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Analysing disposition strategies in reverse supply chains: Fuzzy TOPSIS approach

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Purpose - The article aims to explore the product disposition strategies in reverse supply chains and to develop a framework to prioritize these strategies for effective reverse supply chain implementation.

Design/Methodology/Approach –The disposition strategies, based on the literature review were selected, and fuzzy TOPSIS methodology has been applied for the prioritization of these disposition strategies. A case of cell phone manufacturing firm is discussed for the illiustration and validation of the methodology. Three respondants from the firm helped in exploring the disposition strategies and data collection of the firm.

Findings - The results of the study show that dissemble and recycle is the most preferred disposition strategy for the firm. Redistribution of returned products after their refurbishing is second most prioritized disposition strategy. Landfill and inciretion of cell phones is the last and least prefreferred option for the firm.

Research limitations/implications- The study will provide useful guidance to the firm for disposition decision making of cell phones returned to the firm. It will help academicians and practitioners for evaluating, improving and benchmarking the disposition strategies for the disposition of returned cell phones. One of the limitations of the study is that it only considers the single case of manufacturing firm. In future, more case studies may be carried out for generalization of the results.

Originality / value - It is evident from the literature review that there are very few studies on disposition decisions in reverse supply chain. Also, disposition strategies for cell phones are first time being explored and prioritized.Hence, this study can be viewed as an attempt to increase the level of awareness on reverse supply chain issues.

Keywords - Reverse Supply Chain, Reverse Logistics, Disposition, Fuzzy TOPSIS, Cell phone manufacturing

Paper type – Research Paper

1. Introduction

In today's highly competitive business environment, the success of any business depends to a large extent on the efficiency of the supply chain. Competition has moved beyond firm-to-firm rivalry to rivalry between supply chains. Traditionally, businesses have concentrated on improving the forward supply chain for their products (e.g., manufacturer-wholesaler-retailer-consumer). However, another important and emerging dimension of successful SCM is the reverse logistics process (Marien, 1988). As the business environment becomes more competitive, it becomes increasingly important for them to concentrate on optimizing the backward loop, as well. Reverse supply chain practices have been in existence for a long time, especially in the automotive industry, where manufacturers try to recover value from recycling car parts. Reverse supply chains differ from forward supply chains in information flow, physical distribution flow and cash flow. To manage reverse supply chain, companies need sophisticated information systems. Some of the technology involved in reverse supply chain is similar while in some areas the technology used differs from that of traditional supply chain. Technology used in reverse supply chain such as real-time inventory tracking system (bar codes and sensors) are similar to that used in the forward supply chain. On the other hand, activities such as repair optimization, slow moving inventory optimization, warranty tracking and de-manufacturing of product is different. In designing a successful reverse supply chain, it is important to know what type of product will be returned at which point in time at which place and in which condition. Hence, importance of data is immense. Tightly integrated automatic data capture, system directed disposition support, unique receipt handling, credit processing, comprehensive and flexible reporting are some of the important functional capabilities in reverse supply chain which can help a company have a competitive edge over its competitors.Reverse supply chain deals with products that have reached their life cycle or the ones returned by the final users, and then aims at best extracting their remaining values by repair, refurbishing, remanufacturing, cannibalization, and recycling (Thierry *et al.,*1995) or other activities in order to protect the environment. Furthermore, reverse supply chain management can reduce the negative environmental impacts of waste disposal and resource extraction, and reduce production costs. All these factors will be taken into consideration while designing the operational framework to handle product disposition strategies for effective reverse supply chains. There are few articles on disposition decisions in reverse supply chain (Agrawal *et al.*, 2016a; Agrawal *et al.*, 2016b). The proposed study contributes to the very few studies available on disposition decisions in reverse supply chain.

In this article, we've defined the reverse supply chain process, the steps involved and how it can be used as a strategic business weapon for organizations by studying the product disposition strategies. Drivers for implementing reverse supply chains are also explored alongwith inherent challenges that a reverse supply chain facessuch as managing customer expectations on returns policies, partnering with other players in the supply chain and handling the mounting pressure from regulatory authorities. This will enable us to develop a strategy to adopt a recyclable approach to production and increase the sustainability of the business organization. The study identifies the disposition strategies from the review of previous literature. A fuzzy TOPSIS methodology has been utilized for the priporitization of these disposition strategies for a cell manufacturing firm. Fuzzy TOPSIS methodology has been utilized by number of authors in the area of supply chain management(Agrawal*et al.*, 2015; Kumar and Singh, 2016; Singh *et al.*, 2017; Kirkire *et al.*, 2018;).

The remainder of the paper is organized as follows: Section 2 comprises a literature review on reverse supply chain and drivers for its implementation. Section 3 identifies the dispotion strategies of reverse supply chain utilized in the past. Section 4 discusses about the fuzzy TOPSIS methodology utilized for the priortitization of disposition strategies. Subsequently, the case of cell manufacturing is discussed in Section 5. Results are discussed in Section 6. Finally,Section 7 summarizesallthefindingsandconcludesthestudyincludingfuturescopeofresearch.

