

## Modeling the Barriers in Managing Closed Loop Supply Chains of Automotive Industries in Bangladesh

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### Abstract

Closing the supply chain loop at the end of a product's life cycle is gaining popularity among researchers and practitioners. Due to its paramount influence on social and environmental issues, with the continuous adaptation of the closed loop supply chain (CLSC) as a means of saving natural resources (energy, material, etc.) and reducing production costs. This paper proposes a structured framework using Delphi and fuzzy TOPSIS approaches for identifying and assessing major Bangladeshi automotive industry CLSC barriers. Through a literature review and extracting opinions from experts, a total of five major barriers and 16 sub-barriers were identified and evaluated via fuzzy TOPSIS. The results revealed that economic barriers were dominant for CLSC implementation in the existing supply chain followed by information-related barriers. This research may be a guideline to manufacturers when formulating strategic decisions and organizational visions for CLSC implementation.

**Keywords:** Closed loop supply chain; Barriers; Fuzzy TOPSIS; Delphi; Automotive industry; Sustainability.

### 1. Introduction

Supply chain management is considered as an integral part of most businesses and plays a vital role in the improvement of a company's competitive advantages (Autry & Moon, 2016). Integration of environmental and remanufacturing initiatives into the supply chain and other business processes has substantial benefits (Alqahtani and Gupta, 2019). Many large enterprises and medium organizations have identified the benefits of these remanufacturing initiatives on business performance and they have defined closed loop supply chain management (CLSCM) as one of the main efforts to integrate remanufacturing and environmental parameters into supply chain systems (Abbey et al., 2015; Taleizadeh et al., 2018). Most of the supply chain management innovations emphasized on waste reduction enabling remanufacturing for economic reasons as well as environmental reasons (Manners-Bell & Lyon, 2019). Regarding such a perspective, Spengler, et al., (2004) indicated that closed loop supply chain management was a method for designing or redesigning the supply chain, including the recycling of metals and plastics, repairing and reusing of parts and components for the production of new devices, and remanufacturing or refurbishing of all discarded products and devices for second-hand use. Vehicles have been comprised of substantial proportions of such second-hand devices (Go et al., 2011). In the USA, approximately 25 million tons of materials and 12 million cars have been recycled annually from old vehicles (LeBlanc, 2016). Wong, Lai, Lun, and Cheng (2016) indicated that recycling of used parts helped to save natural materials and energy consumption through reducing the emissions of hazardous gases, especially carbon emissions. This strategy also diminished manufacturing production costs (Wong, Lai, Lun, & Cheng, 2016).

Recently, the total amount of vehicles in Bangladesh increased substantially because of its dense population and its strong economic and technological developments (Kamal & Ferdousi, 2009). As a result, the Bangladeshi automotive industry experienced rapid growth. Within the industry, vehicle production requires high consumption of energy and other resources annually (Stoycheva et al., 2018). Therefore, recycling and reusing components and parts inhibits such negative effects. The closed loop supply chain facilitates component reuse and parts remanufacture processes (Savaskan, Bhattacharya, & Van Wassenhove, 2004). Savaskan's, Bhattacharya's, & Van Wassenhove's (2004) concept may also be considered from the context of the automotive closed loop supply chain for producing vehicles.

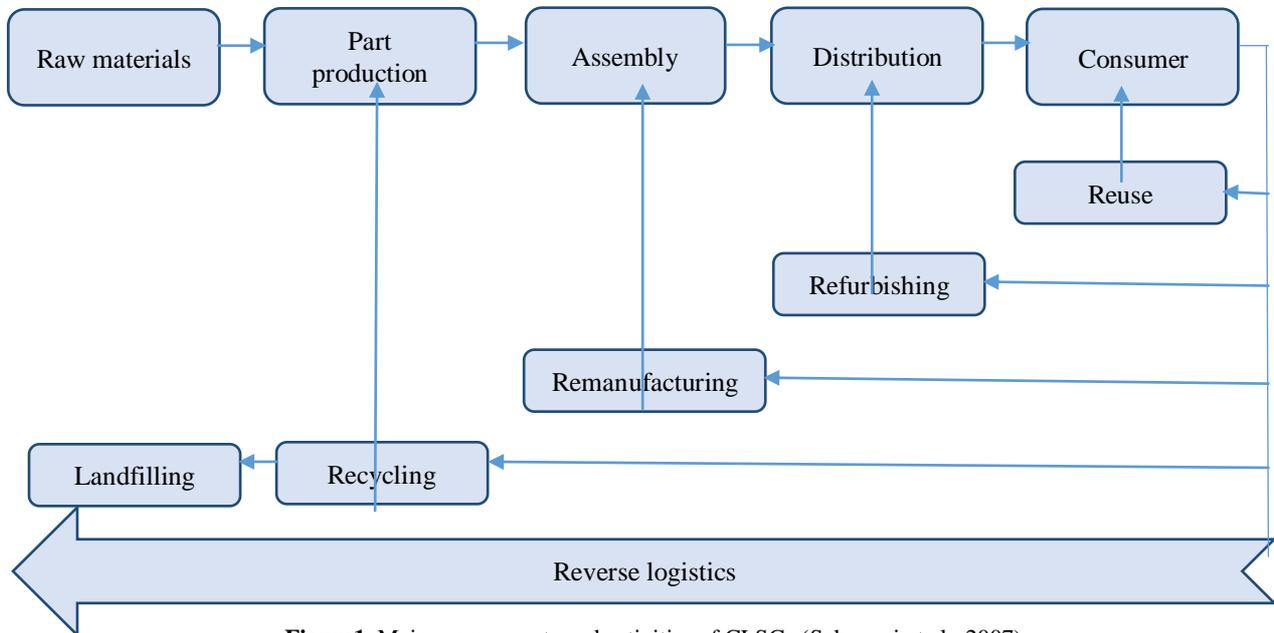
Given various continuous improvements of green supply chains, upon product life cycle termination, developed countries are receptive to remanufacturing through supply chain loop closure (Besbes, Allaoui, Goncalves, & Loukil, 2013). Bangladeshi automotive manufacturers may contemplate the strategy toward achieving sustainability because the government is more attentive to environmental protection and it forces enterprises to reproduce parts from old products. However, barriers for automotive closed loop supply chain exist in Bangladesh as well as in the world. Therefore, automotive manufacturers and third-party remanufacturers have taken collaborative initiatives to resolve different problems in managing closed loop supply chain (Lu et al., 2014). Improperly identifying and analyzing barriers affects the managing of closed loop supply chains. When managing closed loop supply chains, investigating barriers is vital among modern competitive business environments (Shi et al., 2019). Investigating barriers contributes to developing an effective business strategy (Ike, 2017). Moreover, in Bangladesh, there is a lack of extensive barrier investigations regarding automotive closed loop supply chains.

Therefore, the aim of this study was to identify the automotive closed loop supply chain barriers and examine them quantitatively toward formulating effective business strategies for sustainability purposes. To achieve these objectives, a Delphi-based fuzzy TOPSIS method was applied to identify and analyze significant closed loop supply chain barriers for the automotive industry. This study incorporated the fuzzy TOPSIS method because it was a straightforward process that used a large number of alternatives and criteria in the decision-making process with few calculations (Zhang & Xu, 2015).

**2. Literature review**

**2.1. Closed loop supply chain**

During the past few decades, the economic and environmental advantages of product remanufacturing were widely recognized, and sustainable closed loop supply chains (CLSCs) have gained industry attentiveness (Kannan et al., 2010). The development of closed loop supply chains leads to an integrated approach to the simultaneous consideration of forward and reverse supply chains (Govindan & Soleimani, 2017). Guide and Van Wassenhove (2009) defined CLSCs as "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time." Conceptually, a closed loop supply chain combines the traditional supply chain with reverse logistics. Many organizations proactively took anticipative measures regarding the potential of various, changing environmental requirements that contributed toward CLSC popularity (Choi et al., 2013). Sahyouni et al. (2007) identified major activities and components of the closed loop supply chain (Figure 1).



**Figure1.** Major components and activities of CLSCs (Sahyouni et al., 2007)

All products generated, carried, used and discarded within the supply chain have some environmental impact and are related to the material and energy consumed and to waste released during its lifecycle (Tsoufas & Pappis, 2006). Because of mass consumption and indiscriminate disposal habits, huge volumes of waste are generated that inundate available landfills. Practical and value-maximizing alternatives to waste disposal are recovery and recycling (Van Wassenhove, 2009). A closed loop supply chain has significant impact on the sustainability of environment and production. It develops recycling activities to conserve natural resources (e.g., materials, energy) and landfill availability (Georgiadis & Besiou, 2008).

