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Identification of critical factors for the implementation of reverse logistics in the manufacturing industry of Pakistan

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Abstract

Purpose – The purpose of this research is to identify major barriers to the implementation of reverse logistics (RL). Also, the study addresses best practices among reuse, remanufacture, recycling, refurbishment and repair as alternatives for RL processes.

Design/methodology/approach – This study targets supply chain management experts for their opinions regarding the identification of critical barriers and alternatives for RL implementation. Their opinions were extracted through a Web questionnaire based on 14 criteria with 5 alternatives. The tools of multi-criteria decision-making are used for analysis, i.e. fuzzy VIKOR and fuzzy TOPSIS.

Findings – The results indicate that lack of recognition of competitive advantage to be gained through RL practice is the most critical barrier to RL implementation. The least barrier or major facilitator for RL is "supportive initiative for end-of-life products." The top-ranked alternative in this study is reuse followed by remanufacturing. The least important alternative is "repair" in the case of Pakistan. These alternatives are ranked based on "*q* values" derived through fuzzy VIKOR.

Research limitations/implications – The results of this study can only be generalized for the manufacturing sector of Pakistan during the period of the study.

Practical implications – The findings of this study will assist managers in deploying the best practices concerning RL.

Originality/value – Fuzzy VIKOR and fuzzy TOPSIS have not been applied to RL alternatives in previous research.

Keywords Fuzzy TOPSIS, Fuzzy VIKOR, Manufacturing sector, Pakistan, Reverse logistics, Fuzzy set theory, MCDM

Paper type Research paper

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1. Introduction

In today's manufacturing world, mega-competition on the global scale has led to radical transformations in supply chains. Over the past few years, the community of supply chain management researchers and practitioners has given increasing importance to reverse logistics (RL). The academic literature in marketing and supply chain has given substantial attention to RL, as it reflects the channel distribution ability of a firm (Horvath *et al.*, 2005). For both firms and their suppliers, RL has major cost implications in the supply chain (Daugherty *et al.*, 2005). To remain competitive, it has become necessary for many firms to adopt RL practices in their supply chains.

There are very few empirical studies related to the reverse flow of products in a supply chain, despite the due consideration given to RL by both practitioners and researchers (Srivastava and Srivastava, 2006). In recent practice, RL is being adopted for strategic reasons by many manufacturing companies. These reasons include to improve the corporate social image and to gain the economic benefits of RL (Govindan *et al.*, 2015). In the best circumstances, the implementation of RL may lead to reduced operational costs and higher sales revenue. However, many barriers limit RL implementation. These barriers include difficulty with supply chain members, lack of the necessary technical skills and uncertain profitability (Subramanian and Ramanathan, 2012). Thus, there is a need to collect information on the barriers to RL, and how to overcome them, from practitioners.

Pakistan has a developing economy with great potential to grow. It is currently the 13th largest manufacturing country in the world. About 20% of the gross domestic product (GDP) comes from the manufacturing sector. The sector has registered a 3.4% average annual growth from 2011 to 2016. In 2012, the large-scale manufacturing sector in Pakistan grew by 2% and small-scale manufacturing (SME) grew by 8% [1].

Despite its environmental and economic relevance in developing countries, limited research has been conducted on RL. The available theory and literature on the implementation and management of RL are limited, although the concept is gaining popularity in practice. In the majority of developing countries, manufacturers ignore RL. This appears to be driven by more focus on changes in functional priorities, the minimal interest of top management and insufficient commitment (Gunasekaran and Ngai, 2012). Issues related to damaged goods and quality problems present substantial challenges for RL processes. This is reflected in the design of RL networks, where quantity, quality and arrival time of returns are of paramount importance (Srivastava and Srivastava, 2006). The practices of RL vary from company to company and by channel position within the supply chain. In developed countries, more elaborate RL systems exist because of a greater ability to recover value from returned products. However, RL is used less in developing countries because of several barriers. This appears to be the case in Pakistan, with RL underused compared to its prevalence in developed countries.

In alignment with the abovementioned discussion, the objective of this research is to provide critical insights and determine the most critical barriers to the implementation of RL in the case of Pakistan. The second objective of this study is to determine the best alternative for RL implementation to overcome these barriers. To address the mentioned objectives, this research uses multi-criteria decision-making (MCDM) techniques, i.e. fuzzy VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) and fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). Manufacturing technique for order performance companies in Pakistan have apparently not overcome the barriers that hinder the implementation of RL. This may be because of a lack of knowledge about strategies and practices that support the use of RL. To support broader adoption of RL in Pakistan, this study tries to identify the most critical barriers and best alternative practices for RL implementation.