2. Literature review

Research on reverse supply chain has been growing since the Sixties and research on strategies and models on reverse logistics can be seen in the publications in and after the nineties. However, efforts to synthesize the research in an integrated broad-based body of knowledge have been limited. Rogers and Tibben-Lembke (2001) provided various definitions of reverse logistics, some of which were broader and included sustainability, revenue enhancement, and cost reduction as important goals. Carter and Ellram (1998) state that three primary intra-organizational activities impact reverse logistics: commitment to environmental issues, ethical standards, and policy entrepreneurs who adopt an environmentally friendly philosophy. Most research focuses only on a small area of RL systems, such as network design, production planning or environmental issues. Fleischmann *et al.* (1997) studied RL from the perspectives of distribution planning, inventory control and production planning. Carter and Ellram (1998) focused on the transportation and packaging,purchasing and environmental aspects in their review of RL literature. Reverse logistics has also been discussed in the context of recovery process for waste/by- product stream (Pourmohammadi *et al.,* 2008) and in terms of the logistics network and governance structure (Roy *et al.,* 2006). Recent, although limited, research has begun to identify sustainable supply chain practices, which include the reverse logistics factors, lead to more integrated supply chains, which ultimately can lead to improved economic performance (Jayant *et al.,* 2012). In addition, reverse supply chains are increasingly being considered and prioritized as a corporate strategy to stay competitive (Marien, 1998; Genchev, 2009).

In the past, there have been some studies to identify the managerial drivers responsible for reverse supply chains. A framework (Figure 1) was created for reverse supply chains by identifying four managerial drivers in the reverse chain as Facilities, Handling, Ease of Access, and Information (Tyagi *et al.,* 2012) This managerial framework includes four drivers in the reverse chain that were extrapolated from the review of literature (Tibben-Lembke, 2002) and from in-depth field work. They took the viewpoint of a company that is focusing on its reverse supply chain. The company articulates its competitive strategy, operations strategy, and supply chain strategy based on customer segments. The reverse supply chain strategy extends vertically to its partners, suppliers, and end consumers.

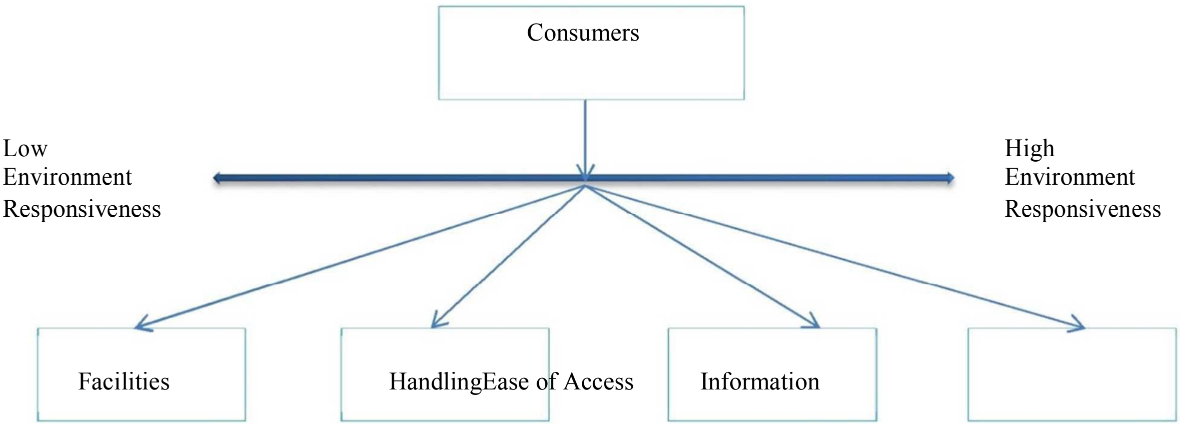

Figure 1: Conceptual Framework for Reverse Supply Chain Management Source: Adapted from Tyagi *et al.* (2012)

A reverse logistics decisions conceptual framework (Lambert *et al.,* 2011) offers flexibility and covers a wide variety of situations that may arise in the practical working environment. The proposed framework considers seven important elements of the reverse logistics system. It is divided into three hierarchical levels (strategic, tactical, and operational). The seven elements are: coordinating system, gatekeeping, collection, sorting, treatment, information system and disposal system. Each of these is reviewed in terms of generic process mapping, decisions, economics aspects, and performance measures.Reverse supply chain refers to the movement of goods from customer to vendor. This is the reverse of the traditional supply chain movement of goods from vendor to customer. Reverse logistics is the process of planning, implementing and controlling the efficient and effective inbound flow and storage of secondary goods and related information for the purpose of recovering value or proper disposal. In the literature of reverse logistics, many authors shows that a firm's reverse logistics activities are affected by intra-organizational factors, including a sincere commitment to environmental issues and successfully implemented ethical standards, and the existence of policy entrepreneurs who make a strong commitment and take personal responsibility for organizational adoption of an environmentally friendly philosophy. Literature also indicates that a firm's reverse logistics activities are directly affected by one or more environmental forces: customers, suppliers, competitors and government agencies(Stock,1992; Pohlen and Farris, 1992; Kopichi *et al.,*1993). The presence or absence of these factors can become drivers or barriers to reverse logistics implementation in a particular industry.

