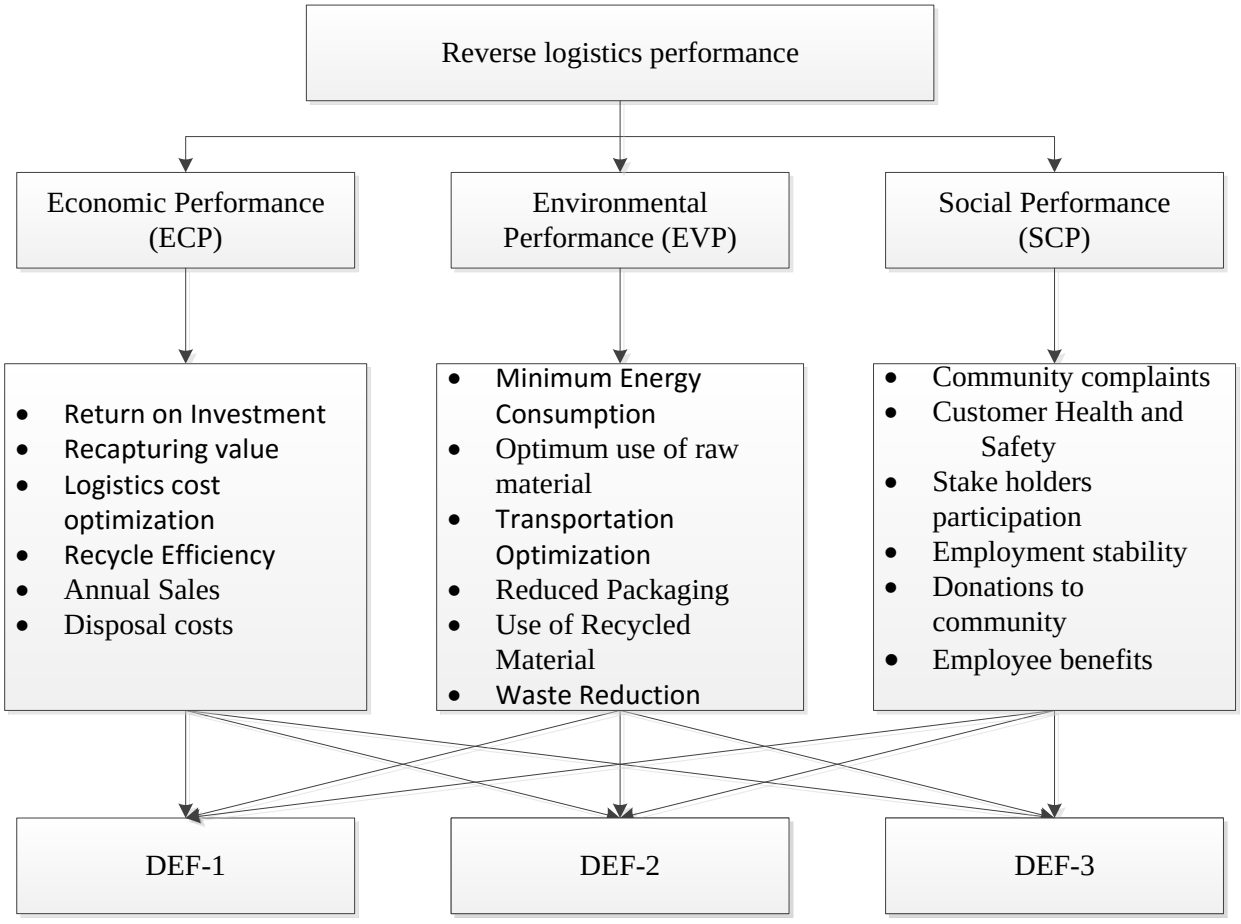

Figure 8.2 AHP frame work for the TBL performance evaluation of RSC

Table 8.1 Triangular fuzzy numbers

Linguistic variables	Positive triangular fuzzy numbers	Positive reciprocal triangular fuzzy numbers
Extremely strong	(9, 9, 9)	(1/9, 1/9, 1/9)
Intermediate	(7, 8, 9)	(1/9, 1/8, 1/7)
Very strong	(6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate	(5, 6, 7)	(1/7, 1/6, 1/5)
Strong	(4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate	(3, 4, 5)	(1/5, 1/4, 1/3)
Moderately strong	(2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate	(1, 2, 3)	(1/3, 1/2, 1)
Equally strong	(1, 1, 1)	(1, 1, 1)

Pair wise comparison at top level

Paired wise comparison of top level criteria ECP, EVP, and SCP were made by the decision maker, and transformed into triangular fuzzy numbers and are shown in table 8.2.

Table 8.2 Triangular fuzzy comparison Matrix for top level criteria

	ECP	EVP	SCP
ECP	(1, 1, 1)	(4,5,6)	(1/3, 1/2, 1)
EVP	(1/6, 1/5, 1/4)	(1, 1, 1)	(2, 3, 4)
SCP	(1, 2, 3)	(1/4, 1/3, 1/2)	(1, 1, 1)

The value of fuzzy synthetic extent with respect to the each criterion is calculated by using equation (8.2) and table 8.2 in MS Excel spreadsheet.

$$S_{ECP} = (5.333, 6.500, 8.000) \otimes \left[\frac{1}{17.750}, \frac{1}{14.033}, \frac{1}{10.750}\right] = (0.300, 0.463, 0.744)$$

$$S_{EVP} = (3.167, 4.200, 5.250) \otimes \left[\frac{1}{17.750}, \frac{1}{14.033}, \frac{1}{10.750}\right] = (0.178, 0.299, 0.488)$$

$$S_{SCP} = (2.250, 3.333, 4.500) \otimes \left[\frac{1}{17.750}, \frac{1}{14.033}, \frac{1}{10.750}\right] = (0.127, 0.238, 0.419)$$

The degree of possibility of S_i over S_k ($i \neq k$) can be determined by equations (8.6)-(8.8)

$$V\,(S_{ECP} \geq S_{EVP}) = 1$$

$$V\,(S_{ECP} \geq S_{SCP}) = 1$$

$$V\ (S_{EVP} \geq\ S_{ECP}) = \frac{(0.300 - 0.488)}{(0.299 - 0.488) - (0.463 - 0.300)} = 0.534$$

$$V\ (S_{EVP} \geq\ S_{SCP}) = 1$$

$$V\ (S_{SCP} \geq\ S_{ECP}) = \frac{(0.300 - 0.419)}{(0.238 - 0.419) - (0.463 - 0.300)} = 0.344$$

$$V\ (S_{SCP} \geq\ S_{EVP}) = \frac{(0.178 - 0.419)}{(0.238 - 0.419) - (0.299 - 0.178)} = 0.795$$

Now, by using equation (8.9)

$$d'\ (S_{ECP}) = V\ (S_{ECP} \geq S_{EVP}, S_{SCP}) = \min\ (1.000,1.000) = 1.000$$

$$d'\ (S_{EVP}) = V\ (S_{EVP} \geq S_{ECP}, S_{SCP}) = \min\ (1.000,0.534) = 0.534$$

$$d'\ (S_{SCP}) = V\ (S_{SCP} \geq S_{ECP}, S_{EVP}) = \min\ (0.344, 0.795) = 0.344$$

Hence the Weight vector is written as equation (8.10),

$$W' = (1.000, 0.534, 0.344)^T$$

Via normalization, we get

$$W = (0.533, 0.284, 0.183)^T$$

Where W is a non-fuzzy number

Similarly, weights for these three criteria were obtained for rest of the eight decision maker's responses and combined weights were calculated by taking geometric average of these weights.