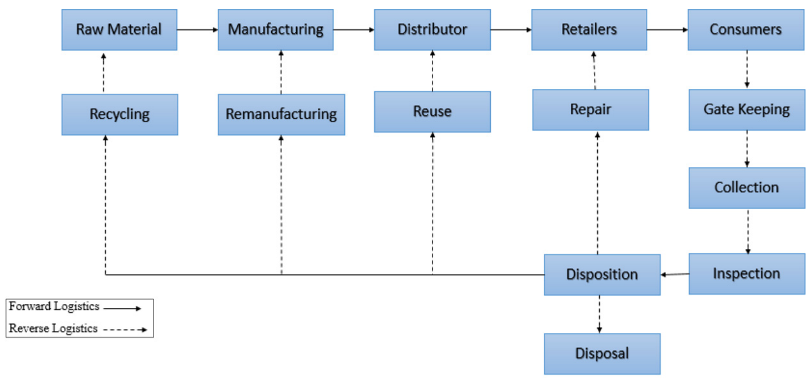
The rest of this paper is organized as follows: Section 2 reviews the related literature on RL; Sections 3 and 4 describe the research methodology including a comparison of fuzzy VIKOR and fuzzy TOPSIS; Section 5 presents the results and discussion of the research; and finally, Sections 6 and 7 describe conclusions and directions for future research.

2. Literature review

The practice of RL has evolved over time and its definition has changed accordingly in the research literature. The earliest definition of RL describes it as a reverse flow of goods (Murphy and Poist, 1989). As RL developed, environmental concepts were added to its definition (Carter and Ellram, 1998). After this refinement, it was defined as the cost-effective flow of finished goods from the point of consumption to the point of origin for recapturing value or disposal through effective planning (Rogers and Tibben-Lembke, 1999a). The concept of RL deals with the collection and transportation of used products and packages (Mutha and Pokharel, 2009). Researchers have characterized the process of RL by subordinate processes of collection, inspection, reprocessing, disposal and re-distribution of products (Fleischmann *et al.*, 2000). These key processes involved in RL are depicted in Figure 1.

RL processes begin where forward logistics end. The first step in RL acquires used products from the end customer (Guide and Van Wassenhove, 2001). After the acquisition process, the used products are delivered to different facilities for inspection, sorting and disposition (Fleischmann *et al.*, 2003). For the collection of the used products, three methods have been defined in scholarly studies. These methods include collection from retailers, collection from end customers and collection by a third-party logistics provider (Kumar and Putnam, 2008). After the collection process, the used products are sorted into categories through an inspection process. The outcome of the sorting mostly depends on factors like the cost of transportation, disposal, dismantling and quality of the product (Zikopoulos and Tagaras, 2007). For the disposition process, three alternatives are adopted, i.e. recovery of product, reuse and waste management (Thierry *et al.*, 1995). These three alternatives are constantly in flux because of evolving technological developments. They currently include upgrading of products, recovery of materials and advanced waste treatment practices (Krikke, 2011). Effective implementation of RL processes can reduce costs of operations, enhance revenue and thus generate additional profits (Poist, 2000).

However, there is a high level of uncertainty in planning, forecasting, allocation of capacity and resources for handling and controlling the reverse flows in a supply chain



Source: Fleischmann et al. (2000)

Figure 1. Basic flow of reverse and forward logistics

(Tibben-Lembke and Rogers, 2002). Products can have different lifecycles and varying replacement policies based on the user. This can lead to systematic variation and uncertainty in the volume of returned items over time. Moreover, RL flows from many origins to one destination, whereas the converse is true for forward logistics flows. This type of difference between forward and RL makes it difficult to integrate both into a single supply chain (Fleischmann *et al.*, 1997). There are other differences between forward and RL that make their integration difficult. A number of these differences are summarized in Table 1.

Because of shorter product life cycles and an increase in the use of consignment inventory, RL has become a necessity for companies. Furthermore, there is an increasing trend of returning products from customers that has made the use of RL more advantageous (Daugherty *et al.*, 2001). Therefore, due concentration is given to RL as a strategic capability not only to improve profit directly but also to enhance the level of customer satisfaction (Richey *et al.*, 2004). Moreover, firms with larger volumes of returning products are left with no choice but to consider RL processes (Stock and Mulki, 2009). However, in RL processes, retail managers often play a vital role in determining the cost-saving procedures for returned products, which in turn determines the efficiency of the overall RL system (Horvath *et al.*, 2005).