To implement reserve logistics, a number of driving forces should be considered. According to Prahinski and Kocabasoglu (2006), managers' support or commitment has a huge effect on company policy and operation. Hsu *et al.* (2009) evaluated the business process of reverse logistics by studying the business activities of distribution centers. According toMeade *et al.* (2007), the driving forces of reserve logistics are the environmental factor and the business factor. Company management may have some concern on the benefits of practicing reserve logistics (Gunasekaran and Ngai, 2003). However, companies should pay more attention to several barriers (Ravi and Shankar, 2005), such as lack of IT systems, problems with product quality, company policies, lack of training and education, etc.Knemeyer *et al.* (2002) proposed a conceptual model that puts the various exogenous and endogenous factors together. Under this model, the external (or macro) environment or task environment may be defined as the specific organization or group that is relevant to goal setting and goal attainment, and that affects decisions, actions, and outcomes. It includes sectors with which the organization interacts directly and that have a direct impact on the organization's ability to achieve its goals: industry, competitors, customers, techniques of production, suppliers, stock market, raw materials, market sectors, government and perhaps the human resources and international sectors.

3. Disposition strategies in reverse supply chiain

Based on green supply chain and reverse supply chain literatures, the current research on reverse logistics processes focus on product disposition options. Also known as product recovery options, Skinner *et al.* (2008) describe that right management of product disposition is a strategic move that paves the way towards superior performance. In analyzing reverse logistics among automobile, electronics and appliances manufacturers, Kumar and Putnam (2008) supported the existence of potential profit within recycled and remanufactured product through reuse services. Reuse services include equipment leasing where rents are generated from services rendered by a typical product.Careful considerations are required when selecting product disposition options for reprocessing returns received from downstream supply chains. Thierry *et al.* (1995) revealed that repair, refurbishing, remanufacturing, cannibalization and recycling are various operations to reduce the amount of waste that are landfilled or incinerated. Among the factors that are taken into consideration when evaluating the destiny of products bound to be reprocessed is the depth of disassembly (Thierry *et al.,* 1995), impact to the environment (Gehin*et al.,* 2008), age and condition of the returned product (Guide *et al.,* 2000), quality of recovered product compared to original specification (Ijomah *et al.,* 2007), destination of used products in secondary market (Rogers*et al.,*2010) and cost and profit structure of this green initiative. The type of product disposition depends on several key decisions such as cost and value of recovery, level of product sophistication and market value of products (Fernandez *et al.,* 2008). Based on a review of reverse logistics and environment related literatures, adopted product disposition options are outlined in the figure 2 below.