The closed loop supply chain is more closely linked to other operational activities and business processes. For example, Fleischmann et al. (2003) integrated closed loop supply chain with spare parts management. Fleischmann et al. (2003) indicated that inventory and spare parts management could reduce the overall cost in managing the closed loop supply chain. Major business processes involved in CLSCs are product acquisition, reverse logistics, sorting and disposition, recovery, and re-distribution (Krikke et al., 2004). Materials flow is another important factor in managing closed loop supply chains. Between the two types of flows, forward flow and backward flow, CLSCs involve backward material flows from customers to suppliers. As retrieval of reused products is crucially important to the manufacturer, relationships between the different tiers of supply chain play vital roles in CLSC success (Östlin et al., 2008).

Several CLSC models were developed during the past few decades. Özkır and Başlıgil (2012) proposed a multi-objective model with three recovery options for closed-loop supply chains: material recovery, component recovery, and product recovery. For a single, multi-stage closed-loop supply chain, John and Sridharan (2013) developed a model to determine the flow of materials between each stage of the supply chain. Kim et al. (2018) found that supply chain planning was affected by uncertainty from customer demand and product collectors. To mitigate uncertainty, Kim et al. (2018) proposed a robust optimization model. Braz et al. (2018) examined the bullwhip effect and its cause among CLSCs, and found that the main mitigating factor was related to increasing the product return rate. Ruiz-Torres et al. (2019) proposed a model which helped to manage return flows by establishing incentives for returners while simultaneously determining a capacity contract with the new component provider.

## **2.2. Barriers in managing automotive closed loop supply chain**

The automotive CLSC includes the stages of collecting used vehicle parts and components and remanufacturing. Unfortunately, barriers exist among all stages. These barriers should be investigated CLSC improvement, productivity enhancement, and waste minimization. The reviewed literature revealed that several researchers investigated the barriers and challenges in CLSC management. For example, Seitz (2007) investigated the European automotive industry, and found that product recovery and redistribution impacted the automotive CLSC. Zaabi et al. (2013) discovered several barriers to developing a sustainable supply chain, and analyzed the relationship between barriers to identify the most influential barrier. Lack of shared understanding and incentives among different stakeholders in all stages of the closed loop supply chain were identified as barriers by some researchers (Shaharudin et al., 2015; Govindan et al., 2016).

Garg et al. (2015) identified some environmental issues such as increasing transportation because of forward and reverse logistics in close loop supply chain which results in high carbon emission. Mohajeri and Fallah (2016) addressed the carbon footprint problem as a CLSC environmental barrier because of transporting returned products from the customer. Mohajeri and Fallah (2016) found that inaccurate forecasts may increase financial risks and the risks of collection and recovery. Collection and recovery mostly depend on CLSC design. Poor supply chain design can significantly affect the organizational efficiency and effectiveness (Zokaei et al., 2017). However, the unbalanced distribution of collected products from customers is problematic for automotive supply chains. Paydar et al. (2017) identified that lack of supervision and uncertainty in the number of collected products were the main contributors to such problems. Lack of social and environmental awareness among the customers and manufacturers is one of the major problems among CLSC practices (Keyvanshokoo et al., 2016). Governmental adoption of necessary processes may motivate manufacturers and collectors by setting reasonable target collection rates and increasing the incentives and rewards (Wang et al., 2018).

Based on the reviewed literature, the authors identified The most 10 influential barriers and sub-barriers for managing CLSCs for automotive industries. Moreover, six barriers were considered via the lens of the Bangladeshi automotive industry. To ensure the validity of these identified barriers, several discussion sessions were conducted with managers, industrial engineers, and supply chain specialists. All barriers were divided into five major groups with respect to expert guidance representing relevant fields. Table 1 shows the selected barriers.

**Table 1.** Barriers in managing the closed loop supply chain for the automotive industry

Major barriers	Sub-barriers	A brief description of each barrier	Relevant literature
A. Environmental barriers (B <sub>1</sub> )	(1) High carbon emission due to extended transportation (B <sub>11</sub> )	In a closed loop supply chain, extended transportation due to the collection of used products increases the carbon emission rate.	Fahimnia et al. (2013), Garg et al. (2015), Mohajeri & Fallah (2016), Bazan et al. (2017)
	(2) Lack of proper solid waste management (B <sub>12</sub> )	Lack of solid waste management may hinder the efficient reverse flow of materials in a closed loop supply chain.	Beamon (1999), Xu et al. (2017)
	(3) Lack of environment-friendly technology for dismantling (B <sub>13</sub> )	For remanufacturing of vehicles environment-friendly dismantling is required and lack of such technology may challenge the whole supply chain.	This paper
B. Economic barriers (B <sub>2</sub> )	(1) The low profit margin for refurbished products (B <sub>21</sub> )	Refurbished vehicles have low profit margin which may discourage the manufacturers.	Zhang et al. (2019), Zhou et al. (2017), Ovchinnikov (2011)
	(2) Lack of investment (B <sub>22</sub> )	Lack of investment to develop facilities and maintain reverse logistics.	This paper
	(3) Price fluctuation (B <sub>23</sub> )	Price fluctuation may result in economic problems in managing the closed loop supply chain.	Zhang et al. (2019), Wei & Zhao (2011), Atasu et al. (2008)
	(4) The high cost of the process of environmental adaptation (B <sub>24</sub> )	Sometimes manufacturers averse to adopt a closed loop supply chain due to the high cost of the process of environmental adaptation.	This paper
C. Information related barriers (B <sub>3</sub> )	(1) Lack of accuracy in forecasting (B <sub>31</sub> )	Lack of accurate forecasting may result in imbalance supply and demand.	Krapp et al. (2013), Clotey et al. (2012), Paydar et al. (2017)
	(2) Lack of information sharing among stakeholders (B <sub>32</sub> )	Lack of information sharing may cause the bullwhip effect which challenges the overall supply chain.	Shaharudin et al. (2015), Govindan et al. (2016)
	(3) Lack of information about returned product quality (B <sub>33</sub> )	Poor quality of returned product results in financial loss. Hence proper information about the returned product is required.	Aras et al. (2004), Hwang et al. (2009)
D. Manufacturing and technology related barriers (B <sub>4</sub> )	(1) Poor product design (B <sub>41</sub> )	Lack of proper consideration for remanufacturing at the design stage.	Krikke et al. (2004)
	(2) Lack of proper inventory management (B <sub>42</sub> )	Efficient closed loop supply chain requires efficient inventory management.	Fleischmann & Minner (2004)
	(3) Lack of modern production technology (B <sub>43</sub> )	Lack of modern production technology may interrupt the remanufacturing process.	This paper
E. Organizational barriers (B <sub>5</sub> )	(1) Lack of long term strategic planning (B <sub>51</sub> )	Lack of long term strategic planning and policies may result in the inefficient closed loop supply chain.	This paper
	(2) Lack of appropriate performance measure (B <sub>52</sub> )	The organization needs to set appropriate performance measures to take full advantages from the closed loop supply chain.	This paper
	(3) Lack of awareness (B <sub>53</sub> )	Awareness among the customers and manufacturers is required for the efficient closed loop supply chain.	Keyvanshokoo et al. (2016)

### 2.3. Fuzzy TOPSIS

The Technique for Order of Preferences by similarity to Ideal Solution (TOPSIS), developed by Hwang & Yoon (1981), is a multi-criteria decision-making tool that is used for ranking a number of selected factors. The TOPSIS method facilitates complex decisions involving a large number of factors or alternatives. Conversely, Zadeh's (1965) fuzzy set theory incorporates elements that have degrees of membership. Fuzzy set theory is usually applied where data uncertainty and inaccuracy exist. Since most of the MCDM techniques use human opinions and thoughts, data

uncertainty exists within decision domains. Therefore, given the presence of uncertainty, fuzzy set theory was combined with many MCDM techniques. This study integrated fuzzy set theory and the TOPSIS method.

The reviewed literature showed various supply chain management applications of the fuzzy TOPSIS method. For example, production facilities were evaluated by Pochampally et al. (2004) using a fuzzy TOPSIS method. Janaki et al. (2018) applied the fuzzy TOPSIS method to evaluate the performances of oil distribution industry supply chains. Petrucci et al. (2018) evaluated suppliers based on some sustainability criteria using a fuzzy TOPSIS method. Farajpour et al. (2018) used fuzzy TOPSIS to assess parameters that influenced information flows among supply chains. The fuzzy TOPSIS method can support decision-makers when quantifying automotive supply chains (Azizi, Aikhuele, & Souleman, 2015). The TOPSIS approach was also useful for examining automotive industry supply chain barriers (Mittal & Sangwan, 2014).