Globalization in the most recent decade brought access to knowledge, capital and technology from developed countries to the least developed countries. However, despite accelerating economic growth, RL is still at an early stage of maturity in these countries (Hung Lau and Wang, 2009). Despite the vital importance of RL, the literature on it is very limited, especially in the manufacturing area (Somuyiwa and Adebayo, 2014). However, some studies on RL in developing countries do exist. For instance, one study of RL is mainly focused on developing countries including India and Malaysia (Sharma *et al.*, 2011). Moreover, Oleveira *et al.* (2019) investigates major barriers in circular economy supply chains of expanded polystyrene packaging from a Brazilian perspective. These findings highlighted the major components of efficient reverse logistic strategies in polystyrene recycling in Brazil. Lamba *et al.* (2019) uses fuzzy analytic hierarchy process to prioritize barriers in RL in an e-commerce

Table 1. Generalized form of the difference between the process of forwarding and reverse logistics

Forward logistics	Reverse logistics
The quality of the product is uniform	The quality of the product is not uniform
The option for disposition of a product is clear	The option for disposition of a product is not clear
Product routing in unambiguous	Product routing is ambiguous
Different points at which cost is involved is easily understood	Different points at which cost is involved is not easily understood
The distribution channels are standardized	The distribution channels are exception driven
Products are packaged in a uniform process	Often the product packaging is damaged
The process of pricing product is uniform	The process of pricing product is not uniform
The management of inventory is consistent	The management of inventory is not consistent
The life cycle of a product is easily manageable	The life cycle of the product in this process is less likely to be managed
Issues related to financial management are visible and clear	Issues related to financial management are not clear
The type of involvement of negotiation between different parties is straightforward	The type of involvement of negotiation between different parties is less straightforward
Forecasting is done in the simplest way	Forecasting for RL process is much more difficult
Transportation involved is one way	Transportation involved from many to only one
The visibility of the process is highly transparent	The visibility of the process is much less transparent

Source: Tibben-Lembke and Rogers (2002) supply chain. These results emphasize that a lack of investment and a lack of understanding of different practices are substantial barriers to RL implementation in e-commerce. Phochanikorn *et al.* (2019) uses fuzzy MCDM to analyze barriers to RL in the palm oil industry in Thailand. This analysis resulted in flexible decision strategies for both the short- and long term.

Research related to RL seems to have been largely ignored in Pakistan. Pakistan has a developing economy, with the manufacturing sector having substantial importance. In 2011, manufacturing contributed about 15% to Pakistan's GDP (World Bank Report, 2012) [2]. According to the Ministry of Commerce of Pakistan, in the year 2012, the major manufacturing industries of Pakistan are textiles, chemicals, machinery and tobacco [3]. The manufacturing sector of the country is expected to grow at 6.2% as compared to the year 2016–2017 [4], which was 5.8%. The growth rate of various manufacturing sectors for the year 2016–2017 is given in Table 2.

Practices related to green manufacturing and green supply chains are being implemented in China through legislation. However, there is also pressure from the customer side as stakeholders (Huang *et al.*, 2013). Different barriers have been identified for RL implementation in developing countries. These are lack of government laws and regulating authority (Bouzon *et al.*, 2015a; Hung Lau and Wang, 2009); lack of public awareness of environmental issues (Kannan *et al.*, 2014); resource scarcity, lack of leadership awareness of financial and economic gains (Eltayeb *et al.*, 2011); a limited number of markets and end of life (EOL) recovery issues (Rahimifard *et al.*, 2009).

A research study conducted in Greece concluded that the main barriers to RL systems are complications arising in a company's operation through RL and lack of economic justification for investment (Kapetanopoulou and Tagaras, 2011). The major impediments highlighted for the automobile industry are the lack of supply chain coordination and integration. Likewise, in Bernon *et al.* (2013) managers' resistance to change, incompatibility of Information Technology (IT) systems and the lack of willingness to share cost information are identified as major roadblocks for product return. Similarly, Abdulrahman *et al.* (2014) found impediments because of an inability to acquire a monitoring system for returns, low commitment and absence of RL expertise. The research in the automotive industry shows that lack of expertise, the minimal interest of top management, high cost in financial and human resources and the lack of technological systems are the main barriers at the internal level. Whereas, the reluctance of social actors, perception of poor quality products, government and competitor reluctance are some of the obstacles at the external level (González-Torre *et al.*, 2010).