Combined weight of decision makers

$$W = (0.513, 0.335, 0.130)^T$$

Comparison at second level

Responses of one of the decision makers for comparison of economic performance with respect to sub criteria are shown in table 8.3.

Table 8.3 Triangular fuzzy comparison Matrix at second level with respect to economic performance

	EC-1	**EC-2**	**EC-3**	**EC-4**	**EC-5**	**EC-6**
EC-1	(1, 1, 1)	(1/3, 1/2, 1)	(3, 4, 5)	(3, 4, 5)	(2,3,4)	(2,3,4)
EC-2	(1,2,3)	(1, 1, 1)	(2,3,4)	(5,6,7)	(2,3,4)	(1,2,3)
EC-3	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1, 1, 1)	(3, 4, 5)	(1/3, 1/2, 1)	(2,3,4)
EC-4	(1/5, 1/4, 1/3)	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(1, 1, 1)	(3, 4, 5)	(1/3, 1/2, 1)
EC-5	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(3, 4, 5)	(1/5, 1/4, 1/3)	(1, 1, 1)	(1/4, 1/3, 1/2)
EC-6	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/4, 1/3, 1/2)	(1,2,3)	(2,3,4)	(1, 1, 1)

Similar steps, discussed for top level were followed for this decision maker and weight for all sub criteria were found to be

$$\mathrm{W} = (0.320, 0.346, 0.146, 0.041, 0.040, 0.107)^{\mathrm{T}}$$

and combined weight of all nine decision makers were found by taking geometric mean of responses of all nine decision makers. The combined weights are found to be as follows.

$$\mathrm{W} = (0.336, 0.345, 0.175, 0.007, 0.029, 0.079)^{\mathrm{T}}$$

All the weights for criteria and sub criteria are summarized in table 8.4. Global weight for each of the performance measures are also calculated by multiplying top level criteria weight with respective sub criteria weight and are shown in table 8.4.

Table 8.4 Weights of performance measures for electronics industry

Criteria	SubCriteria	Weights	
		Individual	Global
Economic Performance (ECP)		0.513	
	Return On Investment	0.336	0.172
	Recapturing Value	0.345	0.177
	Logistics Cost Optimization	0.175	0.090
	Recycle Efficiency	0.007	0.004
	Annual Sales	0.029	0.015
	Disposal Costs	0.079	0.041
Environmental Performance (EVP)		0.335	
	Minimum Energy Consumption	0.267	0.071
	Optimum use of raw material	0.322	0.086
	Transport Optimization	0.221	0.059
	Reduced Packaging	0.010	0.003
	Use of recycled material	0.029	0.008
	Waste Reduction	0.082	0.022
Social Performance (SCP)		0.130	
	Community complaints	0.258	0.034
	Customer Health and Safety	0.283	0.037
	Stake Holders Participation	0.162	0.021
	Employment Stability	0.110	0.014
	Donations to Community	0.131	0.017
	Employee Benefits	0.054	0.007

8.5 Comparison of the performances of three electronic organizations

Three organizations from Indian electronics industry were chosen for the study to achieve a generalized set of results. The organizations were selected based on their interest in sustainable business operations as well as performance evaluation related practices.

First organization, DEF-1 is a pioneer in the manufacturing of mobile phones. The organization has annual turnover of approximately $2b in last financial year from its business in India. In India, the organization has a mobile handset manufacturing facility in Chennai. At present the organization has approximately 110,000 outlets including 50,000 stores selling organization`s product exclusively having more than 5000 employees. In year 2010, Organization introduced take back program in Indian to take back used mobile phones for remanufacturing/ recycling. The organization used its well-established supply chain for take back mobile phones.

Second organization, DEF-2 limited manufactures, assembles and distributes a comprehensive range of electronic hardware including computer peripherals in India. The organization has annual turnover of approximately $1.5 b in last financial year. The organization has manufacturing facilities in Chennai, Pondicherry, and in Uttaranchal having approximately 2300 employees across India. It has strong chain of distributors and dealers with 92,500 outlets in 8,700 towns in Indian. The organization has implemented RSC program to reduce cost, and improve customer satisfaction. Recently, Organization has established a recycling unit in Chennai and has integrated remanufacturing with its current manufacturing facility.

Third organization, DEF-3 has annual turnover of approximately $ 30 m in last financial year. The organization has manufacturing facility in NCR Delhi having more than 350 employees. The organization manufactures, assembles and distributes color television sets in India. The organization has its own recycling facility for rejected color television's set.

All three organizations were compared for each of the sub criteria of each top-level criteria. For example, "Return On Investment" sub criteria of top level criteria "economic performance" were compared by the researchers for three organizations. Responses in terms of linguistic variables were converted into triangular fuzzy number by using table 8.1 and these numbers are shown in table 8.5.

Table 8.5 Comparison for sub-criteria "Return On Investment"

	DEF-1	**DEF-2**	**DEF-3**
DEF-1	(1, 1, 1)	(1,2,3)	(1/3, 1/2, 1)
DEF-2	(1/3, 1/2, 1)	(1, 1, 1)	(1, 2, 3)
DEF-3	(1, 2, 3)	(1/3, 1/2, 1)	(1, 1, 1)

Other steps of methodology were followed and relative weights for "Return On Investment" were obtained as follows.

$$W = (0.333, 0.333, 0.333)^T$$

Another example, “Recycling Efficiency” sub criteria of top level criteria “economic performance” were compared by the researchers for three organizations. Responses in terms of linguistic variables were converted into triangular fuzzy number by using table 8.1 and these numbers are shown in table 8.6.

Table 8.6 Comparison for sub-criteria “Recycling Efficiency”

	DEF-1	**DEF-2**	**DEF-3**
DEF-1	(1, 1, 1)	(2,3,4)	(1/3, 1/2, 1)
DEF-2	(1/4, 1/3, 1/2)	(1, 1, 1)	(2, 3, 4)
DEF-3	(1, 2, 3)	(1/4, 1/3, 1/2)	(1, 1, 1)

Other steps of methodology were followed and relative weights for “Return On Investment” were obtained as follows.

$$W = (0.366, 0.356, 0.278)^T$$

Further steps of FAHPEA approach were followed for rest of all the sub criteria and relative weights for each sub criteria were obtained. Relative weights for all sub criteria for three organizations are shown in table 8.7.

Table 8.7 Relative weights of performance measures for all sub criteria

SubCriteria	**Weight**		
	DEF-1	**DEF-2**	**DEF-3**
Return On Investment	0.333	0.333	0.333
Recapturing Value	0.366	0.356	0.278
Logistics Cost Optimization	0.380	0.306	0.314
Recycle Efficiency	0.333	0.333	0.333
Annual Sales	0.550	0.048	0.402
Disposal Costs	0.449	0.351	0.200
Minimum Energy Consumption	0.438	0.275	0.287
Optimum use of raw material	0.298	0.317	0.385
Transport Optimization	0.333	0.333	0.333
Reduced Packaging	0.384	0.310	0.305
Use of recycled material	0.111	0.069	0.819
Waste Reduction	0.567	0.356	0.077
Community complaints	0.550	0.048	0.402
Customer Health and Safety	0.427	0.088	0.485
Stake Holders Participation	0.550	0.048	0.402
Employment Stability	0.449	0.200	0.351
Donations to Community	0.333	0.333	0.333
Employee Benefits	0.038	0.206	0.756

8.6 Results and discussion based on framework

The weights for each of the criteria and sub criteria (performance measures) were obtained for the electronics industry. Global weights were calculated by multiplying each of the sub criteria weight with respective top-level criteria weight and all are summarized in table 8.4. Performance index for each of the sub criteria for all three organizations are calculated by multiplying global weight of sub criteria with corresponding relative weight shown in table 8.6. Performance index for each of sub criteria for all three organizations are shown in table 8.7.