#### **2.4. Research gap**

The rapid development of automotive industries in Bangladesh necessitates the adoption of a sustainable CLSC concept to support green technologies and reduce the depletion of natural resources. This action can improve business efficiency and facilitate guidance toward crafting and implementing sustainable manufacturing policies. However, the path is not so easy. Many barriers inhibit Bangladeshi automotive industries from adopting CLSCs. Therefore, this study examines such barriers quantitatively in the context of Bangladeshi automotive industry. This study is intended to provide guidance for industrial managers. Moreover, assessing CLSC barriers quantitatively may provide a basis for crafting effective CLSC management strategies. To achieve these aims, the current research has the following objectives:

- (a) To identify barriers in managing closed loop supply chain for automotive industries of Bangladesh.
- (b) To assess the barriers quantitatively using Delphi and fuzzy TOPSIS methods.
- (c) To suggest some managerial implications to manage these barriers for effective closed loop supply chain.

#### **3. Solution methodology**

In this section, the theoretical background of the present research has been discussed. The aim of this research was to identify and analyze automotive closed loop supply chain barriers in the context of Bangladesh. To achieve these objectives, the authors applied the Delphi method and fuzzy TOPSIS. Figure 2 shows a step-by-step process of current research.

##### **3.1. Delphi method**

The Delphi method is an iterative process of collecting data from a group of experts through a series of structured questionnaires (Jason & Glenwick, 2016). It is a dynamic method for collecting and assessing data among numerous, different research fields to support effective decision making (Lee & Seo, 2016; Brady, 2015). Within this study, this systematic technique was used to identify and assess barriers among Bangladeshi automotive CLSCs through a carefully designed questionnaire. To obtain the best possible outcomes, this research considered opinions from several supply chain managers and specialists representing the Bangladeshi automotive industry.

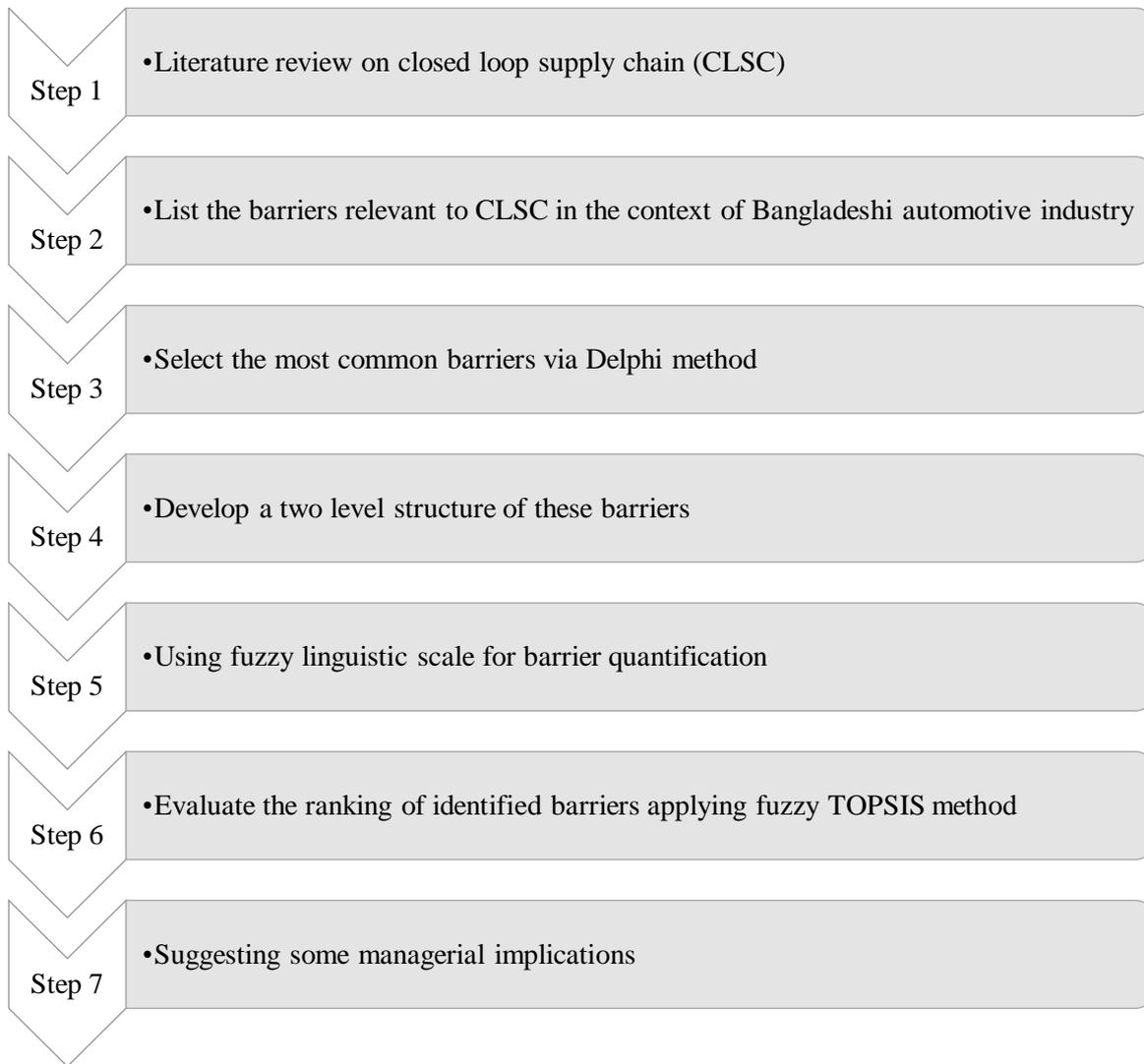
In the Delphi method, there is no hard and fast rule about the number of experts for data collection and analysis. In other words, different numbers of experts for evaluating criteria may be used within the Delphi method; no universal number exists (Bouzon et al., 2016). For instance, Okoli and Pawlowski (2004) suggested 10 to 18 experts for ensuring the best results whereas Murry and Hammons (1995) advised 10 to 30 experts' opinions. This study used a total of 20 supply chain and logistics managers. These experts had sufficient knowledge about supply chains, CLSCs, and reverse logistics. A three-round Delphi method was conducted to identify the most relevant barriers to Bangladeshi automotive CLSCs.

##### **3.2. Fuzzy TOPSIS methodology**

This study used a fuzzy TOPSIS method to evaluate and rank the potential barriers to the automotive CLSC. The steps involved in fuzzy TOPSIS method are presented below (Chu & Lin, 2003; Sun, 2010; Han, & Trimi, 2018):

*Step 1: Determine the weight of the evaluation criteria*

In this step, the weight of each evaluation criteria was determined by using fuzzy linguistic variables. In this study, weights were set with these linguistic variables by consulting with experts. Table 2 shows the linguistic variables.



**Figure2.** Step by step methodology for the present research

**Table2.** Membership function of linguistic scale

Linguistic variable	Corresponding triangular fuzzy number
Very low (VL)	(1,1,3)
Low (L)	(1,3,5)
Medium (M)	(3,5,7)
High (H)	(5,7,9)
Very high (VH)	(7,9,9)

Step 2: Construct the fuzzy decision matrix and choose the appropriate linguistic variables for alternatives with respect to criteria

In this step, with the assistance of expert input and using linguistic variables, fuzzy decision matrix  $A$  was developed for barriers and sub-barriers. Each linguistic variable was converted into a triangular fuzzy number with the help of Table 3. In this matrix, each element  $a_{ij}$  denoted the importance level of barriers and sub-barriers with respect to criteria. This fuzzy decision matrix was:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}, i = 1,2, \dots, m; j = 1,2, \dots, n \tag{1}$$

Where  $a_{ij}$  indicated the level of importance of barrier  $i$  with respect to the criterion  $j$  given by experts and  $a_{ij} = (x_{ij}, y_{ij}, z_{ij})$ . Here,  $(x_{ij}, y_{ij}, z_{ij})$  was the triangular fuzzy number derived from the linguistic scale.