Developed areas such as the USA, Europe and Japan have implemented refined concepts for RL, whereas developing countries practice it at a minor level. According to Locke and Golden-Biddle (1997), the existing social convention can be used to derive specific queries

Industry	Growth rate (%)
Iron and steel	20.48
Electronics	17.02
Food, beverages and tobacco	11.49
Automobiles	11.22
Pharmaceuticals	9.19
Paper and board products	7.18
Nonmetallic mineral products	4.44
Engineering products	4
Coke and petroleum products	2.79
Fertilizers	1.66
Textile	0.81

Table 2. Large-scale manufacturers' growth rate by industry-specific data (the year 2016–2017) [8]

related to any research with aid of the establishment of grounded theory and from these results novel concepts can be introduced (Locke and Golden-Biddle, 1997). A few research studies in China, India and Brazil have investigated factors affecting practices of RL (Hung Lau and Wang, 2009; Erol *et al.*, 2010; Sajan and Sridharan, 2015). However, in our research, we found no prior research in the case of Pakistan regarding barriers to RL implementation. Therefore, this study covers the literature gap regarding the barriers to implementation of RL through MCDM techniques in the case of Pakistan.

MCDM techniques are applied in many domains to solve important problems (Elomda *et al.*, 2013; Ali *et al.*, 2020a, 2020b). In the last few decades, MCDM techniques have become an important branch of operation research (Figueira *et al.*, 2004; Babar *et al.*, 2020). MCDM techniques have enabled decision-makers in the present era to make effective models and decisions in uncertain situations (Nădăban *et al.*, 2016; Ali *et al.*, 2019a, 2019b).

A well-known technique for MCDM is "technique for order performance to ideal solution" (TOPSIS) that was first proposed by Hwang and Yoon (Hwang and Yoon, 1981). The simple TOPSIS technique deals with the principle of selecting an alternative from a positive and negative ideal solution (Yavuz, 2016; Khan *et al.*, 2020). TOPSIS has been used in a fuzzy environment using triangular fuzzy numbers (Chen, 2000). VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR) is a tool for MCDM used for decision-making problems that contain criteria that conflict with each other (Opricovic, 1998). The choice of an alternative using VIKOR is determined through a ranking index, i.e. closeness to the ideal solution. The first paper in which VIKOR is used as a methodological tool was published in 2002 (Chang, 2014; Ali *et al.*, 2019a, 2019b).

In this paper, we discuss barriers to the implementation of RL and the most feasible alternatives to overcome this problem for the manufacturing sector of Pakistan. The five alternatives that have been chosen for this study are reuse, remanufacturing, refurbishment, recycle and repair. We identify 14 criteria related to RL barriers. Some of the barriers are lack of IT system standards, lack of personnel technical skills, low recognition of competitive advantage through RL, lack of expert at the management level and lower waste management practices. Likewise, poor relations with suppliers, inconsistent quality of raw materials and uncertainty related to economic issues posed some challenges to a manufacturing organization to adapt the practice of RL. Also, in most of the developing countries, there is rarely any awareness at a public level about RL practices. In addition, there are few initiatives for EOL products. These are some of the barriers that will be used as criteria in this study. Finally, because of these multiple criteria and multiple alternatives, MCDM approaches such as fuzzy VIKOR and fuzzy TOPSIS are appropriate methods to interpret and analyze the data.

3. Data collection and research methodology

In this section, the methodology used, i.e. fuzzy VIKOR and fuzzy TOPSIS techniques are briefly discussed. In addition, we briefly summarize our data collection process.

3.1 Data collection

A web-based questionnaire was created for data collection, which was then distributed among thirty experts. The first part of the questionnaire comprised demographic questions and the second part consisted of assigning weights to different criteria affecting RL practices based on the expert's opinion. The final part of the questionnaire consisted of rating the different alternatives against the proposed criteria based on the expert's opinion. A seven-point scale of linguistics variables was used for criteria evaluation. Barriers were used as criteria against each alternative (negative attributes) and respondents were asked to choose the most important alternative in terms of having a low barrier toward its implementation. There were a total of five alternatives ranked based on 14 criteria with priority set by participants in a rating form.

Twenty participants were supply chain and logistics managers, working in the different manufacturing sectors of Pakistan, i.e. English biscuits manufacturer, Qarshi Group of Industries, Bestway group, Engro fertilizers, etc. Most of the respondents belonged to medium and large-scale industries of Pakistan. Ten participants were related to well-reputed academic institutes, i.e. Lahore University of Management Sciences, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, National University of Science and Technology, etc. For each academic expert, a minimum threshold of five years teaching experience with three international publications was set, whereas for industrial professionals, five years of professional experience was the threshold. The technique used is discussed briefly below.

3.2 Fuzzy TOPSIS

TOPSIS is extended to the fuzzy environment for group decision-making. The linguistic variables used for rating and weighting of criteria are given in Tables 3 and 4.