Table 8.8 Performance Indexes of three organizations

SubCriteria	Performance Index		
	DEF-1	DEF-2	DEF-3
Return On Investment	0.0574	0.0574	0.0574
Recapturing Value	0.0647	0.0629	0.0493
Logistics Cost Optimization	0.0341	0.0274	0.0282
Recycle Efficiency	0.0012	0.0012	0.0012
Annual Sales	0.0082	0.0007	0.0060
Disposal Costs	0.0182	0.0142	0.0081
Economic Performance Index	**0.1838**	**0.1639**	**0.1502**
Minimum Energy Consumption	0.0312	0.0196	0.0204
Optimum use of raw material	0.0256	0.0273	0.0331
Transport Optimization	0.0197	0.0197	0.0197
Reduced Packaging	0.0010	0.0008	0.0008
Use of recycled material	0.0009	0.0005	0.0063
Waste Reduction	0.0124	0.0078	0.0017
Environmental Performance Index	**0.0908**	**0.0757**	**0.0820**
Community complaints	0.0184	0.0016	0.0135
Customer Health and Safety	0.0157	0.0032	0.0179
Stake Holders Participation	0.0116	0.0010	0.0085
Employment Stability	0.0064	0.0029	0.0050
Donations to Community	0.0057	0.0057	0.0057
Employee Benefits	0.0003	0.0014	0.0053
Social Performance Index	**0.0581**	**0.0159**	**0.0558**
RSC Performance Index	**0.333**	**0.255**	**0.288**

Performance indexes for economic performance, environmental performance, and social performance are determined by summing up performance indexes of respective sub criteria.

RSC performance index is determined by summing the performance index for all 18 measures for each of three organizations. DEF-1 has best performance index (0.333), followed by DEF-3 (0.288) and DEF-3 has lowest performance index (0.255). Economic performance indexes for all three organizations are higher in comparison to environmental and social performance indexes. Environmental performance indexes are higher than social performance indexes. Industry weights shown in table 8.4 also indicate similar trends. It reveals that economic performance has been considered most important whereas the social performance has been rated least. Social performance indexes of DEF-1 and DEF-3 are better than the DEF-2. Organizations need to be attentive to improve their social performance in order to improve their TBL performance. For the organization DEF-1, recapturing value (0.0647) has the highest performance index, and return on investment (0.0574) is second best performance measure for the organization. Similar trends are followed by DEF-2. Both of these performance measures are also best two performance measures for the organization DEF-3. It is also evident from previous research. Ravi et al. (2005a) stated that recapturing value from used products is essential for RSC. The recovery of the products for remanufacturing, repair, reconfiguration, and recycling can lead to profitable business opportunities (Andel, 1997). It can make significant contributions to return on investment. In fact, most of the other economic performance measures for three organizations have higher performance indexes in comparison to the environmental and social performance measures. This shows that organizations are more focused towards operational performance and profitability. Among environmental performance minimum energy consumption, optimum use of raw material and transport optimization are the top three important performance measures for all three organizations. Although these measures can make significant contributions to the environmental sustainability, these factors contribute to the economic performance also. In Social performance perspective, community complaints (0.0184) is the most important performance

measure for the organization DEF-1, and customer health and safety (0.0157) is the second most important performance measure for the organization. Similar performance trends are shown by the organization DEF-3 but these performance indexes are comparatively low for DEF-2. Employee benefits show very poor performance for DEF-1 and DEF-2 in comparison to DEF-3. Generally, social sustainability has not been given adequate attention by the organizations. Performance Index also suggests that most of the sub criteria with higher weights belong to economic and environmental performance, and lower weights for social performance measures. This is also evident from the weights shown in table 8.4 for the electronic industry in India. In summary, above results indicate that all the three organizations and electronic industry in India are more focused towards economic and environmental performance in comparison to the social performance. Organizations need to focus on improving their social performance.

8.7 Concluding remarks

The study proposed a methodological framework based on TBL approach and FAHPEA approach for evaluating the RSC performance. The framework is used for evaluating and comparing the RSC performance of three electronics organizations practicing RSC. The results indicated that organizations have highest performance index for economic performance followed by environmental performance, and social performance. In economic performance, recapturing value and return on investment have higher performance indexes for all three organizations. Minimum energy consumption, optimum use of raw material, and transport optimization are the performance measures, which have higher indexes from environmental performance perspectives. In social performance, community complaints, and customer health and safety have higher performance indexes. Over all, reduced packaging, use of recycled material, and employee benefits show very poor performance indexes. Improvements on these

performances may help the organizations for improving their RSC performance. The framework contributes to the limited number of present studies on performance evaluation system for RSC system especially from TBL perspectives, which may help in overcoming the limitations of present systems. In future, more frameworks can be developed for RSC performance evaluation based on TBL approach by using other MCDM techniques and may be compared with proposed framework. One of the limitations of application of FAHPEA example is that a large sample size could be used for estimating weights and global weights of performance measures. Findings of this study will help organizations in optimizing their RSC as well as in benchmarking of their performance with respect to best in industry.

Chapter 9. Conclusions and future directions

9.1 Introduction

Over last few years, reverse supply chain (RSC) has gained a lot attention because of increased flow of product returns, environmental concerns, legislation, and corporate social responsibility. RSC is in nascent stage and organizations are facing number of issues while implementing and practicing RSC. Earlier studies reported in Indian context are limited and staggered across the sectors. The research work aimed at exploring the Indian electronics industry and addressing the issues and complexities involved in managing RSC. The research work focused on select issues to explore them in-depth by using the multiple research tools such as survey method, case method, and development of models and decision frameworks.

A comprehensive literature review and exploration of Indian electronics industry was carried out to come across several issues and challenges related to RSC. Perusal of literature implied that some of select issues have not received necessary attention among academicians and researchers. The research work identified these select issues as adaptation and implementation, forecasting product returns, disposition decisions, outsourcing decisions, and performance evaluation system of RSC.

Rogers and Tibben-Lembke (1999) suggested that there are number of factors affecting RSC practices. The presence or absence of these factors can become drivers or barriers to RSC implementation in an industry. It is evident from the literature that no study is available on critical success factors for Indian electronics industry. Uncertainties in terms of quantity, quality, and timing of products influence the several strategic and operational decisions in RSC. Forecasting product returns accurately is one of tools to manage these uncertainties. Perusal of literature shows that number of models have been developed for forecasting product returns for reuse, recycle, remanufacturing by considering different business scenarios. However, none of them considers the factors like consumer behaviour, customs and culture, demographics,

rules and regulations collectively, which can make a very different scenario and may affect forecasting product returns substantially. By foresting product returns organizations may have an idea of expected business from RSC activities in future. The volume, qulaity, and timing of product returns may help in outsourcing decisions. It is observed that RSC is not the part of core business of many organizations and it is a potential candidate for outsourcing. Most of the studies are focused on the outsourcing part of RSC activities, mainly collection and transportation. No comprehensive framework is available for decision making with respect to completely or partly outsourcing the RSC activities. Another important issue is the disposition of returned products, which significantly influences the performance of RSC. However, there are very few studies available on disposition decisions. Literature review in chapter 2 also indicated that there are limited studies, which are focused on evaluating the performance of RSC for which it is intended to. In light of these issues, the research work has responded to these gaps by using survey method and case method. To assist the scientific analysis of the issues, the research has applied well-established methodologies such as Fuzz-TOPSIS, GERT, GTMA, GTMA & SBSC, and FAHPEA for developing models and decision frameworks. The chapter presents the syntheses of work done, and major findings of the research work. Furthermore, contributions, Implications of the research work, and recommendations for industry along with limitations and scope for future research are highlighted.