Step 3: Normalize the fuzzy decision matrix

The normalized fuzzy decision matrix denoted by  $R$  is presented as follows:

$$R = [r_{ij}]_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (2)$$

The normalization process was performed by following formula:

$$r_{ij} = \left( \frac{x_{ij}}{z_j^+}, \frac{y_{ij}}{z_j^+}, \frac{z_{ij}}{z_j^+} \right), z_j^+ = \max_i z_{ij} \quad (3)$$

The normalized  $r_{ij}$  represented a triangular fuzzy number.

Step 4: Determine weighted fuzzy normalized decision matrix

The weighted fuzzy normalized decision matrix was calculated as follows (matrix  $V$ ):

$$V = [V_{ij}]_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (4)$$

$$V_{ij} = r_{ij} \otimes W_j \quad (5)$$

Step 5: Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS)

Ranges of triangular fuzzy numbers (TFNs) belonged to closed interval [1, 9]. Fuzzy positive ideal solution (FPIS)  $S^+$  and fuzzy negative ideal solution (FNIS)  $S^-$  were defined as follows:

$$S^+ = (V_1^+, V_2^+, \dots, V_n^+) \quad (6)$$

$$S^- = (V_1^-, V_2^-, \dots, V_n^-) \quad (7)$$

Where,  $V_j^+ = (9, 9, 9)$  and  $V_j^- = (1, 1, 1), j = 1, 2, \dots, n$ .

Step 6: Calculate the distance of each alternative from FPIS and FNIS

The distances ( $d^+$  and  $d^-$ ) of each alternative from  $S^+$  and  $S^-$  were calculated by area compensation method.

$$d^+ = \sum_{j=1}^n d(V_{ij}, V_j^+), i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (8)$$

$$d^- = \sum_{j=1}^n d(V_{ij}, V_j^-), i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (9)$$

Step 7: Obtain the closeness coefficient and rank the order of the barriers and sub-barriers

The closeness coefficient  $CC_i$  was calculated to determine the ranking order of all barriers and sub-barriers once the  $d^+$  and  $d^-$  of each alternative had been calculated. In this step, similarities to ideal solution was calculated using the following formula:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1, 2, \dots, m \quad (10)$$

According to  $CC_i$ , ranking order of all barriers and sub-barriers was determined.

## 4. Application of the solution methodology

### 4.1. Data collection using Delphi method

The Bangladeshi automotive industry shows quick growth when compared to other developing countries. Some leading automotive companies in Bangladesh are Pragoti, Walton Hi-Tech Industries Limited, Runner Automobiles, PHP Automobiles, and Akij Motors. Nowadays, with the continuous improvement of green supply chains, developed countries are receptive to remanufacturing through closing the supply chain loop when a product's life cycle terminates. The Bangladeshi Government is now paying more attention to environmental protection and forcing enterprises to reproduce parts from old products. To achieve sustainability, Bangladeshi automotive manufacturers should accept this strategy considering different environmental and economic issues. Some companies are also trying to incorporate CLSCs within their respective long-term business strategies. Adopting the CLSC among Bangladeshi automotive industries is preliminary. There are many barriers for implementing the sustainable concept that must be identified and mitigated properly. Hence, proper identification of CLSC barriers will help to develop sustainable business strategies. Such situations necessitate developing a structured framework to identify the key barriers and formulating strategies to overcome them.

This study investigated six Bangladeshi automotive companies. These companies were selected using a purposive sampling method whereby the case-in-point company was not chosen randomly (Bell et al., 2018; Gentles et al., 2015). Accordingly, 20 supply chain managers and logistics managers were selected based on a purposive sampling method

for data collection and result validation. Data were collected in two phases. In the first phase, the most relevant automotive CLSC barriers were selected by supply chain and logistics managers using the Delphi method. A list of barriers for further analysis was determined and is presented in Table 1. Three evaluation criteria were selected by the experts: severity, probability of occurrence, and manageability. In the next phase, these 20 experts were asked to give their opinions concerning selecting the potential barriers to managing automotive industry CLSCs. Again, the same three evaluation criteria were selected by the experts: severity, probability of occurrence, and manageability.

**4.2. Application of fuzzy TOPSIS**

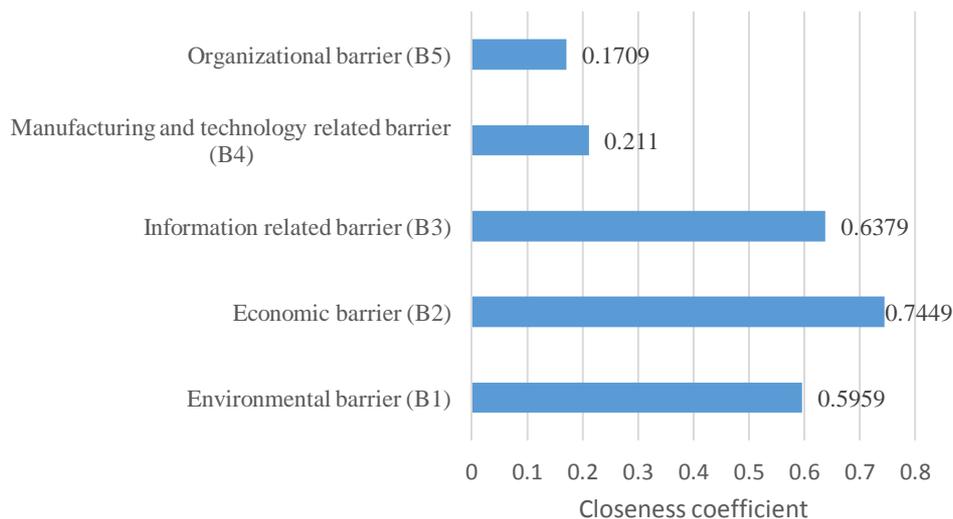
In this step, the finalized barriers and sub-barriers were ranked with the help of fuzzy-TOPSIS tool and experts’ feedback. The barriers of the automotive closed loop supply chain were structured in two levels. The first level represented major barriers and the second level represented sub-barriers of the automotive closed loop supply chain. There were five major barriers and 16 sub-barriers. All these barriers and sub-barriers were evaluated against three criteria.

A fuzzy decision matrix was formed for major barriers with the assistance of respondents’ opinions using linguistic variable scale and Eq. (1). Afterward, the normalized fuzzy decision matrix was developed using Eqs. (2) and (3). Weights of all criteria were set by the experts. Then weighted normalized fuzzy decision matrix was calculated using Eqs. (4) and (5). Then using Eqs. (6) and (7), fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) were calculated for the major barriers. All these calculations have been shown in the Appendix A section (Tables A1-A5). Finally, the closeness coefficient and rank of order were calculated using Eqs. (8), (9) and (10). Table 3 shows the positive and negative distance of major barriers and rank of order of each barrier with closeness coefficient

**Table3.** Calculation of positive distance, negative distance and closeness coefficient

	$d_i^+$	$d_i^-$	$CC_i$	Rank
B <sub>1</sub>	2.8487	4.2008	0.5959	3
B <sub>2</sub>	1.7451	5.0947	0.7449	1
B <sub>3</sub>	2.5383	4.4719	0.6379	2
B <sub>4</sub>	5.3657	1.4347	0.2110	4
B <sub>5</sub>	5.6709	0.1689	0.1709	5

Figure 3 shows that the economic barrier (B<sub>2</sub>) has the highest closeness coefficient (0.7449) and ranked first. This indicated that the automotive industries of Bangladesh should formulate their CLSC strategy by giving the highest consideration to this barrier. Information related barrier (B<sub>3</sub>) ranked second, and its closeness coefficient was 0.6379. Among all these five major barriers, organizational barrier (B<sub>5</sub>) ranked last with a closeness coefficient of 0.1709.



**Figure3.** Closeness coefficient of barriers

After calculating the closeness coefficient and rank of the order of major barriers, relative closeness coefficient, and local rank of each sub-barrier under the major barrier were calculated similarly. Finally, the global closeness coefficient of each barrier was calculated by multiplying the relative closeness of major barriers with the relative closeness coefficient of the sub-barriers (Table 9). Therefore, the final ranking of sub-barriers was determined according to the global closeness coefficient of each barrier.

**5. Results and discussion**

In this section, details of the current research findings were discussed. These findings may help automotive manufacturers and supply chain specialists to understand CLSC barriers within the Bangladeshi automotive industry. The current research revealed that the ranking of specific sub-barriers can be summarized as follows:

$$B_{22} > B_{11} > B_{32} > B_{24} > B_{23} > B_{31} > B_{21} > B_{12} > B_{33} > B_{13} > B_{51} > B_{42} > B_{41} > B_{53} > B_{43} > B_{52}$$

From the above ranking, it was found that lack of investment (B<sub>22</sub>) ranked highest, indicating that it was the greatest sub-barrier in managing the closed loop supply chain for Bangladeshi automotive companies.