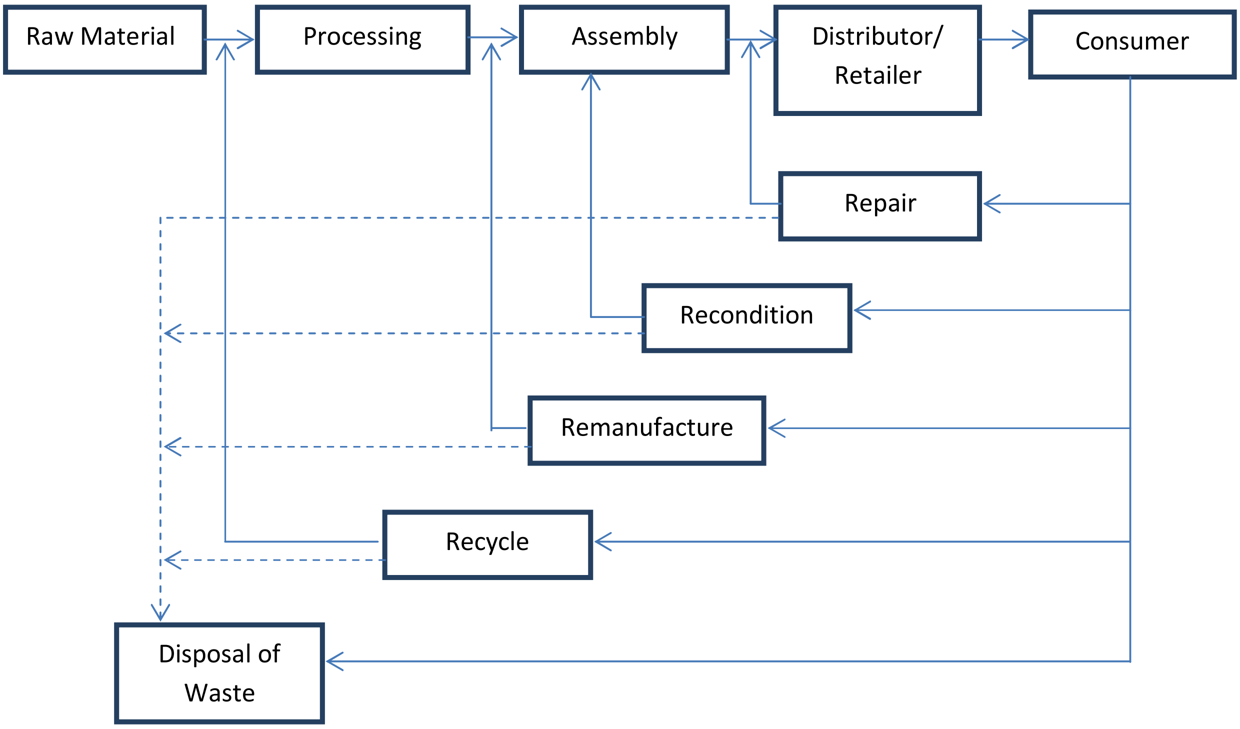

Figure2. Product Disposition Options in Closed Loop Supply Chain Processes

Several options exist today for disposing of returned goods. The choice of one or more options should be governed not only by financial concerns (a cost-benefit analysis) but also by nonfinancial concerns like brand image, customer satisfaction, and regulatory compliance.

Option 1: Refurbish/repair/remanufacture

In this disposition option, damaged or discontinued returns are repaired or refurbished and sold again. The financial driver for this option is the comparison between the cost of repair and refurbishment plus the cost of transportation and handling versus the market price of the repaired/refurbished/remanufactured item. However, nonfinancial concerns are equally relevant. It's important that companies identify refurbished/ repaired/ remanufactured parts separately to avoid any risk to brand image due to product failures in the field.

Option 2:Auction or discount sale

Auctioning generally involves contracting with auction agencies that deal in a particular type of product or service. Discount sales involve offering returned goods at a heavy discount. Care must be taken that discount sales and auctioning do not have an adverse impact on the brand perception of the products.

Option 3: Disassemble and recycle

Recycling returned goods helps to extract and recover raw materials and parts for use in the production of new parts or products. A strong push for recycling comes from regulations like the previously mentioned European Union's WEEE directive. The need to comply with regulations like WEEE and the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) has made recycling the preferred disposition option for many product categories.

Option 4: Redistribute

For assets like containers, pallets, and packaging materials, redistributing—that is, introducing them to the forward supply chain—leads to better asset utilization. Another consideration is that the cost of disposal for these assets can be as high as their purchase price. Research has shown that reusable assets are more economical in the long run even though the purchase price is initially higher than that for one-way counterparts.

Option 5: Donate

Donating returned goods can be appropriate when the handling and transportation costs for other disposal methods will be high and no value will be derived from the sale of the goods. The potential tax savings to be obtained from government and local authorities may also make it an attractive option.

Option 6: Energy generation from waste

Refurbishing and recycling, of course, is not a viable option for food products. A more practical option for disposition of food items is energy generation. Organic waste can be converted to renewable energy through a process called anaerobic digestion. This method of decomposition is a good way to dispose of returned, expired, and recalled food products.

Option 7: "Zero returns" policy

Under this unusual policy, a manufacturer does not accept returned goods. Instead, it incentivizes retailers and distributors with a "return allowance" and provides guidelines for disposition.

Option 8: Landfill/incinerate

Landfill disposal is the simplest option of all but it should be the last resort. Governments around the world have been discouraging landfill disposal for a long time. In Europe, certain types of waste are strictly prohibited in landfills, and companies have to either find alternate means of disposition or treat them before disposal. For food items, landfill disposition is allowed subject to regulatory compliance. Incineration also typically is subject to regulation.

These product disposition strategies are discussed in multiple literatures which depict their popularity across different industries. They are shown in the below table 1 in a comprehensive format.

Table 1. Literature review of disposition strategies

Disposition Strategy	**Authors**
Repair	Talbot *et al.*(2009), Fernandez *et al.*(2008), Gonzalez and Adenso-Diaz(2005), Thierry *et al.*(1995), Kumar and Putnam(2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006), Tien*et al.*(2002), Bras(1997), Ijomah *et al.*(2007), Gehin *et al.*(2008), Ljungberg (2007), Daughetry *et al.*(2001), Srivastava and Srivastava (2006), Hanafi*et al.*(2008), Roy (2000), de Brito and Dekker(2003), Toffel(2004), Guide *et al.*(2000)
Repack	Skinner *et al.*(2008), Prahinski and Kocabasoglu (2006), French and LaForge(2005), Daughetry *et al.*(2001)
Reuse	Talbot *et al.*(2009), Dowie(1994), Gonzalez and Adenso-Diaz (2005), Rogers *et al.*(2002), Aizawa*et al.*(2008), Ferrer(2001), Thierry *et al.*(1995), Kumar and Putnam (2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006), Tien*et al.*(2002),Zuidwijk and Krikke (2008), Veerakamolmal (1999), French and LaForge(2005),Rose and Ishii (1999), Eltayeb *et al.* (2010), Bras(1997), Gehin *et al.*(2008), Ljungberg(2007),Daughetry *et al.*(2001), Hanafi*et al.*(2008), Roy (2000), Carter and Ellram (1998), de Brito and Dekker(2003), Toffel(2004)
Recondition/ Refurbish	Dowie(1994), Skinner *et al.*(2008), Fernandez *et al.*(2008), Rogers *et al.*(2002), Thierry *et al.*(1995), Kumar and Putnam (2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006), Veerakamolmal (1999), Bras(1997), Ijomah *et al.*(2007), Gehin *et al.*(2008), Ljungberg(2007), Daughetry *et al.*(2001), Srivastava and Srivastava (2006), de Brito and Dekker(2003), Toffel(2004)
Remanufacture	Talbot *et al.*(2009), Dowie(1994), Skinner *et al.*(2008), Fernandez *et al.*(2008), Gonzalez and Adenso-Diaz (2005), Rogers *et al.*(2002), Ferrer(2001), Thierry *et al.*(1995), Kumar and Putnam (2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006), Zuidwijk and Krikke (2008), Veerakamolmal (1999), French and LaForge(2005),Rose and Ishii (1999), Eltayeb *et al.* (2010), Bras(1997), Ijomah *et al.*(2007), Gehin *et al.*(2008), Srivastava and Srivastava (2006), Roy (2000), Toffel(2004), Guide *et al.*(2000)