TOPSIS under the fuzzy environment can be calculated through the following steps (Ali *et al.*, 2020a, 2020b):

Step 1: The committee of decision-makers is formed. The evaluation criteria are described to the participants. The group members will make decisions based on the criteria given. The opinion of experts was collected through a questionnaire. Define Z as the number of experts, n as the number of alternatives and m as the number of criteria.

Step 2: To find weights of each criterion and rating of alternative against each criterion, select appropriate linguistic variables. Weight will be assigned to the responses obtained from decision-makers. Define $\tilde{y}_{ij}^{k}$ as the fuzzy rating for the ith alternative, in the jth criteria assigned by the kth decision-maker. Define $\tilde{w}_{j}^{k}$ as the fuzzy weight assigned to the jth

Linguistic variables	Weights
Very low (VL)	(0,0,0.1)
Low (L)	(0,0.1,0.3)
Medium low (ML)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium high (MH)	(0.5,0.7,0.9)
High (H)	(0.7,0.9,1.0)
Very high (VH)	(0.9,1.0,1.0)

Table 3. Importance of weight for linguistic variables

Linguistics variables	Rating
Very poor (VP)	(0,0,1)
Poor (P)	(0,1,3)
Medium poor (MP)	(1,3,5)
Fair (F)	(3,5,7)
Medium good (MG)	(5,7,9)
Good (G)	(7,9,10)
Very good (VG)	(9,10,10)

Table 4. Ratings for linguistic variables

criteria by the kth decision-maker. The overall fuzzy criteria weights $\tilde{w}_j$ and alternative ratings $\tilde{y}_{ij}$ can be calculated as follows:

$$\tilde{y}_{ij} = \frac{1}{Z}\left(\tilde{y}_{ij}^{1} \oplus \tilde{y}_{ij}^{2} \oplus \ldots \oplus \tilde{y}_{ij}^{k} \oplus \ldots \oplus \tilde{y}_{ij}^{Z}\right) \tag{1}$$

$$\tilde{w}_j = \frac{1}{Z}\left(\tilde{w}_j^{1} \oplus \tilde{w}_j^{2} \oplus \ldots \oplus \tilde{w}_j^{k} \oplus \ldots \oplus \tilde{w}_j^{Z}\right) \tag{2}$$

Step 3: Construct a fuzzy decision matrix. In matrix format, a fuzzy multi-criteria group decision-making problem can be expressed through $\tilde{D}$ and $\tilde{w}$:

$$\tilde{D} = \begin{bmatrix} \tilde{y}_{11} & \cdots & \tilde{y}_{1n} \\ \vdots & \vdots & \vdots \\ \tilde{y}_{m1} & \cdots & \tilde{y}_{mn} \end{bmatrix}$$

$$\tilde{w} = [\tilde{w}_1,\ \tilde{w}_2,\ \ldots,\ \tilde{w}_n]$$

Triangular fuzzy numbers describe these linguistics variables as $\tilde{y}_{ij} = \left(a_{ij},\ b_{ij},\ c_{ij}\right)$ and $\tilde{w}_j = \ (w_{j1},\ w_{j2},\ w_{j3})$.

Step 4: The normalized fuzzy decision matrix is constructed from the fuzzy decision matrix defined in the above step. The equation is given below:

$$R = \left[\tilde{r}_{ij}\right]_{\mathrm{m}\times\mathrm{n}}$$

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*},\ \frac{b_{ij}}{c_j^*},\ \frac{c_{ij}}{c_j^*}\right)$$

where $c_j^* = \ \max_i c_{ij}$

Step 5: The next step is to calculate a weighted normalized fuzzy decision matrix through the equation given below:

$$\tilde{U}_{ij} = {}_{\left[\tilde{w}_j \times \tilde{r}_{ij}\right]\mathrm{m}\times\mathrm{n}}$$
$$i = 1, \ldots, m; j = 1, \ldots, n;$$

Step 6: When all the abovementioned calculations are performed, determine the fuzzy positive ideal solution as F^* and fuzzy negative ideal solution as F^-. F^* and F^- can be defined as follows:

$$F^* = \ \tilde{u}_1^*,\ \tilde{u}_2^*,\ \ldots,\ \tilde{u}_n^*$$

$$F^- = \ \tilde{u}_1^-,\ \tilde{u}_2^-,\ \ldots,\ \tilde{u}_n^-$$

The value of $\tilde{u}_j^* = (1,1,1)$ and $\tilde{u}_j^- = (0,0,0),\ j = (1,2,\ldots,\ n)$.

Step 7: In this step, the distance from the positive and negative ideal solution will be determined as follows:

$$S_i \text{ steric} = \sum_{j=1}^{n} s\left(\tilde{u}_{ij},\ \tilde{u}_j^*\right)$$

$$S_i \text{ negative} = \sum_{j=1}^{n} s\left(\tilde{u}_{ij},\ \tilde{u}_j^-\right)$$

"*s*()" is used to denote the distance between two fuzzy numbers.