**5.1. Environmental barriers (B<sub>1</sub>)**

Amongst the five major barriers, environmental barriers (B<sub>1</sub>) were ranked third. In the current manufacturing era, environment-related barriers are considered as one of the major issues in supply chains. It has become one of major challenges for the manufacturing firms. This study examined three critical sub-barriers under environmental barriers. The rank of the order of these sub-barriers is represented in Table 4. High carbon emission due to extended transportation (B<sub>11</sub>) was the highest ranked sub-barriers. So, automotive industries should prioritize their attention on this barrier. Supply chain specialists can optimize the supply chain network so that carbon emission through extended transportation is minimized. Lack of proper solid waste management (B<sub>12</sub>) ranked second and had very high significance in managing automotive CLSC. Automotive manufacturers should give this barrier proper attention. Lack of environment-friendly technology for dismantling (B<sub>13</sub>) was next in the sub-barrier ranking. Most of automotive companies are uninterested in purchasing environment-friendly technologies for dismantling used products because of their high prices. Therefore, automotive companies should allocate sufficient funds among their respective budgets. Ultimately, it can improve business performance.

**Table4.** Rank of the order of environmental sub-barriers

	Severity (5,7,9)	Probability of Occurrence (3,5,7)	Manageability (5,7,9)	CC <sub>i</sub>	Rank
B <sub>11</sub>	(3,5,7)	(3,5,7)	(7,9,9)	0.7706	1
B <sub>12</sub>	(5,7,9)	(3,5,7)	(5,7,9)	0.3011	2
B <sub>13</sub>	(5,7,9)	(5,7,9)	(3,5,7)	0.2294	3

**5.2. Economic barriers (B<sub>2</sub>)**

Automotive companies may face difficulties in managing CLSCs because of a low profit margin for refurbished products (B<sub>21</sub>), lack of investment (B<sub>22</sub>), price fluctuation (B<sub>23</sub>), and high cost of the process of environmental adaptation (B<sub>24</sub>). In this study, economic barriers were ranked first. Ranking of all sub-barriers under this major barrier is presented in Table 5. Because of high investment, many automotive manufacturers are unwilling to develop CLSCs. However, adopting CLSCs may be beneficial in improving business performance. Hence, lack of investment (B<sub>22</sub>) was ranked first under economic barriers. Long term economic benefits can be achieved by establishing research and development departments. Next, the high costs of the environmental adaptation (B<sub>24</sub>) process ranked second. Automotive firms should allocate enough budget for environmental adaptation. Next was price fluctuation (B<sub>23</sub>). Although it is almost an uncontrollable barrier, automotive companies should take preventive actions to confront this challenge. Finally, low profit margin for refurbished products (B<sub>21</sub>) was ranked last under economic barriers. Selling price of refurbished product is relatively low compared to a new one. Therefore, sometimes automotive manufacturers remain averse to adopt closed loop supply chain.

**Table5.** Rank of order of economic sub-barriers

	Severity (5,7,9)	Probability of Occurrence (3,5,7)	Manageability (5,7,9)	CC <sub>i</sub>	Rank
B <sub>21</sub>	(5,7,9)	(1,3,5)	(3,5,7)	0.2798	4
B <sub>22</sub>	(1,1,3)	(3,5,7)	(1,3,5)	0.7455	1
B <sub>23</sub>	(7,9,9)	(3,5,7)	(3,5,7)	0.4408	3
B <sub>24</sub>	(1,3,5)	(3,5,7)	(1,3,5)	0.4634	2

**5.3. Information related barriers (B<sub>3</sub>)**

In this research, the information related barrier (B<sub>3</sub>) ranked second of the five major barriers. The sub-barriers were: lack of accuracy in forecasting (B<sub>31</sub>), lack of information sharing among stakeholders (B<sub>32</sub>), and lack of information about returned product quality (B<sub>33</sub>). All contribute significantly in effective CLSC management. Lack of information

sharing among stakeholders (B<sub>32</sub>) ranked first in this category. Among CLSCs, information must be shared between different tiers of the supply chain. Lack of information sharing can cause many serious effects, such as the bullwhip effect. Lack of accuracy in forecasting (B<sub>31</sub>) was another key barrier in CLSC management, and it ranked second among information-related barriers. Inaccurate forecasting results in an imbalance between supply and demand. Remanufacturing of products was one of the key CLSC functions. Lack of information about returned product quality (B<sub>33</sub>) may hamper CLSC remanufacturing activity. Financial loss may also be occurred because of the poor quality of returned products. This sub- barrier was ranked third under the information-related barriers (B<sub>3</sub>) category. The rank of order of information related sub-barriers is presented in Table 6.

**Table6.** Rank of the order of information related barriers

	Severity (5,7,9)	Probability of Occurrence (3,5,7)	Manageability (5,7,9)	CC <sub>i</sub>	Rank
B <sub>31</sub>	(5,7,9)	(3,5,7)	(5,7,9)	0.3802	2
B <sub>32</sub>	(3,5,7)	(5,7,9)	(3,5,7)	0.6198	1
B <sub>13</sub>	(5,7,9)	(5,7,9)	(3,5,7)	0.2782	3

**5.4. Manufacturing and technology related barriers (B<sub>4</sub>)**

The manufacturing and technology related barrier (B<sub>4</sub>) ranked fourth in this study. However, it has significant contributions in CLSC management. Without modern manufacturing and production technology, Its proper CLSC management becomes impossible. Table 7 shows the overall ranking of manufacturing and technology related sub-barriers. In this category, lack of proper inventory management (B<sub>42</sub>) ranked first. Inventory management significant impacts total supply chain performance. Automotive companies should take special initiatives for inventory management of returned parts and products for effective CLSC management. Product design has significant contribution in remanufacturing and CLSC management. Poor product design (B<sub>41</sub>) ranked second under the manufacturing and technology-related barriers. Finally, lack of modern production technology (B<sub>43</sub>) ranked third. Modern technology adds competitive advantage for companies. However, Bangladeshi automotive companies are sometimes unwilling to purchase modern technology because of lack of investment.

**Table7.** Rank of the order of manufacturing and technology related barriers

	Severity (5,7,9)	Probability of Occurrence (3,5,7)	Manageability (5,7,9)	CC <sub>i</sub>	Rank
B <sub>41</sub>	(1,3,5)	(1,3,5)	(1,3,5)	0.5571	2
B <sub>42</sub>	(3,5,7)	(5,7,9)	(7,9,9)	0.5810	1
B <sub>43</sub>	(7,9,9)	(3,5,7)	(5,7,9)	0.2978	3

**5.5. Organization related barriers (B<sub>5</sub>)**

Organizational barrier (B<sub>5</sub>) ranked as the last of the five major barriers. This study considered lack of long-term strategic planning (B<sub>51</sub>), lack of appropriate performance measure (B<sub>52</sub>), and lack of awareness (B<sub>53</sub>). Table 8 represents the rank of order of these sub-barriers. Lack of strategic planning (B<sub>51</sub>) ranked as the most important sub-barrier. Most Bangladeshi automotive companies lack long-term strategic planning. Industrial managers and supply chain specialists should formulate long-term strategic planning for CLSC adoption. Lack of awareness (B<sub>53</sub>) among the stakeholders ranked second in this major category. Industrial managers should take initiatives to build awareness among customers and stakeholders. Finally, the lack of setting appropriate performance measures ranked last.

**Table8.** Rank of the order of organizational barriers

	Severity (5,7,9)	Probability of Occurrence (3,5,7)	Manageability (5,7,9)	CC <sub>i</sub>	Rank
B <sub>51</sub>	(3,5,7)	(3,5,7)	(5,7,9)	0.7564	1
B <sub>52</sub>	(5,7,9)	(3,5,7)	(3,5,7)	0.1299	3
B <sub>53</sub>	(7,9,9)	(5,7,9)	(5,7,9)	0.5766	2

Table 9 shows the overall global ranking of all sub-barriers. Lack of investment (B<sub>22</sub>) was ranked first with closeness coefficient of 0.555. High carbon emission due to extended transportation (B<sub>11</sub>) and lack of information sharing among stakeholders (B<sub>32</sub>) ranked second and third, respectively. Lack of appropriate performance measure (B<sub>52</sub>) ranked last. In this research, all the sub-barriers were ranked to better understand them. Moreover, this study will help industrial managers and supply chain specialists to formulate CLSCs strategically.