Cannibalize	Fernandez *et al.*(2008), Ferrer(2001), Thierry *et al.*(1995), Prahinski and Kocabasoglu (2006), Gehin *et al.*(2008), de Brito and Dekker(2003)
Recycle	Talbot *et al.*(2009), Dowie(1994), Skinner *et al.*(2008), Fernandez *et al.*(2008), Gonzalez and Adenso-Diaz (2005), Rogers *et al.*(2002), Ferrer(2001), Thierry *et al.*(1995), Kumar and Putnam (2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006),Zuidwijk and Krikke (2008), Veerakamolmal (1999), French and LaForge(2005),Rose and Ishii (1999), Eltayeb *et al.* (2010), Bras(1997), Gehin *et al.*(2008), Ljungberg(2007), Daughetry *et al.*(2001), Srivastava and Srivastava (2006), Roy (2000), Carter and Ellram (1998), de Brito and Dekker(2003), Toffel(2004), Guide *et al.*(2000), Bouzon et al. (2014), Başaran (2012), Anderson and Brodin(2005)
Dispose	Talbot *et al.*(2009), Dowie(1994), Skinner *et al.*(2008), Fernandez *et al.*(2008), Gonzalez and Adenso-Diaz (2005), Rogers *et al.*(2002), Ferrer(2001), Thierry *et al.*(1995), Kumar and Putnam (2008), King *et al.*(2006), Prahinski and Kocabasoglu (2006),French and LaForge(2005),Rose and Ishii (1999), Eltayeb *et al.* (2010), Bras(1997), Ijomah *et al.*(2007), Gehin *et al.*(2008), Ljungberg(2007), Daughetry *et al.*(2001), Srivastava and Srivastava (2006), Roy (2000), Carter and Ellram (1998), Rajgopal and Bansal (2015), Khan et al. (2014)

4. FUZZY TOPSIS Methodology

Selection of one disposition strategy over another should be a function of the financial benefits to be gained as well as of nonfinancial implications, such as brand equity and regulatory compliance. Companies can develop a framework to rank the various disposition strategies and choose the best disposition strategy by examining financial transactions in the reverse supply chain as a profit and loss (P&L) and cash-flow statement, and complementing it with nonfinancial considerations. In addition, this type of framework can help to monitor the performance of the reverse supply chain and identify areas for improvement.

There are various methods used to rank the product disposition strategies. Multiple 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, 2007). The TOPSIS method was developed by Hwang and Yoon (1981) to provide solutions of the MCDM the problems. This method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution, and the farthest from the negative ideal solution. According to Kim *et al.* (1997), four TOPSIS advantages are addressed: (i) a sound logic that represents the rationale of human choice; (ii) a scalar value that accounts for both the best and worst alternatives simultaneously; (iii) a simple computation process that can be easily programmed into a spreadsheet; and (iv) the performance measures of all alternatives on attributes can be visualized on a polyhedron, at least for any two dimensions. These advantages make TOPSIS a major MCDM technique as compared with other related techniques such as analytical hierarchical process (AHP) and ELECTRE. The traditional TOPSIS method assumes ratings and weights of criteria's in crisp numbers. However in many real life scenarios crisp data are inadequate to model real life situation since human judgement are vague and cannot be estimated with exact numeric values. In such situations, the fuzzy set theory is introduced to model the uncertainty of human judgments. Zadeh (1965) first introduced fuzzy set theory into MCDM including TOPSIS as an approach for effectively dealing with the vagueness and ambiguity of the human judgements. In fuzzy TOPSIS all the ratings and weights are defined by means of linguistic variables. Fuzzy sets consider the grey area of data, rather than considering membership of a set to be simply true or false. In other words, fuzzy sets allow partial membership of a set. There are two main characteristics of fuzzy systems that give them better performance for specific applications including fuzzy systems suitability for uncertain or approximate reasoning, and ability of decision-making with estimated values under incomplete or uncertain information(Kahraman *et al.,* 2007). Because of all these advantages fuzzy logic has been combined and used along with TOPSIS, and has resulted in a fuzzy-TOPSIS methodology for prioritizing product disposition strategies. The following steps, based on the technique introduced by Chen*et al.* (1998), 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. A 5-point scale having the linguistic terms low, fairly low, medium, fairly high, and high as shown in Figure 3 are selected for the proposed research.