9.2 Syntheses of the work done

The research work has focused on the theoretical development of RSC and aimed at identifying the issues, which influences the implementation and performance of the RSC in Indian electronics industry. The research work has investigated the select RSC issues by using both qualitative and quantitative research with the help of survey method and case study method,

and developed models and decision frameworks. The syntheses of work done is shown in figure 9.1 and enumerated in the following sections.

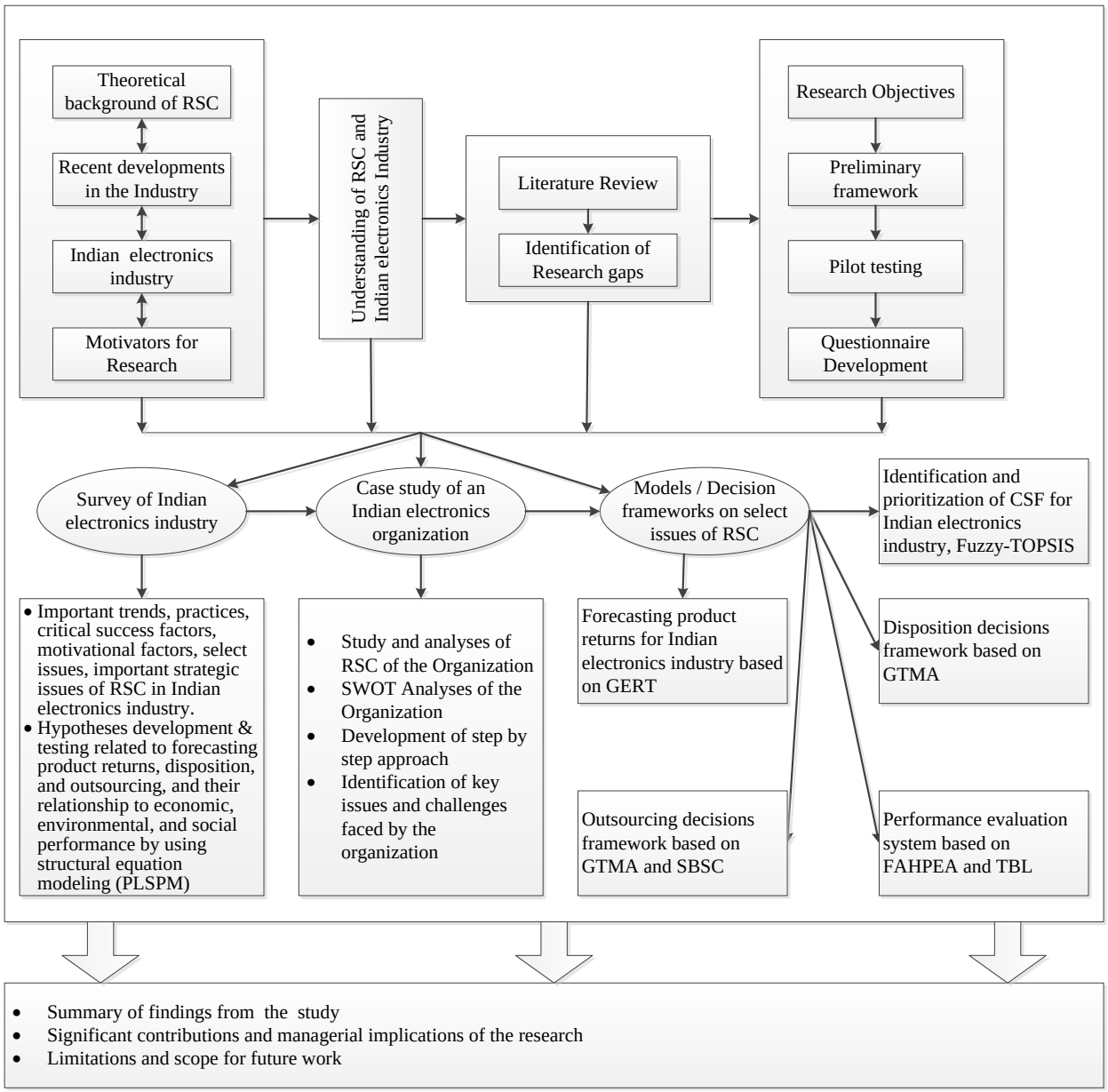

Figure 9.1 Syntheses of the work done

- A literature review was carried out to explore the various RSC activities and issues pertaining to RSC. Methodology for literature review is elaborated in detail including the classification of literature based on select issues and justification, inter-rater reliability, and

validity of the literature review. Research gaps in contemporary research were identified with the help of this literature review.

- Based on the literature review and research gap analysis, research objectives were established for the research work.
- The research has justified the use of survey method along with case study method for investigation of various issues including select issues in Indian electronics industry assuring reliability and validity in respective research. A questionnaire was developed and responses were obtained ensuring the reliability, validity, and other necessary quality related parameters for the research. Pilot test of questionnaire was performed for the improvement and quality of the questionnaire. The data from the pilot test were utilized for the identification and prioritization of critical success factors for RSC in Indian electronics industry by using fuzzy-TOPSIS methodology.
- The observations related to important trends, practices, critical success factors, and motivational factors, select issues, important strategic issues of RSC in Indian electronics industry were made with the help of descriptive analysis, and Cronbach's alpha was determined for each construct to ensure the internal consistency.
- Hypotheses were developed to investigate the underlying relationships and significance of various constructs specific to select issues for Indian electronics industry. Hypotheses were developed for forecasting product returns, disposition decisions, and outsourcing and their relationship with economic, environmental, social performance of RSC. The measurement models were analyzed for each construct to ensure the statistical fitness of the data for structural equation modeling. PLSPM approach of structural equation modeling was used for testing the hypotheses. Three separate models were develop for testing hypotheses so that in future other issues may be incorporated and tested in similar manner.

- A case of Indian electronics organization was analyzed for key issues and challenges in RSC. The electronics organization is one of leading mobile manufacturer in India. Both forward and RSC of organization were studied and examined from the RSC perspectives. SWOT analysis of the organization was carried out to investigate the present business practices and future opportunities for the organization especially in the light of RSC. A step by step approach for the case study was developed based on the research processes discussed in past literature (Stuart et al., 2002; Yin, 2003; Eisenhardt, 1989). The approach enabled in identifying and examining the key issues and challenges faced by the organization.
- It is evident from the survey, hypotheses results, and findings of case study that product returns, disposition decisions, and outsourcing decisions are important and have great influence on the performance of RSC. Following decision frameworks have been developed and explained as follows.

➢ Uncertainties in terms of quality, quantity, and timing of product returns is a major issue for any RSC. One of ways of managing these uncertainties effectively is forecasting product returns in RSC. A model based on GERT network theory was developed for forecasting product returns. This forecasting model provides the percentage of product returns and also the time of product returns. The model has been validated through practical case example of a leading mobile phone manufacturing organization in India.