Step 8: The closeness coefficient CC_i is calculated for each alternative *i* as follows:

$$CC_i = \frac{S_i \quad \text{negative}}{S_i \quad \text{steric} + S_i \quad \text{negative}} \tag{3}$$

Step 9: Based on the closeness coefficient values, choose the alternative having the highest CC_i value.

3.3 Fuzzy VIKOR

Using the VIKOR method under a fuzzy environment, the barriers toward implementation of RL can be evaluated. Steps involved in the calculation of fuzzy VIKOR are (Razi and Ali, 2018; Awan and Ali, 2019) as follws:

Steps 1–3: Similar to Steps 1–3 above, using input from experts, the decision matrix $\tilde{D}$ and weight vector $\tilde{w}$ are developed:

$$\tilde{D} = \begin{bmatrix} \tilde{y}_{11} & \cdots & \tilde{y}_{1n} \\ \vdots & \vdots & \vdots \\ \tilde{y}_{m1} & \cdots & \tilde{y}_{mn} \end{bmatrix} \tilde{w} = [\tilde{w}_1,\ \tilde{w}_2,\ \ldots,\ \tilde{w}_n]$$

where $i = 1, \ldots, m; j = 1, \ldots, n$.

Step 4: Use the BNP_i formula to convert each fuzzy weight and rating into crisp values. The equation is given below:

$$BNP_i = \frac{[(c_i - a_i) + (b_i - a_i)]}{3} + a_i, \quad i = 1, \ldots, m \tag{4}$$

Step 5: For all criterion rating, determine the best crisp value f_j^* and f_j^- by using the relation given below:

$$f_j^* = \begin{Bmatrix} \max_i E_{ij}, & \text{for benefit criteria} \\ \min_i E_{ij}, & \text{for cost criteria} \end{Bmatrix}$$

$$f_j^- = \begin{Bmatrix} \min_i E_{ij}, & \textit{for benefit criteria} \\ \max_i E_{ij}, & \textit{for cost criteria} \end{Bmatrix}$$

Step 6: S_i and R_i, the separation from fuzzy values, can be calculated as follows:

$$S_i \; = \sum_{j=1}^{n} \cdot \frac{\tilde{w}_j^* \left(f_j^* - E_{ij}\right)}{f_j^* - f_j^-} \tag{5}$$

$$R_i = \max_j \frac{\tilde{w}_j^* \left(f_j^* - E_{ij}\right)}{f_j^* - f_j^-} \tag{6}$$

Step 7: In this step, the value of Q_i will be determined using the following relation:

$$Q_i = \frac{v\left(S_i - S^*\right)}{\left(S^- - S^*\right)} + \frac{(1-v)\left(R_i - R^*\right)}{\left(R^- - R^*\right)} \tag{7}$$

where S^* represents the minimum value of S_i, whereas S^- represents the maximum value of S_i. R^* represents minimum, whereas R^- represents the maximum value of R_i. The value of v is 0.5, which is a weight for maximum group utility.

Step 8: Select the best alternative as a compromise solution after ranking the alternatives by sorting each S, R and Q value in ascending orders.

4. Problem with fuzzy TOPSIS

Both fuzzy VIKOR and fuzzy TOPSIS provide a ranking list. The VIKOR-based solution is considered as most feasible compared to the TOPSIS method because TOPSIS does not consider the relative importance of ideal solution distance (Zhang and Wei, 2013). Furthermore, fuzzy VIKOR is also preferred over TOPSIS because a compromise solution is given by it that provides an advantage over TOPSIS (Opricovic and Tzeng, 2004). Moreover, VIKOR considers the interrelation, whereas TOPSIS does not. The percentage of the problem solved is decreased when the number of criteria is increased as shown in earlier studies. Recent research uses fuzzy TOPSIS when comparing results with VIKOR, but it suggested that if the number of criteria increases, then the most preferred technique will be fuzzy VIKOR (Razi and Ali, 2018).

So, based on the abovementioned studies, we concluded that the fuzzy VIKOR approach is much more suitable as compared to TOPSIS. The results and discussions that follow are based on the findings from the fuzzy VIKOR approach. It is also recommended to not use TOPSIS and VIKOR simultaneously for future research.

5. Results and discussion

Fourteen criteria were considered in this study. All of the criteria were barriers, i.e. "negative attributes." The results derived from both fuzzy TOPSIS and fuzzy VIKOR are ranked in Table 5.