**Table9.** Overall global rank of the order of all sub-barriers

Major barriers	Relative closeness coefficient	Sub-barriers	Relative closeness coefficient	Relative Rank	Global closeness coefficient	Global Rank
Environmental barriers (B <sub>1</sub> )	0.5959	High carbon emission due to extended transportation (B <sub>11</sub> )	0.7706	1	0.459	2
		Lack of proper solid waste management (B <sub>12</sub> )	0.3011	2	0.179	8
		Lack of environment-friendly technology for dismantling (B <sub>13</sub> )	0.2294	3	0.137	10
Economic barriers (B <sub>2</sub> )	0.7449	Low profit margin for refurbished products (B <sub>21</sub> )	0.2798	4	0.208	7
		Lack of investment (B <sub>22</sub> )	0.7455	1	0.555	1
		Price fluctuation (B <sub>23</sub> )	0.4408	3	0.328	5
		High cost of the process of environmental adaptation (B <sub>24</sub> )	0.4634	2	0.345	4
Information related barriers (B <sub>3</sub> )	0.6379	Lack of accuracy in forecasting (B <sub>31</sub> )	0.3802	2	0.243	6
		Lack of information sharing among stakeholders (B <sub>32</sub> )	0.6198	1	0.395	3
		Lack of information about returned product quality (B <sub>33</sub> )	0.2782	3	0.177	9
Manufacturing and technology related barriers (B <sub>4</sub> )	0.2110	Poor product design (B <sub>41</sub> )	0.5571	2	0.118	13
		Lack of proper inventory management (B <sub>42</sub> )	0.5810	1	0.123	12
		Lack of modern production technology (B <sub>43</sub> )	0.2978	3	0.063	15
Organizational barriers (B <sub>5</sub> )	0.1709	Lack of long term strategic planning (B <sub>51</sub> )	0.7564	1	0.129	11
		Lack of appropriate performance measure (B <sub>52</sub> )	0.1299	3	0.022	16
		Lack of awareness (B <sub>53</sub> )	0.5766	2	0.099	14

## 6. Managerial and practical Implications

With the continuous improvement of green supply chains, a sustainable CLSCs are increasingly becoming popular among manufacturers, academics, and decision-makers. This research may be beneficial for manufacturers when conceptualizing the nature of key CLSC barriers. Through assessing the key CLSC barriers, the decision-makers of relevant areas can refine their existing manufacturing strategies to save natural resources. This study can be a guideline for manufacturers when identifying key barriers and developing policies for mitigating their limitations.

The managerial implications of this research are summarized below:

- **Developing strategic policy for implementing closed loop supply chain:** To reduce emission of carbon gas and other toxic gases, it is urgent to develop a strategic policy for CLSC implementation within the existing business. This paper may be beneficial to automotive manufacturers who attempt to identify major CLSC barriers and adopt CLSCs with respect to their current service practices.

- **Arranging different training programs:** Remanufacturing, refurbishing all discarded products, and recycling have increased in popularity among manufacturing environments for economic and environmental reasons. To achieve sustainability as well as compete with developed countries, different training programs must be arranged for enhancing user awareness. Government can play a vital role in this regard. Presently, government is paying more attention to environmental protection and forces enterprises to reproduce parts from old products.
- **Developing organizational vision and managerial policy to adapt new practice:** In order to adapt a green supply chain, each organization must formulate its vision and proper policy. This paper will help managers to craft vision and formulate managerial policy.

## 7. Conclusions

With the rapid development of green manufacturing, CLSCs are a common practice. For environmental and economic reasons, many developed countries are pursuing CLSCs. Closed loop supply chain management (CLSCM) helps to save natural materials and energy consumption through reducing the emissions of hazardous gases especially carbon emissions. This strategy also curtails the production cost of manufacturers. In Bangladesh, the automotive industry is growing very rapidly because of a dense population and strong economic and technological developments. It is necessary to implement manufacturing policy and achieve sustainable remanufacturing as a competitive means. Although remanufacturing/recycling has brought a revolutionary change in business, the path is not so easy for all. Many implementation barriers exist. So, to achieve benefits, supply chain managers must focus on the identification of the barriers and formulation of strategic decisions. This research aimed to address the following questions:

1. Which are the key barriers of implementing closed loop supply chain in automotive industry in the context of Bangladesh?
2. What is the severity of these barriers?
3. What should be the strategy for successful implementation of these factors in existing one?

To address the preceding questions, this study proposed a structured framework to examine Bangladeshi CLSC barriers. For this purpose, a Delphi based fuzzy TOPSIS approach has been applied. A total of five major barriers and 20 sub-barriers were selected through the literature review and expert's feedback using Delphi analysis. A fuzzy TOPSIS approach was applied to identify barrier severity. The five major barriers were Environmental barriers ( $B_1$ ), Economic barriers ( $B_2$ ), Information related barriers ( $B_3$ ), Manufacturing and technology related barriers ( $B_4$ ) and Organization related barriers ( $B_5$ ). Their ranking was as follows: *Economic barriers* > *Information related barriers* > *Environmental barriers* > *Manufacturing and technology related barriers* > *Organization related barriers*. The economic barrier ( $B_2$ ) had the highest priority and ranked first. This indicated that the automotive industries of Bangladesh should formulate their CLSC strategy by giving the highest consideration to this barrier. The information-related barrier ( $B_3$ ) ranked second. Among all five major barriers, the organizational barrier ( $B_5$ ) ranked last with a closeness coefficient of 0.1709. To protect the environment, decision makers of automotive industries should give more attention to these attributes. Moreover, the government should enforce laws and arrange different training programs to raise awareness which ultimately improves the economy.

### 7.1. Limitations of the research

The limitations of this study were as follows:

1. In this study, only five major drivers and 20 sub-drivers were considered for ranking.
2. Only five automotive companies were selected in a specific area (Dhaka base).
3. Feedbacks were collected from 20 groups of logistics experts. This might not reveal the real picture of the business.
4. The proposed methodology was applied in a case study which may not be applicable to another company. Thus, this study may lack universal application. However, given its uniqueness as a case study, some transferability may be appropriate for similar entities.
5. Delphi based fuzzy TOPSIS approach was used to rank the factors which is dependent on human judgments.

The limitations can provide a new way for future research.

### 7.2. Direction of future research

1. In future, more barriers of closed loop supply chain can be considered.
2. The impact and interaction among these factors can be assessed using other MCDM techniques like VIKOR, PROMETHEE, and so on.
3. Further assessment may occur by considering more automotive industries in Bangladesh.

Appendix A

**Table A1.** Fuzzy decision matrix by experts for major barriers

	Severity (5,7,9)	Probability of occurrence (3,5,7)	Manageability (5,7,9)
B <sub>1</sub>	(3,5,7)	(3,5,7)	(5,7,9)
B <sub>2</sub>	(3,5,7)	(3,5,7)	(7,9,9)
B <sub>3</sub>	(5,7,9)	(7,9,9)	(5,7,9)
B <sub>4</sub>	(3,5,7)	(1,3,5)	(3,5,7)
B <sub>5</sub>	(5,7,9)	(3,5,7)	(3,5,7)

**Table A2.** Normalized fuzzy decision matrix for major barriers

	Severity (5,7,9)	Probability of occurrence (3,5,7)	Manageability (5,7,9)
B <sub>1</sub>	(1.000,0.600,0.429)	(0.333,0.556,0.778)	(0.556,0.778,1.000)
B <sub>2</sub>	(1.000,6.000,0.429)	(0.333,0.556,0.778)	(0.778,1.000,1.000)
B <sub>3</sub>	(0.600,0.429,0.333)	(0.778,1.000,1.000)	(0.556,0.778,1.000)
B <sub>4</sub>	(1.000,0.600,0.429)	(0.111,0.333,0.556)	(0.333,0.556,0.778)
B <sub>5</sub>	(0.600,0.429,0.333)	(0.333,0.556,0.778)	(0.333,0.556,0.778)