➢ A framework for selection of best disposition option based on various disposition attributes has been developed with the help GTMA methodology. Attributes, based on past literature review and expert's opinion were selected from the economic, environmental, and social aspects of RSC. This approach involves the determination of permanent function, referred as disposition index for the matrices of various selected disposition options. The disposition index for various disposition options were determined and best disposition option

was selected based on the value of disposition index. A case of mobile phone manufacturing organization was discussed for the illustration of the approach.

- A framework for outsourcing RSC decisions whether outsource RSC activities partly or fully to third party service providers has been developed with the help of GTMA and SBSC. Attributes and sub-attributes, based SBSC have been selected with the help of literature review and discussion with the experts. A case of mobile manufacturing organization has been discussed for the illustration of the approach. Various scenarios were examined and developed for the selection of best scenario for the outsourcing RSC activities. This approach also involves the determination of permanent function, referred as outsourcing index for the matrices of various scenario based outsourcing options. The outsourcing index for various outsourcing options were determined and best scenario option was selected based on the value of outsourcing index.

- A frame work, incorporating the concept of triple bottom line into RSC is developed for performance evaluation of RSC. The framework is based on the FAHPEA and compares the performance of three Indian electronics organizations from triple bottom line perspectives.

9.3 Summary of the findings from the study

In the light of above syntheses of the work done, major findings of the research are enumerated as follows.

9.3.1 Findings from the survey

It is evident that there are few studies focused on research related to RSC in Indian context and offers a lot of potential for future scope of research. The research is diversified across the sectors and no single sector has been explored in-depth. The research work focused on Indian electronics industry. Most of the industry is dependent on import of parts / components /

products. There is lack of availability of sophisticated technology for remanufacturing and recycling of electronics products. Results of the survey indicated that a lot of importance is being given to the RSC and it has become a part of corporate strategy of many organizations. Better customer service, improved corporate image, higher recapturing value, competitive advantage in market are some of the important motivational factors for many organizations to adopt RSC practices. However, there are number of issues such as allocation of financial resources, risk associated with adoption of RSC, disposition decisions, inadequate performance evaluation system, integration with forward supply chain, and so on. All these issues make the RSC implementation uncomfortable for some of the organizations.

The study identified the critical success factors for adaptation and implementation of RSC. The most critical success factors were found to be top management awareness, resource allocation, and contract terms and conditions. Formation of joint consortium, economic factors, and consumer awareness & social acceptability are also some of the critical success factors for the organizations. It was also observed from the survey that recycling, and transportation are two major RSC activities outsourced by the organizations. The survey also examined the various factors affecting the accuracy in forecasting product returns which plays an important role both in short term and long term planning of RSC. It was observed that disposition decisions location is fragmented and staggered among the organizations in the industry and not much attention has been given to it from strategic perspectives.

Hypotheses testing revealed that select issues such as forecasting product returns, disposition decisions, and outsourcing decisions greatly influences the performance RSC. It was found that explanatory factors influence the accuracy in forecasting product returns. Accuracy in forecasting is positively associated with economic, environmental, and social performance of the RSC respectively. Effectiveness of disposition decisions is influenced by the internal and external factors, and it is positively associated with economic, environmental,

and social performance of the RSC respectively. Hypotheses were tested for association of outsourcing benefits with economic, environmental, and social performance. It was found that outsourcing benefits might led to the improved performance of RSC.

9.3.2 Findings from the case study

The case study has provided an in-depth understanding of key strategic issues and challenges in an electronics organization by using a framework consisting of theoretical and real life practical approach. The study finds that RSC is in evolving phase in Indian electronics industry. There is need to address various issues organizations are coming across while dealing with the RSC.

The study revealed that the electronics industry is coming across a new challenge of managing product returns because of changed business environment, and complying e-waste management rules and regulations. The study identified top management awareness, resource management, economic factors, and contracts terms & conditions with the supplier as CSFs for the industry, which are in line with the findings of the survey. The organization has authorized third party recycler for collection and recycling of end of products rather than outsourcing, which may help better in complying with rules and regulations. Managing uncertainties is important through forecasting product returns for future planning and decision-making. The organization need to explore diversified disposition options for effective management of product returns. Another key observation is that the organization has not set up any formal performance evaluation system for RSC activities. The study validates the findings of the survey on select issues of RSC in Indian electronics industry.

9.3.3 Findings from the models / decision frameworks

The research found that there is no study available for identifying and prioritizing CSFs for Indian electronics industry. Fuzzy-TOPSIS methodology was applied for prioritization of CSFs. It was found that top management awareness, economic factors, and resource management are some of the critical factors, which are important for the implementation of RSC in Indian electronics industry.

The research work developed decision framework for the select issues in RSC. The findings of the research work are explained as follows.

- Explanatory variables specific to the demographics and surrounding environment contributes to the uncertainties in the RSC. There are very few models for forecasting product returns specific to the country and industry. In addition, the product returns are stochastic in nature and forecasting product returns is more complex than forward supply chain. GERT based model predicts not only the quantity but also the timing of product returns in context of Indian business environment.
- There are very few studies available related to disposition decisions in RSC. A framework for disposition decisions in RSC has been developed by using GTMA. A case of mobile phone manufacturing organization was discussed for the illustration of the approach. The results indicate that recycling should be preferred to remanufacturing for the disposition of returned mobile hand-set for the organization in present business scenario.
- As discussed in research gap analysis, no study was found related to outsourcing RSC activities partly or fully. The research work developed a framework for outsourcing decision making whether outsource RSC partly or fully by using GTMA and SBSC. The study found that there are very few studies on incorporating concept of sustainability into RSC. Also, it is clear that RSC can make significant contributions to the efforts of an organization towards

sustainability. The study considered both external and internal factors by developing SBSC for the selection of attributes and sub-attributes. A case of mobile phone manufacturing organization was discussed for the illustration of the approach. The results suggest that the organization must outsourced all the RSC activities in the present business scenario for the organization.

Perusal of literature indicates that there are very studies available on performance evaluation system of RSC, especially social performance of RSC. The research work developed a performance evaluation system based on TBL by using FAHPEA. The results indicated that organizations have highest performance index for economic performance followed by environmental performance, and social performance. In economic performance, recapturing value and return on investment have higher performance indexes for all three organizations. Minimum energy consumption, optimum use of raw material, and transport optimization are the performance measures, which have higher indexes from environmental performance perspectives. In social performance, community complaints, and customer health and safety have higher performance indexes. Over all, reduced packaging, use of recycled material, and employee benefits show very poor performance indexes. Improvements on these performances may help the organizations for improving their RSC performance.

9.4 Significant contributions and managerial implications of the research

A mixed research comprising of different approaches such as modelling based, survey, and case study based were carried out to explore the various issues in context of Indian electronics industry related to RSC. Based on research gaps, this research work addressed select issues of RSC such as identifying and prioritizing critical success factors, forecasting product returns, disposition decisions, and out sourcing decisions, and framework for evaluating performance

of RSC. Significant contributions and managerial implications of the research are enumerated as follows.