The overall weights assigned by decision-makers have also been used to find critical barriers toward the implementation of RL. Among the 14 criteria, the lack of recognition of competitive advantage to be gained through the process of RL was identified as the top barrier. Previous research studies also conclude that the main barrier toward the implementation of RL is the assumption of companies that the competitive advantage to be gained through RL is low (Bouzon *et al.*, 2015b). The criterion ranked second is uncertainty related to the economic issues. This criterion is under the category of economic-related issues. It was identified to be most critical toward the implementation of RL in previous research, as the investment made for RL is considered not justifiable (Tan and Hosie, 2010). The major facilitator toward RL implementation was "supportive initiative for EOL." Rahman and Subramanian (2012) concluded that there are no policies devised regarding the implementation of RL for end-of-life products (Rahman and Subramanian, 2012). However, Pakistan's present government has started to take initiatives and devised some policies regarding sustainability issues. The government of Pakistan has initiated different projects to make the country green. Furthermore, most of the companies have also incorporated the concept of sustainability.

Table 6 given below shows the distance of alternatives from their ideal solution. The alternative "reuse" is ranked first. The experts judged reuse as the most feasible alternative because the value of Q is at a minimum distance from zero. The same procedure is followed for the rest of the alternatives and ranked according to Q values. The least important alternative is "repair." It does not mean that this alternative cannot be used, it means that this alternative will not have any significant effects on RL practice.

The results derived from fuzzy TOPSIS along with its closeness factors are given in Table 7.

Ranking	Fuzzy VIKOR	Fuzzy TOPSIS
1	Reuse	Recycle
2	Remanufacturing	Remanufacturing
3	Refurbishment	Repair
4	Recycle	Reuse
5	Repair	Refurbishment

Table 5. Comparison of alternatives derived from fuzzy VIKOR and fuzzy TOPSIS

Alternative	Q value
Reuse	0.37
Recycle	0.80
Repair	0.93
Refurbishment	0.61
Remanufacturing	0.50

Table 6. Q value of alternatives from fuzzy VIKOR

Alternative	CC values
Recycle	0.513925
Repair	0.503308
Remanufacturing	0.503323
Reuse	0.495811
Refurbishment	0.472739

Table 7. CC values of fuzzy TOPSIS

This study presents an effort toward the implementation of RL in Pakistan. In our findings, the top-ranked alternative is "reuse." A product can be reused with a slight cleaning and without involving any production process. The lowest barrier identified through the rating of each alternative against criteria is government support toward activities involving the reuse of products. The criteria with the highest rating in reuse indicating a barrier were issues related to handling and storing of items, as this requires a substantial investment. The present government of Pakistan has initiated different programs toward making the country green. Moreover, young entrepreneurs in Pakistan have started to integrate the concept of preventing environmental pollution in their businesses. Through the energy audit, Pakistani entrepreneurs found that they can save up to 15%–25% in energy and power cost by reusing dumped products [5]. Despite this development, the reuse practices in Pakistan are still at a minor level as compared to other countries. A network for reusable items has been developed in the USA with factors including technical, economic, regulatory and behavioral (Park, 2014). Reuse as an alternative has also been given importance by Carrasco-Gallego *et al.* (2012). This research reviews several case studies that develop a network for reusable items such as wheelchairs, reusable glass bottles and a variety of trays, pallets and trolleys. However, other research studies conclude that difficulties that arise with reuse are timing, quantities and investment (Al-Salem *et al.*, 2009).

Remanufacturing is the second-best alternative for RL practice. Motivating forces behind remanufacturing are environmental restrictions. As devised by the law, most of the companies in the present era are required to take back their products for remanufacturing (Heda *et al.*, 2017). Previous research identified uncertainty regarding quality, quantity and timing from product returns as influencing the success of remanufacturing (Rogers and Tibben-Lembke, 1999b). These observations are consistent with our research. It seems that the lack of a system to monitor returns hurts the implementation of remanufacturing. To combat these problems, Jayaraman and Luo (2007) developed a model that determines the location for remanufacturing facilities and optimal quantities for remanufactured products and cores. Remanufacturing is also being given importance in Pakistan as the Islamabad Chamber of Commerce and Industry has started promoting the remanufacturing industry both for small- and medium-sized enterprises. The major reason behind this promotion is to overcome the problem of huge quantities of scrap in different areas and for achieving better economic value from scrap material [6]. RL practices in terms of remanufacturing have also been given importance in India as different models have been developed for profit maximization through the process of remanufacturing (Sasikumar and Kannan, 2009).