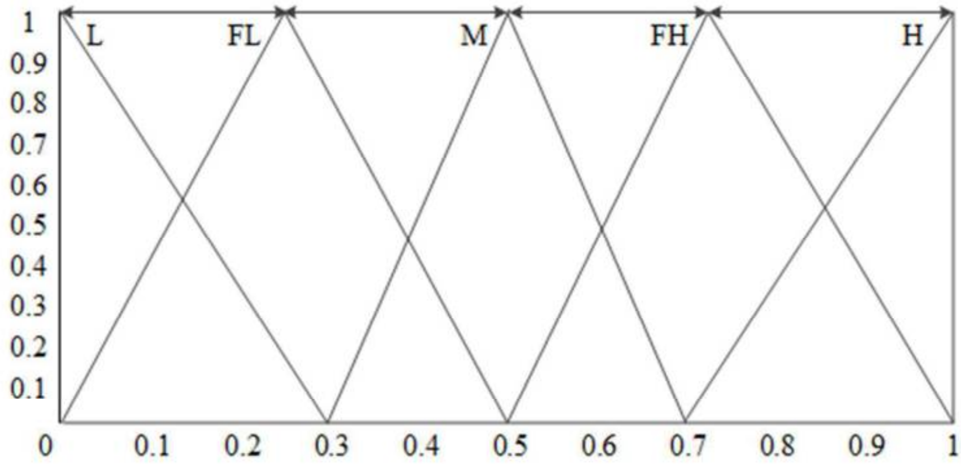

Figure 3. Linguistics scales and triangular fuzzy numbers

The numerical value of each linguistic term is determined with the help of the figure above and are presented in the following table2.

Table 2. Fuzzy scale definition

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

$$D = \begin{bmatrix} x_{12} x_{12} \cdots x_{12} \cdots x_{12} \\ x_{12} x_{12} \cdots x_{12} \cdots x_{12} \\ \cdots \;\; \cdots \; \cdots \; \cdots \; \cdots \; \cdots \\ x_{12} x_{12} \cdots x_{12} \cdots x_{12} \\ \cdots \;\; \cdots \; \cdots \; \cdots \; \cdots \; \cdots \\ x_{12} x_{12} \cdots x_{12} \cdots x_{12} \end{bmatrix} \qquad (1)$$

Where x_{ij} is the score assigned by the i^{th}Ranking (R) to the j^{th}factor.$i = 1,2, \dots\dots\dots, m$are the number of Rankings and $j = 1,2, \dots\dots\dots, n$ are the number of product disposition strategies (PDSs).

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.

$$R = [r_{ij}]_{mXn}, r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) (2)$$

Where $c_j^* = \max_i c$

Step 4: Calculate the weighted normalized decision matrix.

$$V = [v_{ij}]_{mXn}; \ i = 1,2,\ldots\ldots. m; j = 1,2,\ldots\ldots. n \ (3)$$

The weighted normalized value v_{ij} is calculated as

$$v_{ij} = r_{ij} * w_j; \quad (4)$$

where $w_j = (1,1,1) \forall j \in n$, because all the Rankings are considered to have same weight.

Step 5: Determine the ideal and negative-ideal solution for the PDSs.

$$A^* = \{v_1^*, v_2^*, \ldots\ldots. v_n^*\} (5.1)$$
$$A^- = \{v_1^-, v_2^-, \ldots\ldots. v_n^-\} (5.2)$$

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

$$v_j^* = (1,1,1) (6.1)$$
$$v_j^- = (0,0,0) \quad (6.2)$$

Step 6: Calculate the sum of distances from positive and negative ideal solution for each factor.

$$D_j^* = \frac{\sqrt{\sum_{i=1}^{m} d(v_{ij} - v_i^*)}}{m}, j = 1,2,\ldots\ldots. n \ (7.1)$$

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

$$D_j^- = \frac{\sqrt{\sum_{i=1}^{m} d(v_{ij} - v_i^-)}}{m}, \quad j = 1,2,\ldots\ldots. n \ (7.2)$$