- A comprehensive literature review of RSC has been carried out that establishes a sufficient basis for other contemporary researchers.
- The research has clearly identified the research gaps and correlated them with issues on which research was carried out. The research work attempted to fill these gaps in the literature. Researchers and practitioners may utilize these research gaps for further research in the area of RSC.
- It is evident from the literature review that research in RSC is diversified across the sectors and limited studies are available related to developing countries like India. The research work focused on single sector, Indian electronics industry and makes significant contribution to the limited available studies. Managers in the electronics industry may utilize these findings of the research for the adoption and implementation of RSC.
- The research work identified and prioritized the critical success factors for Indian electronics Industry. No such previous study was available on critical success factors for Indian electronics industry. The study will help the managers and practitioners in implementation of RSC. It will enable the managers in identifying the factors, which they need to work out for successful implementation. The findings of the research will help the managers and academicians in the development of RSC strategies and practices in Indian electronics industry.
- A Questionnaire was developed and a survey of Indian electronics industry was conducted. The observations from the survey provides the great insight into the trends, current practices, and key issues in RSC which includes select issues such as critical success factors, forecasting product returns, disposition decisions, and TBL performance for the Indian electronics industry. These issues were first time being analyzed for the Indian electronics industry. The findings of the survey will help managers and researchers to have better

understanding of Indian electronics industry. It will also provide base for further exploration of the industry. Hypotheses were developed related to forecasting product returns, disposition decisions, and outsourcing benefits and their association with TBL performance of RSC. The managers can utilize the results of these hypotheses for exploring and emphasizing these issues for improving their RSC performance. Separate models have been developed for each of the issues that will help the researchers to test the other issues in similar way.

- A case study of Indian electronics organization has been developed and contributes to the very few case studies available for Indian electronics industry related to RSC. Both forward and RSC have been discussed along SWOT analysis of the organization. The information and analysis will help the managers in identifying and examining the various issues in their organization. The observations and findings may help other organizations to improve their RSC.
- A model for forecasting product returns considering consumer behaviour, customs and culture, demographics, rules and regulations collectively for developing country like India have been developed for the first time. At present most of the organizations in India do not have formal structure to manage their product returns. Manufactures can develop an effective RSC for returned products through precise forecasting of product returns and their expected timing of return. This forecasting model provides the percentage of product returns and also the timing of product returns. Managers can utilize these RSC estimates for the future RSC planning. The model has been validated through a case example of a leading mobile phone manufacturing organization in India.
- A disposition decision framework was developed by identifying various disposition attributes and selecting the best disposition option by using GTMA. The research work makes significant contribution to the few studies available on disposition decision making in RSC. The managers for a particular product and over a period may repeatedly calculate the

disposition index, and the value of index may be benchmarked. These values may be utilized in decision making for different disposition options. A case of mobile phone manufacturing organization was discussed for the illustration of the approach. The findings of the study will help in improving the overall RSC performance. The framework may help the managers and researchers in disposition decision-making and further development on the disposition decisions while dealing with the product returns in RSC.

- The research attempts to incorporate concept of sustainability into the RSC and developed a framework for outsourcing decision making based on SBSC. The study provides an overview of reasons for outsourcing and solution methodologies for outsourcing RSC. The study is among very few studies available on decision making with respect to outsourcing RSC partly or fully. SBSC will help the managers to achieve the operational and financial efficiency and will help them to make contributions to the sustainability efforts of the organization. The study will help managers in ensuring the sustainable development even when they are outsourcing the RSC activities. The attributes and sub-attributes selected in the study will guide the decision makers to visualize and analyse the impact of these attributes and sub-attributes on outsourcing decisions. A combination of SBSC and GTMA provides a realistic and holistic view of the problem for outsourcing decisions in RSC. The alternatives in the case illustration are scenario based, which provides flexibility to the managers for developing alternatives according their business need. The research work again tried to incorporate the sustainability into the RSC. A framework incorporating the concept of triple bottom line into RSC is developed for the evaluation of performance of RSC. The framework contributes to the limited number of studies available on performance evaluation system of RSC especially from TBL perspectives. Findings of the study will help organizations in optimizing their RSC as well as in

benchmarking of their performance with respect to best in industry. It will also motivate organizations to work in a holistic manner rather than only on economic terms.

9.5 Select recommendations based on the research work

The exploration and analysis through this research work helped in identifying the potential areas of improvements for Indian electronics Industry. However, the issues and challenges from organization to organization depending on the number of factors, products, demographics, and business environment, summarization of select recommendations may guide practitioners for future actions. The research work makes following recommendations to assist Indian electronics industry.

- It is evident that RSC may become a profitable business if implemented properly. The study identified and prioritized the CSFs for RSC implementation in Indian electronics industry. It is recommended that organizations should utilize these factors for exploring the possibility of implementing RSC. The factors, which are positive, may be the drivers for RSC implementation while attempt should be made to overcome barriers for RSC implementation.
- Organizations should consider the possibility of forming joint consortium particularly in case of recycling which requires high investment in equipment and high volume is desired.
- Organizations should plan their e-waste management thorough effective RSC planning to comply with e-waste management rules and regulations 2011, and 2016.
- Forecasting product returns is important for managing uncertainties in the RSC. The organizations may know the expected business form the RSC and may plan other activities accordingly.
- The organizations must consider disposition decisions as strategic issues and the responsible person at appropriate location must take disposition decision.

- The organizations must consider the TBL aspect of sustainability while taking outsourcing decisions. The study recommends use of SBSC for outsourcing decisions in RSC. This will enable them to ensure their contribution towards sustainability even if they outsource RSC activities.
- The research has incorporated concept of sustainability into the RSC and developed framework for evaluating TBL performance of RSC. This will enable them to measure the contribution of RSC in sustainability efforts of the organizations. Organizations may consider RSC as a part of corporate social responsibility and my invest money in RSC under "Corporate social responsibility policy-2014".
- The Government of India may offer several incentives for "Make in India" drive. The organizations must have close watch on this and may consider for manufacturing and subsequently remanufacturing in the country rather than depending on imports from other countries.

9.6 Limitations and scope for future work

Every research work has its own strengths and limitations. This research work is also subjected to some of the limitations. Limitations of the research work and suggested directions for future work are discussed as follows.

- One of the limitations of the research work is that it focused on the Indian electronics industry, and therefore findings and conclusions have limited scope of generalization for other industries. In future, similar research in other industries may be considered for better generalization of findings.
- Another limitation is that select issues were considered for the research work. Select issues were considered so that they could be analyzed in-depth by using both qualitative and quantitative data through survey method, case method, and modeling. The work may further

be extended for other issues like marketing, information technology, trust, coordination in RSC.

- Survey method was utilized for generalization of results but it was constrained by small sample size and relatively low response rate. In future, larger sample size and higher response rate may be achieved by enhancing the response rate. Although, measurement models were found statistically fit for the structural equation modeling, larger sample size may be used for better significance and acceptance of the results.
- Hypotheses were developed related to forecasting product returns, disposition decisions, and outsourcing decisions, and their association with performance of RSC. Since separate models have been developed for each issue, more issues may be considered for hypotheses development and their association may be tested with performance of RSC by using similar steps followed in this research. In future, number of issues may be combined to assess their effect on the performance of RSC.
- Although research justified the use of single case along with survey method, more case studies may be developed for the validation and generalization of the findings of research work.
- The model developed for the identification and prioritization of CSFs is based on the pilot testing data with five experts from the Indian electronics industry. Future studies may consider larger sample size to assess the methodology and the effectiveness of the proposed solution to enable generalization. Future studies may be carried out to identify organization specific or product specific identification of CSFs for RSC implementation.
- In forecasting product returns model, GERT has been utilized for developing the network based on certain scenario. In future, this methodology may be utilized to develop more networks for other real life scenario for various RSC activities.
- In disposition decision framework, other methodologies may be applied and results may be compared with the results of this study. One of the limitations is that the limited numbers of

disposition options were examined. More disposition options like donation to community, selling in secondary markets may also be considered in future studies.