Refurbishment was ranked third and recycling was ranked fourth. Refurbishment means that products are brought up to a specific quality level. In recycling, the identity of the original product is lost as it is used in the production of new parts. Previous research has indicated that recycling is not effective when investment cost is high because of the requirement of advanced technological equipment (Fleischmann, 2001). Also, recycling is a concern with low-value products. In addition, volume uncertainty is high for recycling products. For these reasons, this practice has not been given much importance by some academies (Galbreth and Blackburn, 2006). To overcome issues in recycling, a Portuguese glass manufacturing company developed a scenario-based model for quantity and quality of returned products (Zeballos *et al.*, 2012). There is also some serious concern regarding recycling in Pakistan. This practice in Pakistan has not been adopted at a greater level because there is a lack of proper infrastructure through which waste should be disposed of or sent for the process of recycling [7]. This is the major reason behind low practice of recycling as an alternative for RL in Pakistan.

The lowest-ranked alternative in this study is "repair." Previous research indicated that the process of repair is very costly as different products have different needs regarding repair services (Fernández and Junquera, 2003). There are also different manners in which enterprises organize RL channels. These channels range from factory support to independent third parties and there is complexity in claiming which channel is best (Loomba and Nakashima, 2012). Also, in the case of Pakistan, no importance has been given to repair as compared to reuse and remanufacturing. Manufacturing organizations are faced with the problem of selecting which channel is the best to carry out repairing and these channels require investment at a larger level. Also, finding employees with the best technical skills and training staff for this practice requires considerable time and attention. We believe this is why this practice is highly neglected in the case of Pakistan.

6. Conclusion

This study attempts to cover the gap in the literature related to RL barriers. We address this gap by identifying barriers and prioritizing alternatives in a fuzzy environment for the manufacturing industry of Pakistan. Despite its long-term benefits, in most of the developing countries, RL concepts are considered an extra financial burden on the companies. Pakistan, being a developing country, is trying to stabilize its reviving economy by developing its infrastructure, information and communication technology and industrial sector through the China Pakistan Economic Corridor. However, the concept of RL is also gaining importance in developing countries like Pakistan because of its economic and social advantages. To find the barriers to RL, 14 criteria were used in this study to evaluate five alternatives: recycling, reuse, refurbishment, remanufacturing and repairing. To cope with these barriers, MCDM techniques are applied in this study, i.e. fuzzy VIKOR and fuzzy TOPSIS. The most feasible alternative is selected based on fuzzy VIKOR ranking. The results from fuzzy TOPSIS are limited because it does not consider the relative importance of the ideal solution. For this reason, the ranking given by fuzzy VIKOR is considered the most credible in this study. "Reuse" ranked first as the best alternative for RL according to fuzzy VIKOR. The process of reuse is most feasible because a product can be reused without involving any production or processing at a larger scale. Also, it has the advantage of operational effectiveness. Remanufacturing ranked the second-best alternative for RL in the case of Pakistan. The small and medium remanufacturing enterprises in Pakistan are growing at a rapid pace. Likewise, refurbishment ranked third and recycle ranked fourth. Repair ranked fifth as an alternative for RL in the case of Pakistan. The major reason is that the process of repair is costly. Also, there are multiple channels for repair that ranges from the company itself to third parties. These channels further complicate the implementation of repair. The fuzzy VIKOR ranking is also compared with the fuzzy TOPSIS in this study. In fuzzy TOPSIS, recycling ranked first, whereas repair ranked fifth. The findings of this study will assist managers in deploying the best practices concerning RL in the manufacturing sector of Pakistan. Manufacturing firms can also focus on the aim of improving their sustainability projects by using these RL activities as a pragmatic tool.

7. Limitations and future line of research

A few of the limitations of this study are the limited number of experts as respondents. The results of this research could have been obtained in a more refined form if the number of participants could be increased. More alternatives should be taken into consideration for a future line of research. It is further recommended that future research should focus on a specific manufacturing industry to find the most attractive alternatives regarding RL implementation.

Notes

1. www.emergingpakistan.gov.pk/opportunities/punjab/manufacturing/
2. https://siteresources.worldbank.org/INTWDR2012/Resources/7778105-1299699968583/7786210-1315936222006/Complete-Report.pdf
3. www.commonwealthofnations.org/sectors-pakistan/business/industry_and_manufacturing
4. https://profit.pakistantoday.com.pk/2018/04/23/industrial-sector-grows-at-5-8pc-in-fy2018/
5. www.thenews.com.pk/print/201100-Adoption-of-waste-economy-in-Pakistan-to-save-money-environment
6. www.thenews.com.pk/archive/print/315271-icci-for-promoting-remanufacturing-industry
7. www.export.gov/article?id=Pakistan-Waste-Management
8. www.dawn.com/news/1352390

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