**Table A3.** Weighted normalized fuzzy decision matrix for major barriers

	Severity (5,7,9)	Probability of occurrence (3,5,7)	Manageability (5,7,9)
B <sub>1</sub>	(5.000,4.200,3.857)	(1.000,2.778,5.444)	(2.778,5.444,9.000)
B <sub>2</sub>	(5.000,4.200,3.857)	(1.000,2.778,5.444)	(3.889,7.000,9.000)
B <sub>3</sub>	(3.000,3.000,3.00)	(2.333,5.000,7.000)	(2.778,5.444,9.000)
B <sub>4</sub>	(5.000,4.200,3.857)	(0.333,1.667,3.889)	(1.667,3.889,7.000)
B <sub>5</sub>	(3.000,3.000,3.000)	(1.000,2.778,5.444)	(1.667,3.889,7.000)

**Table A4.** Fuzzy positive ideal solution for major barriers

	Severity (5,7,9)	Probability of occurrence (3,5,7)	Manageability (5,7,9)
B <sub>1</sub>	0	1.7451	1.1037
B <sub>2</sub>	0	1.7451	0
B <sub>3</sub>	1.4347	0	1.1037
B <sub>4</sub>	0	2.8746	2.4911
B <sub>5</sub>	1.5347	1.7451	2.4911

**Table A5.** Fuzzy negative ideal solution for major barriers

	Severity (5,7,9)	Probability of occurrence (3,5,7)	Manageability (5,7,9)
B <sub>1</sub>	1.4347	1.1689	1.5973
B <sub>2</sub>	1.4347	1.1689	2.4911
B <sub>3</sub>	0	2.8746	1.5973
B <sub>4</sub>	1.4347	0	0
B <sub>5</sub>	0	1.1689	0

## References

- Abbey, J. D., Meloy, M. G., Guide Jr, V. D. R., and Atalay, S. (2015). Remanufactured products in closed-loop supply chains for consumer goods. *Production and Operations Management*, Vol. 24(3), pp. 488-503.
- Alqahtani, A.Y. and Gupta, S.M. (2019). *Warranty and preventive maintenance for remanufactured products: Modeling and analysis*. Boca Raton, FL: CRC Press.
- Al Zaabi, S., Al Dhaheri, N., and Diabat, A. (2013). Analysis of interaction between the barriers for the implementation of sustainable supply chain management. *The International Journal of Advanced Manufacturing Technology*, Vol. 68(1-4), pp. 895-905.
- Aras, N., Boyaci, T., and Verter, V. (2004). The effect of categorizing returned products in remanufacturing. *IIE transactions*, Vol. 36(4), pp. 319-331.
- Atasu, A., Guide Jr, V. D. R., and Van Wassenhove, L. N. (2008). Product reuse economics in closed-loop supply chain research. *Production and Operations Management*, Vol. 17(5), pp. 483-496.
- Autry, C. and Moon, M. (2016). *Achieving supply chain integration: Connecting the supply chain inside and out for competitive advantage*. Old Tappan, NJ: Parson Education.
- Azizi, a., Aikhuele, D.O., and Souleman, F.S. (2015). A fuzzy TOPSIS model to rank automotive suppliers. *Procedia Manufacturing*, Vol. 2(2015), pp. 159-164.
- Bazan, E., Jaber, M. Y., and Zanoni, S. (2017). Carbon emissions and energy effects on a two-level manufacturer-retailer closed-loop supply chain model with remanufacturing subject to different coordination mechanisms. *International Journal of Production Economics*, Vol. 183, pp. 394-408.
- Beamon, B. M. (1999). Designing the green supply chain. *Logistics information management*, Vol. 12(4), pp. 332-342.
- Bell, E., Bryman, A., and Harley, B. (2018). *Business research methods*. New York: Oxford university press.
- Besbes, K., Allaoui, H., Goncalves, G., and Loukil, T. (2013). A green supply chain design with product life cycle considerations. *Supply Chain Forum*, Vol. 14(2), pp. 18-25.
- Bouzon, M., Govindan, K., Rodriguez, C.M.T., Campos, L.M.S. (2016). Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. *Resour. Conserv. Recycl.* Vol. 108, pp. 182-197.
- Brady, S. R. (2015). Utilizing and adapting the Delphi method for use in qualitative research. *International Journal of Qualitative Methods*, Vol. 14(5), pp. 1-6.
- Braz, A. C., De Mello, A. M., de Vasconcelos Gomes, L. A., and de Souza Nascimento, P. T. (2018). The bullwhip effect in closed-loop supply chains: A systematic literature review. *Journal of cleaner production*, Vol. 202, pp. 376-389.
- Choi, T. M., Li, Y., and Xu, L. (2013). Channel leadership, performance and coordination in closed loop supply chains. *International Journal of Production Economics*, Vol. 146(1), pp. 371-380.
- Chu, T. C., & Lin, Y. C. (2003). A fuzzy TOPSIS method for robot selection. *The International Journal of Advanced Manufacturing Technology*, Vol. 21(4), pp. 284-290.
- Clotey, T., Benton Jr, W. C., and Srivastava, R. (2012). Forecasting product returns for remanufacturing operations. *Decision Sciences*, Vol. 43(4), pp. 589-614.
- Fahimnia, B., Sarkis, J., Dehghanian, F., Banihashemi, N., and Rahman, S. (2013). The impact of carbon pricing on a closed-loop supply chain: an Australian case study. *Journal of Cleaner Production*, Vol. 59, pp. 210-225.
- Farajpour, F., and Yousefli, A. (2018). Information flow in supply chain: A fuzzy TOPSIS parameters ranking. *Uncertain Supply Chain Management*, Vol. 6(2), pp. 181-194.
- Fleischmann, M., and Minner, S. (2004). Inventory management in closed loop supply chains. In *Supply chain management and reverse logistics* (pp. 115-138). Springer, Berlin, Heidelberg.
- Fleischmann, M., Van Nunen, J. A., and Gräve, B. (2003). Integrating closed-loop supply chains and spare-parts management at IBM. *Interfaces*, Vol. 33(6), pp. 44-56.
- Garg, K., Kannan, D., Diabat, A., and Jha, P. C. (2015). A multi-criteria optimization approach to manage environmental issues in closed loop supply chain network design. *Journal of Cleaner Production*, Vol. 100, pp. 297-314.
- Gentles, S. J., Charles, C., Ploeg, J., and McKibbin, K. (2015). Sampling in qualitative research: Insights from an overview of the methods literature. *The Qualitative Report*, Vol. 20(11), pp. 1772-1789.