- In outsourcing decision framework, one of limitations is that the attributes and sub-attributes, and alternative scenarios are based on one organization. However, methodology can easily be acclimatized to different scenarios, and can consider different kind of quantitative and qualitative attributes depending on the business need. In future, a larger group of experts may be utilized and more case studies may be developed for the generalization of results and findings. In addition, a fuzzy based scale may be used to avoid any vagueness or subjective biasness.
- In RSC performance evaluation framework, one of the limitations of application of FAHPEA example is that a large sample size could be used for estimating weights and global weights of performance measures. The research work compares the three electronics organizations; more organizations may be included and compared for generalized bench marking of the performance. In future, more models can be developed for RSC performance measurement based on TBL approach by using other MCDM techniques and may be compared with proposed model.

9.7 Concluding remarks

The research work reported in this thesis may be considered as an attempt to address challenges and issues specific to RSC in Indian context. The research work was carried out in Indian electronics industry in a period when the emergence of “Make in India”, “Digital India”, “e-waste management rules and regulations”, “e-retail” and other initiatives changing the dynamics of business in India. Liberal return policies due to competitiveness and offers like cash on delivery are contributing to increase in product returns. Introduction of restrictions such as e-waste management rules and regulations-2011, 2016 by the Government of India are

compelling organizations to rethink about managing end of life product returns. Organizations are reconfiguring their supply chain and looking forward for the implementation of RSC. The research work identified and prioritized CSF for adaptation and implementation of RSC in India electronics industry. These factors provided useful information of RSC in Indian electronics industry and will provide guidance to the industry for implementing RSC. The research work focused on select issues and analyzed those issues by using survey method, case method, and recommended solutions by developing models and frameworks. The study found that forecasting product returns, disposition decisions, and outsourcing decisions are positively associated with TBL performance of RSC. A framework, based on TBL has been developed for performance evaluation of RSC. The research work focused on TBL performance to investigate the contribution of RSC in sustainability efforts of an organization. According to corporate social responsibility policy, 2014 by the Government of India, organizations are required to spend 1% of their profit on corporate social responsibility. Organizations may introduce sustainability related parameters in the performance evaluation measures of RSC and may invest some part of corporate social responsibility funds into the RSC. The research work developed models, and frameworks, which will help in improving the TBL performance of RSC. The findings of the research work will help the academicians, practitioners and researchers in their future work. The research work will help the managers, academicians, and researchers in implementing, developing, operating the RSC system effectively and efficiently.

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Appendix 1A.

We are conducting a survey of Indian electronics industry for the purpose of empirical study on reverse supply chain. We will keep all the individual responses confidential and will not share with anyone.

---

1. Organization/Company/Firm Profile

1. **(i) Name of the Organization**

   .....

2. **(ii) Year of Establishment**

   .....

3. **(iii) Annual Turnover (Rupees in Crores) of the organization**
   Mark only one oval.

   - ◯ < 100
   - ◯ 100-300
   - ◯ 300-500
   - ◯ > 500

4. **(iv) Number of employees in the organization**
   Mark only one oval.

   - ◯ < 100
   - ◯ 100-300
   - ◯ 300-500
   - ◯ > 500

5. **(v) Products/Services offered by the organization**

   .....

6. **(vi) Reverse supply chain practices by the organization**
   Check all that apply.

   - ☐ Reuse
   - ☐ Recycle
   - ☐ Remanufacturing
   - ☐ Repairing
   - ☐ E-waste management
   - ☐ Product Return Management
   - ☐ Third Party Service Provider
   - ☐ Other: .....

7.

(vii) Reverse supply chain activities outsourced by the organization

Check all that apply.

- [ ] Product Acquisition
- [ ] Production Collection
- [ ] Transportation
- [ ] Inspection & Sorting
- [ ] Repairing
- [ ] Remanufacturing
- [ ] Recycling
- [ ] Disposal
- [ ] Other: .....

8.

(viii) Reverse supply chain disposition is performed at the location of

Check all that apply.

- [ ] End User
- [ ] Retailer
- [ ] Collection Center
- [ ] Inspection & Testing Center
- [ ] Manufacturing Unit
- [ ] Third Party Location
- [ ] Other: .....

2. Important trends in Indian electronics industry

Please rate the following factors for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

9.

(i) Growth of Annual Turnover of the Organization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

10.

(ii) Increase in Import of parts/components/products

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

11.

(iii) Growing Importance of E-Commerece

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

12.

(iv) Increase in Competitiveness in the Market

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

13.

(v) Increase in Product Returns

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

14.

(vi) Shortening of Product Life Cycle

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

15.

(vii) Importance of Consumer Protection & Service

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

16.

(viii) Pressure of Corporate Social Responsibility

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

17.

(ix) Impact of e-waste management rules 2011 & Environmental Guidelines

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

3. Key Trends in Reverse Supply Chain in Indian electronics industry

Please rate the following factors for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

18.

(i) Importance of reverse supply chain in the organization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

19. **(ii) Investment in reverse supply chain activities as % of total investment**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

20. **(iii) Profit from reverse supply chain activities**
Mark only one oval.

	1	2	3	4	5	
No Profit	◯	◯	◯	◯	◯	High

21. **(iv) Importance of revese supply chain as a part of corporate strategy**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

22. **(v) Use of Information Technology in reverse supply chain**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

23. **(vi) Availability of reverse supply chain experts in the market**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

24. **(vii) Availability of third party service providers**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

25. **(viii) Contribution of reverse supply chain into sustainability efforts of the organization**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

26. **(ix) Collaboration with other reverse supply chain partners**
Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

4. Motivation for reverse supply chain

Please rate the following factors for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

27. **(i) For Improving Corporate Image**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

28. **(ii) Increase in Profitability**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

29. **(iii) High Recapturing Value**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

30. **(iv) Environmental and Social benefits**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

31. **(v) Competitive Advantages in the market**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

32. **(vi) Better Customer Service**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

33. **(vii) Pressure of the Stake holders**

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

34.

(viii) Compliance with government rules and regulations

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

5. Forecasting Product Returns and Planning

Please rate the following factors for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

35.

(i) Accuracy in Forecasting Quantity of Product Returns

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

36.

(ii) Accuracy in Forecasting Quality of Product Returns

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

37.

(iii) Accuracy in Forecasting timing of Product Returns

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

Factors Influencing the Accuracy in Forecasting Product Returns

Please Indicate the Importance of following factors in forecasting product returns

38.

(iv) Sales volume and price of product

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

39.

(v) Marketing and advertisement budget

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

40.

(vi) Resistive return policy

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

41.

(vii) Product life cycle

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

42.

(viii) Ease and cost of return

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

43.

(ix) Environmental consciousness of consumers

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

6. Key Strategic issues in reverse supply chain

Please rate the following issues based on importance for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

44.

(i) Degree of Integration of Reverse supply chain to the forward supply chain

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

45.

(ii) Clarity of Product Return policies

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

46.

(iii) Allocation of financial resources to the reverse supply chain

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

47.

(iv) Network design for collection and re-distribution

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

48.

(v) Adequacy of Performance Measurement System

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

49.

(vi) Availability of IT infrastructure and integration with present system

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

50.

(vii) Disposition decisions in reverse supply chain

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

51.

(viii) Technology availability for re-manufacturing / recycling

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

52.