Step 7: Calculate the relative closeness to the ideal solution. The relative closeness with respect to A* is defined as

$$C_j = D_j^- / (D_j^* + D_j^-), j = 1,2,3 \ldots\ldots\ldots. n \quad (8)$$

Step 8: Rank the preference order based on the order of the values of C_j

5. Case Illustration

A cell phone manufacturing firm is considered for the illustration of the proposed methodology. A cell phone manufacturing firm is considered because of growing volume and concern for huge generation of e-waste at the end of life of these products. The firm, ABC Limited is leading manufacturer of cell phones in India and abroad. The firm, ABC Limited became the world leader in the manufacturing and sales of cell phones by 1998. The firm focused on growth through adopation of cutting edge technology, and excellent supply chain activities from procurement of parts and componets to manufacturing to optimized salses and distribution. The firm has established manufacturing units throughout the world including one in NCR Delhi, India and has more than 10,000 employees. The ABC Limited has service centres, distributrs and dealers in most of the major cities in the country including Delhi, Mumbai, Chennai, Bangalore and so on. The firm manages their reverse supply chain well through collection of returned products by using their supply chain network. The firm also manages their product returns through e-retailors including amazon, and flipkarts. The firm has become more conscious on returned products because of institution of e-waste management rules and regulations by government of India. The firm has major issue of disposition of returned cell phones after their collection. The study is carryout to help the firm for exporing various disposition strategies and prioritizing them with the help of fuzzy-TOPSIS methodology. Based of literature review, disoposition strategies discussed above were selected for the study. Three respoondents from the firm were selected based on their expertise and experience relevant to this study.

The first respondant (R1), also having responsibility of reverse logistics is a supply chain manager in the firm, ABC limited. He has 10 years of experience in sales and distribution of cell phones. The respondant manages return of products in the firm through supply network of the firm and will play crucial role in the disposition of returned cell phones. The second respondent (R2), having experience of 8 years is resource manager in the firm who manages all the reousrces in the firm including procurement of parts. He is keenly intested in reverse supply chain in order to utilization of return products optimally for the benefits of the company. The third respondant (R3) is vice president (operations) managing overall operations of the firm. He has multi-functional experience of procurement, manufacturing, and distribution of cell phones of the firm.

6. Results and Discussion

In order to prioritize the factors for reverse logistics implementation, eightproduct disposition strategy factors were identified for reverse logistics. These factors are PDS1: Refurbish/repair/remanufacture, PDS2: Auction or discount sale, PDS3: Disassemble and recycle, PDS4: Redistribute, PDS5: Donate, PDS6: Energy generation from waste, PDS7: "Zero returns" policy, PDS8: Landfill/incinerate. These factors were ranked on the basis of their financial and non-financial implications in the long term. Three rankings (R1, R2, R3) based on secondary research across industries where reverse supply chain plays a crucial part and their relative popularity across literatures. These were used to rate the importance of the above mentioned product disposition strategieson a 5-point scale having the linguistic terms low (L), fairly low (FL), medium (M), fairly high (FH), and high (H).The rankings used the linguistic variables as shown in Table 2 to assess the importance of the product disposition strategies. A decision matrix was prepared based on the responses received from the respondants as shown in the table 3.

Table 3.Decision matrix using linguistic variable

PDSs for reverse logistics implementation	R1	R2	R3
PDS1: Refurbish/repair/remanufacture	FH	FH	FH
PDS2: Auction or discount sale	M	FH	M
PDS3: Disassemble and recycle	H	H	H
PDS4: Redistribute	FH	H	FH
PDS5: Donate	M	M	FL
PDS6: Energy generation from waste	M	FH	FH
PDS7: "Zero returns" policy	M	M	M
PDS8: Landfill/incinerate	L	FL	L

As mentioned in the fuzzy-TOPSIS methodology step 1, triangular fuzzy numbers were used to convert linguistics variable into the fuzzy numbers. By converting the fuzzy linguistic variables into triangular fuzzy membership numbers using table 2, the fuzzy decision matrix D was obtained. In the next step fuzz un-weighted fuzzy decision matrix R was enumerated. Further steps were followed to obtain the weighted normalized decision matrix, shown in table 4 to find the ideal and negative-ideal solutions for the PDSs.

Table 4. Fuzzy weighted normalized decision matrix

PDSs for reverse logistics implementation	R1	R2	R3
PDS1: Refurbish/repair/remanufacture	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
PDS2: Auction or discount sale	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.3,0.5,0.7)

PDS3: Disassemble and recycle	(0.7,0.9,1.0)	(0.7,0.9,1.0)	(0.7,0.9,1.0)
PDS4: Redistribute	(0.5,0.7,0.9)	(0.7,0.9,1.0)	(0.5,0.7,0.9)
PDS5: Donate	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)
PDS6: Energy generation from waste	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
PDS7: "Zero returns" policy	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)
PDS8: Landfill/incinerate	(0.0,0.1,0.3)	(0.1,0.3,0.5)	(0.0,0.1,0.3)

The distance D^{-} and D^{*} of each PDS is derived, respectively, by using equations (6.1), (6.2), (7.1), and (7.2). The closeness coefficient C for each PDS obtained using equation (8). The final results obtained by proposed fuzzy TOPSIS methodology are shown in Table 5.