- Georgiadis, P., and Besiou, M. (2008). Sustainability in electrical and electronic equipment closed-loop supply chains: a system dynamics approach. *Journal of Cleaner Production*, Vol. 16(15), pp. 1665-1678.
- Go, T. F., Wahab, D. A., Rahman, M. A., Ramli, R., and Azhari, C. H. (2011). Disassemblability of end-of-life vehicle: a critical review of evaluation methods. *Journal of Cleaner Production*, Vol. 19(13), pp. 1536-1546.
- Govindan, K., and Soleimani, H. (2017). A review of reverse logistics and closed-loop supply chains: a Journal of Cleaner Production focus. *Journal of Cleaner Production*, Vol. 142, pp. 371-384.
- Govindan, K., Shankar, K. M., and Kannan, D. (2016). Application of fuzzy analytic network process for barrier evaluation in automotive parts remanufacturing towards cleaner production—a study in an Indian scenario. *Journal of Cleaner Production*, Vol. 114, 199-213.
- Han, H., and Trimi, S. (2018). A fuzzy TOPSIS method for performance evaluation of reverse logistics in social commerce platforms. *Expert Systems with Applications*, Vol. 103, pp. 133-145.
- Hwang, C. L., and Yoon, K. (1981). Methods for multiple attribute decision making. In *Multiple attribute decision making* (pp. 58-191). Springer, Berlin, Heidelberg.
- Hwang, H., Ko, Y. D., Yune, S. H., and Ko, C. S. (2009). A closed-loop recycling system with a minimum allowed quality level on returned products. *International Journal of Services and Operations Management*, Vol. 5(6), pp. 758-773.
- Ike, L. (2017). *Strategic management: Concepts & Practices*. Bloomington, IN: Xlibris.
- Janaki, D., Izadbakhsh, H., and Hatefi, S. (2018). The evaluation of supply chain performance in the Oil Products Distribution Company, using information technology indicators and fuzzy TOPSIS technique. *Management Science Letters*, Vol. 8(8), pp. 835-848.
- Jason, L.A. and Glenwick, D.S. (2016). *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods*. New York, NY: Oxford University Press.
- John, S. T., and Sridharan, R. (2013). Modelling and analysis of network design for a closed-loop supply chain. *International Journal of Logistics Systems and Management*, 14(3), pp. 329-352.
- Kamal, Y., and Ferdousi, M. (2009). Supply chain management practices in automobile industry: Study of Ford vs. Toyota. *Dhaka University Journal of Business Studies*, Vol. 30(2), pp. 75-90.
- Kannan, G., Sasikumar, P., and Devika, K. (2010). A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling. *Applied Mathematical Modelling*, Vol. 34(3), pp. 655-670.
- Keyvanshokoh, E., Ryan, S. M., and Kabir, E. (2016). Hybrid robust and stochastic optimization for closed-loop supply chain network design using accelerated Benders decomposition. *European Journal of Operational Research*, Vol. 249(1), pp. 76-92.
- Kim, J., Do Chung, B., Kang, Y., and Jeong, B. (2018). Robust optimization model for closed-loop supply chain planning under reverse logistics flow and demand uncertainty. *Journal of cleaner production*, Vol. 196, 1314-1328.
- Krapp, M., Nebel, J., and Sahamie, R. (2013). Forecasting product returns in closed-loop supply chains. *International Journal of Physical Distribution & Logistics Management*, Vol. 43(8), pp. 614-637.
- Krikke, H., Blanc, I. L., and van de Velde, S. (2004). Product modularity and the design of closed-loop supply chains. *California management review*, Vol. 46(2), pp. 23-39.
- LeBlanc, R. (2016). *Auto or car recycling facts and figures: Facts about car or automobile recycling*. Retrieved from: <https://www.thebalancesmb.com/auto-recycling-facts-and-figures-2877933>
- Lee, S., and Seo, K. K. (2016). A hybrid multi-criteria decision-making model for a cloud service selection problem using BSC, fuzzy Delphi method and fuzzy AHP. *Wireless Personal Communications*, Vol. 86(1), pp. 57-75.
- Lu, Q., Goh, M., Garg, M., & De Souza, R. (2014). Remanufacturing in Asia: location choice and outsourcing. *The International Journal of Logistics Management*, Vol. 25(1), pp. 20-34.
- Manners-Bell, J. and Lyon, K. (2019). *The logistics and supply chain handbook: Disruptive technologies and new business models*. New York, NY: Kogan Page.
- Mittal, V.K. and Sangwan, K.S. (2014). Fuzzy TOPSIS method for ranking barriers to environmentally conscious manufacturing implementation: Government, industry, and expert perspectives. *International Journal of Environmental Technology and Management*, Vol. 17(1), pp. 57-81

- Mohajeri, A., and Fallah, M. (2016). A carbon footprint-based closed-loop supply chain model under uncertainty with risk analysis: A case study. *Transportation Research Part D: Transport and Environment*, Vol. 48, pp. 425-450.
- Murry, J.W. and Hammons, J.O. (1995). Delphi: a versatile methodology for conducting qualitative research. *Rev. High. Educ.* Vol. 18, pp. 423-436.
- Okoli, C., and Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information & Management*, Vol. 42(1), pp. 15–29.
- Östlin, J., Sundin, E., and Björkman, M. (2008). Importance of closed-loop supply chain relationships for product remanufacturing. *International Journal of Production Economics*, Vol. 115(2), pp. 336-348.
- Ovchinnikov, A. (2011). Revenue and cost management for remanufactured products. *Production and Operations Management*, Vol. 20(6), pp. 824-840.
- Özkır, V., and Başlıgil, H. (2013). Multi-objective optimization of closed-loop supply chains in uncertain environment. *Journal of Cleaner Production*, Vol. 41, pp. 114-125.
- Paydar, M. M., Babaveisi, V., and Safaei, A. S. (2017). An engine oil closed-loop supply chain design considering collection risk. *Computers & Chemical Engineering*, Vol. 104, pp. 38-55.
- Petrudi, S., Abdi, M., and Goh, M. (2018). An integrated approach to evaluate suppliers in a sustainable supply chain. *Uncertain Supply Chain Management*, Vol. 6(4), pp. 423-444.
- Pochampally, K. K., Gupta, S. M., and Kamarthi, S. V. (2004, February). Evaluation of production facilities in a closed-loop supply chain: a fuzzy TOPSIS approach. In *Environmentally Conscious Manufacturing III* (Vol. 5262, pp. 125-139). International Society for Optics and Photonics.
- Ruiz-Torres, A. J., Mahmoodi, F., and Ohmori, S. (2019). Joint determination of supplier capacity and returner incentives in a closed-loop supply chain. *Journal of Cleaner Production*, Vol. 215, pp. 1351-1361.
- Sahyouni, K., Savaskan, R. C., and Daskin, M. S. (2007). A facility location model for bidirectional flows. *Transportation Science*, Vol. 41(4), pp. 484-499.
- Savaskan, R.C., Bhattacharya, S., and Van Wassenhove, L. (2004). Closed-loop supply chain models with product remanufacturing. *Management Science*, Vol. 50(2), pp. 239-252.
- Seitz, M. A. (2007). A critical assessment of motives for product recovery: the case of engine remanufacturing. *Journal of Cleaner Production*, Vol. 15(11-12), pp. 1147-1157.
- Shaharudin, M. R., Zailani, S., and Tan, K. C. (2015). Barriers to product returns and recovery management in a developing country: investigation using multiple methods. *Journal of Cleaner Production*, Vol. 96, pp. 220-232.
- Shi, J., Zhou, J., and Zhu, Q. (2019). Barriers of a closed-loop cartridge remanufacturing supply chain for urban waste recovery governance in China. *Journal of Cleaner Production*, Vol. 212, pp. 1544-1553.
- Spengler, T., Stölting, W., and Ploog, M. (2004). Recovery Planning in Closed Loop Supply Chains: An Activity Analysis Based Approach. In *Supply chain management and reverse logistics* (pp. 61-89). Springer, Berlin, Heidelberg.
- Stoycheva, S., Marchese, D., Paul, C., Padoan, S., Juhmani, A. S., and Linkov, I. (2018). Multi-criteria decision analysis framework for sustainable manufacturing in automotive industry. *Journal of Cleaner Production*, Vol. 187, pp. 257-272.
- Sun, C. C. (2010). A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert systems with applications*, 37(12), pp. 7745-7754.
- Taleizadeh, A. A., Mamaghan, M. K., and Torabi, S. A. (2018). A possibilistic closed-loop supply chain: pricing, advertising and remanufacturing optimization. *Neural Computing and Applications*, pp. 1-21.
- Tsoufias, G. T., and Pappis, C. P. (2006). Environmental principles applicable to supply chains design and operation. *Journal of Cleaner Production*, Vol. 14(18), pp. 1593-1602.
- Van Wassenhove, L. N. (2009). The Evolution of Closed-Loop Supply Chain Research. *Operations research*, Vol. 1, pp. 10-19.
- Wang, W., Ding, J., and Sun, H. (2018). Reward-penalty mechanism for a two-period closed-loop supply chain. *Journal of cleaner production*, Vol. 203, pp. 898-917.
- Wei, J., and Zhao, J. (2011). Pricing decisions with retail competition in a fuzzy closed-loop supply chain. *Expert Systems with Applications*, Vol. 38(9), pp. 11209-11216.
- Wong, C.W., Lai, K., Lun, Y.H., and Cheng, T.C. (2016). *Environmental management: The supply chain perspective*. New York, NY: Springer.

- Xu, Z., Elomri, A., Pokharel, S., Zhang, Q., Ming, X. G., and Liu, W. (2017). Global reverse supply chain design for solid waste recycling under uncertainties and carbon emission constraint. *Waste management*, Vol. 64, pp. 358-370.
- Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, Vol. 8(3), pp. 338-353.
- Zhang, X., and Xu, Z. (2015). Soft computing based on maximizing consensus and fuzzy TOPSIS approach to interval-valued intuitionistic fuzzy group decision making. *Applied Soft Computing*, Vol. 26, pp. 42-56.
- Zhang, Y., He, Y., Yue, J., and Gou, Q. (2019). Pricing decisions for a supply chain with refurbished products. *International Journal of Production Research*, Vol. 57(9), pp. 2867-2900.
- Zhou, L., Gupta, S. M., Kinoshita, Y., and Yamada, T. (2017). Pricing decision models for remanufactured short-life cycle technology products with generation consideration. *Procedia CIRP*, Vol. 61, pp. 195-200.
- Zokaee, S., Jabbarzadeh, A., Fahimnia, B., and Sadjadi, S. J. (2017). Robust supply chain network design: an optimization model with real world application. *Annals of Operations Research*, Vol. 257(1-2), pp. 15-44.