(ix) Risk of adopting reverse supply chain

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

7. Critical Success Factors for reverse supply chain implementation

Please rate the following factors importance on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

53.

(i) Compliance with goverment rules and regulations

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

54.

(ii) Economic factors like revenue growth and profitability

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

55.

(iii) Addressing environmental concerns of stakeholders

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

56.

(iv) Top management support

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

57.

(v) Resource allocation and efficient utilization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

58.

(vi) Management information system

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

59.

(vii) Contract terms & conditions with supplier

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

60.

(viii) Direct and Indirect tax benefits offered by the government agencies

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

61.

(ix) Integration of forward and reverse supply chain

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

62.

(x) Joint Consortium with the peer companies

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

63.

(xi) Process capabilities and skilled workers

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

64.

(xii) Consumer awareness and social acceptability of re-manufactured products

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

8. Out Sourcing reverse supply chain activities

Please rate the following based on advantages of outsourcing to third party on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

65.

(i) Focus on core activity of the organization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

66.

(ii) It is economical to outsource reverse supply chain activities

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

67.

(iii) Third party may provide sophisticated technology, system, and better services

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

68.

(iv) Outsourcing reduces investment in reverse supply chain facilities

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

69.

(v) It provides more flexibility

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

70.

(vi) Better customer responsiveness

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

71.

(vii) Third Party takes responsibility of entire product life cycle

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

72.

(viii) Third party may have better environment management

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

9. Disposition Decisions in reverse supply chain

Please rate the following factors for your organization on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

73.

(i) Effectiveness of dispostion decisions

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

Factors influencing dispostion decisions and their impact

74.

(ii) Economic factors for disposition decisions

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

75.

(iii) Environmental factors for disposition decisions

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

76.

(iv) Social factors for disposition decisions

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

77.

(v) Customer behaviour

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

78.

(vi) Market conditions (Including Demand)

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

79.

(vii) Product value

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

80.

(viii) Processing cost

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

81.

(ix) Volume of returned products

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

82.

(x) Quality of returned products

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

83.

(xi) Supply chain capabilities

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

84.

(xii) Importance of goverment rules and regulations

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

10. Performance evaluation of reverse supply chain

Please rate the following performance related factors for your organization in reference to reverse supply chain on the scale of 1 to 5, 1 for Very Low, 2 for Low, 3 for Medium, 4 for High, and 5 for Very High

10.1 Economic Performance

Please rate the following factors based on their performance in reference to product returns in your organization

85.

(i) Return On Investment

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

86.

(ii) Recapturing Value

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

87.

(iii) Logistics Cost Optimization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

88.

(iv) Recycle Efficiency

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

89.

(v) Annual Sales of re-manufactured products

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

90.

(vi) Disposal Costs

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

10.2 Environmental Performance

Please rate the following factors based on their performance in reference to product returns in your organization

91.

(i) Minimum Energy Consumption

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

92.

(ii) Optimum use of raw material

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

93.

(iii) Transport Optimization

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

94.

(iv) Reduced Packaging

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

95.

(v) Use of recycled material

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

96.

(vi) Waste Reduction

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

10.3 Social Performance

Please rate the following factors based on their performance in reference to product returns in your organization

97.

(i) Response to Community complaints

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

98.

(ii) Customer Health and Safety

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

99.

(iii) Stake Holders Participation

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

100.

(iv) Employment Stability

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

101.

(v) Donations to Community

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

102.

(vi) Employee Benefits

Mark only one oval.

	1	2	3	4	5	
Very Low	◯	◯	◯	◯	◯	Very High

11. Respondent Profile

Please provide the following information. All the personal information provided by you would be confidential and will not be shared with anyone. I appreciate your time. Thanks

103.

(i) Name (Optional)

.....

104.

(ii) Designation

.....

105.

(iii) Total Industry Experience

.....

106.

(iv) Your Expertize

.....

107.

(v) Do you want to get findings of the study?

Mark only one oval.

- Yes
- No

108.

(vi) Official E-Mail: (Optional)

.....

109.

(vii) Contact Number: (Optional)

.....

List of publications from the research work

(i) List of Papers Published in International Journals

1. Agrawal, S., Singh, R.K. and Murtaza, Q., 2015. A literature review and perspectives in reverse logistics. *Resources, Conservation and Recycling*, *97*, pp.76-92.
2. Agrawal, S., Singh, R.K. and Murtaza, Q., 2015. Prioritizing critical success factors for reverse logistics implementation using fuzzy-TOPSIS methodology. *Journal of Industrial Engineering International*, *12*(1), pp.15-27.
3. Agrawal, S., K. Singh, R. and Murtaza, Q., 2014. Forecasting product returns for recycling in Indian electronics industry. *Journal of Advances in Management Research*, *11*(1), pp.102-114.
4. Agrawal, S., Singh, R.K. and Murtaza, Q., 2015. Disposition decisions in reverse logistics by using AHP-Fuzzy TOPSIS Approach. *Journal of Modelling in Management, 11*(4), pp. 932-948.
5. Agrawal, S., Singh, R.K. and Murtaza, Q., 2016. Triple Bottom Line Performance Evaluation of Reverse Logistics. *Competitiveness Review: An International Business Journal*, *26*(3). pp. 289-310.
6. Agrawal, S., Singh, R.K. and Murtaza, Q., 2016. Outsourcing decisions in reverse logistics: Sustainable balanced scorecard and graph theoretic approach. *Resources, Conservation and Recycling*, *108*, pp.41-53.
7. Agrawal, S., Singh, R.K. and Murtaza, Q., 2016. Disposition decisions in reverse logistics: Graph theory and matrix approach. *Journal of Cleaner Production, 137*, pp. 93-104.

(ii) List of Papers presented / published in conference proceedings

1. Agrawal, S., Singh, R.K. and Murtaza, Q. 2012. Analyzing Critical Success Factors for Implementing Reverse Logistics in Indian Electronics Industry. XVI Annual International Conference of the Society of Operations Management held at DMS, IIT, Delhi during 21-23 December 2012. Vol. 1, pp. 234-243.
2. Agrawal, S., Singh, R.K. and Murtaza, Q. 20123. Development of Virtual Reverse Supply Chain model for e-waste Management. 3rd International Conference on Production and Industrial Engineering CPIE-2013 held at NIT, Jalandhar during 29-31 March, 2013. pp. 468- 472.
3. Agrawal, S., Singh, R.K. and Murtaza, Q. 2013. Green logistics for sustainable Supply chain management. ISTE Delhi Section held at DTU, Delhi during 5-6 September'2013.

Biographical profile of researcher

Saurabh Agrawal, presently works as an Assistant Professor in Mechanical, Production & Industrial Engineering Department at Delhi Technological University, Delhi, India. He has vast experience of academics, research and the industry both in India and in USA. He has worked in V.Tech. Communications, OR, USA, and Wiquest Communications, TX, USA as supply chain analyst. His research focus is in the areas of supply chain management, reverse supply chain, sustainability and e-waste management. He has published research papers in international journal of repute including Resource, Conservation, and Recycling; Journal of Industrial Engineering, International; Journal of advances in Management Research; Journal of Modelling in Management; and Competitiveness Review: An International Business Journal. He received his Bachelor's Degree in Industrial Engineering from IIT Roorkee (Erstwhile University of Roorkee, Roorkee), India, Master's Degree in Industrial Engineering from IIT Delhi, India, and Master of Business Administration (MBA) from Oregon State University, USA.