Table 5. Closeness coefficient matrix

PDSs for reverse logistics implementation	D*	D^{-}	C	Rank
PDS1: Refurbish/repair/remanufacture	0.341	0.718	0.678	3
PDS2: Auction or discount sale	0.473	0.597	0.556	5
PDS3: Disassemble and recycle	0.183	0.876	0.827	1
PDS4: Redistribute	0.298	0.775	0.722	2
PDS5: Donate	0.597	0.473	0.442	7
PDS6: Energy generation from waste	0.412	0.661	0.616	4
PDS7: "Zero returns" policy	0.526	0.526	0.500	6
PDS8: Landfill/incinerate	0.827	0.247	0.230	8

According to the analysis, the most PDS among the eightPDSs is PDS3 (Disassemble and recycle) and least PDS is PDS8(Landfill/incinerate). The overall ranking of PDSs is:

PDS3> PDS4> PDS1> PDS6> PDS2> PDS7> PDS5> PDS8

PDS3, Disassemble and recycle has the highest value and is ranked as the top most factor.Disassembling and recycling gets a much stronger push from corporates because of the regulatory compliances and recycling electronic products, for instance, makes economic sense because the cost of extraction of rare earth metals from electronic waste is less than that for mining. PDS4, Redistribute is ranked as 2nd most important PDS. Redistributing products, that is, introducing them to the forward supply chain leads to better asset utilization. Sometimes goods are returned due to delivery overages, or they may be unsold or discontinued items. In such cases, it makes sense to redirect the shipments to other geographical areas where they might be consumed.PDS1, Refurbish/repair/remanufacture is ranked 3rd and is very crucial for reverse logistics implementation. In some industry sectors, this disposition option has become a huge market in itself. For instance, the automobile industry sells a wide range of remanufactured automotive components, including engines, clutches, gearboxes, fuel injectors, and other products, in the automotive aftermarket. PDS6, Energy generation from waste is ranked 4th. The financial driver for selecting this option would be the monetary value of energy generated or the utility costs that can be offset compared with the cost of transportation, handling, administration, and running the waste-to-energy plant.PDS2, Auction or discount sale is ranked 5th.A number of companies specialize in auctions and discount sales, providing online marketplaces to sell surplus, salvaged, and returned goods. PDS7, "Zero returns" policyis ranked 6th. There are some potential nonfinancial pitfalls associated with this option. Retailers might sell returned goods through another channel, diluting the products' brand image. In addition, the manufacturer may incur some legal liability if the retailer improperly disposes of the product.PDS5, Donate is ranked 7th and this is one of the easiest disposition strategy to implement in view of operational performance of reverse logistics implementation. PDS8, Landfill/incinerate is the last resort for product disposition. Regulatory restrictions represent a strong nonfinancial driver that discourages companies from taking the landfill or incineration route for their returns. These prioritization of disposition strategies will provide base for disposition products appropriately for the performance of reverse supply chain. Improved performance of reverse logistics contributes to the triple botton line sustainability performance of an organization (Svensson and Wagner, 2015). These findings may help managers in disposition decision making for improving their reverse logistics performance.

7. Conclusion

This paper identifies the key impact areas of the reverse supply chain for supply chain executives to focus upon by studying the driving forces for reverse supply chains as well as the barriers for effective implementation of reverse supply chains. This knowledge serves as a guide for choosing the right disposition strategy for products across industries. Choosing the right disposition strategy provides an opportunity to improve business efficiency at a time when the marginal cost of improvement in forward supply chain operations has been rising. Effective returns management offers various sources of revenue from auctions, refurbishments, recycling, and more. The reverse supply chain, offers a wealth of actionable intelligence that can be employed to improve product design, process design, and operations. In order to improve the efficiency of a reverse supply chain and address market and non-market drivers, a company has to understand which areas of its business are affected by returns and recycling, and where it should therefore be focusing its efforts. Depending on the type of product involved, several disposition options, such as auctions, donations, redistribution, repair, refurbishment, recycling, incineration, landfill disposal, and energy generation can be chosen in parts or as a whole. By making wise disposition choices and routing the returns accordingly, the reverse supply chain can be transformed from a cost center to a revenue source. The gate-keeping choice, (who handles returned goods, and in what manner) identified by Lambert *et al.* (2011) is dictated by both financial considerations and nonfinancial considerations like regulations and brand equity.

This study is conducted by prioritizing the product disposition strategies using three rankings based on secondary research across industries where reverse supply chain plays a crucial part. Future studies must consider larger sample size to assess the methodology and the effectiveness of the proposed solution to enable generalization. Furthermore, the wider rating of the 7 or 11-point linguistic scale could be used instead of using a 5-point linguistics scale.

Thus to conclude, we can say that reverse logistics is in focus worldwide because of its inherent advantages of reuse/recycle of materials and products. Manufacturing companies mostly in developed countries implement reverse logistics practices to gain competitive advantage and to meet regulatory requirements of their respective country. Developing countries like India has also enforced regulatory requirements recently. It's relatively new for Indian industry and limited studies are available for reverse logistics practices in Indian context. The research paper will help the Indian industries to develop reverse a logistics model and prioritize the product disposition strategies based on financial and non-financial considerations. It should also help convince organizations that the reverse supply chain is indeed a profit center that can provide a competitive edge and hence deserves close attention. Indeed, with the Extended Producer Responsibility principle swiftly gaining ground worldwide, growing competition, and evolving business conditions, ignoring the reverse supply chain will no longer be an option in the near future. Companies that address the reverse supply chain in a holistic way will not only gain business efficiencies but also competitive advantages.

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