Analysing the roadblocks of circular economy adoption in the automobile sector: reducing waste and environmental perspectives

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Abstract

The automobile industry is one of the most rapidly growing sectors in our society. The increase in demand for vehicles drives the growth of the automobile sector worldwide. Fabrication of vehicles consumes an enormous amount of water, energy, and resources, thereby increasing carbon emissions. Non-biodegradable and manufacturing waste after the end of life usage results in a significant contribution to incineration, landfills, air acidification and water eutrophication. The adoption of circular economy (CE) initiatives can play a significant role in dealing with increasing waste and environmental pollution. The main goal of CE is to recycle and reuse materials to reduce waste and also to minimise environmental impacts. This article strongly supports the adoption of CE in the Indian automobile industry. For the successful adoption of CE in the Indian automobile sector, firstly, it is important to analyse roadblocks to the adoption. Twenty potential roadblocks towards the adoption of CE have been identified from a literature review and in consultation with experts in the field. To capture the vagueness of the data and to carry out a robust analysis, a TOPSIS method with Fuzzy theory is employed. The results reveal that roadblock 'lacking ability to deliver high quality remanufactured products' is ranked first among all considered roadblocks. This study will help the Indian automobile industry, decision-makers, research practitioners and government officials in developing effective strategies for adopting CE in Indian automobile companies. Sensitivity analysis has been conducted to validate the stability of results.

Keywords: Business Strategy; Environment; Roadblocks; Automobile Industry; Circular Economy; Fuzzy TOPSIS

1. Introduction

The global population is increasing at a very high rate (Govindan and Hasanagic, 2018) with resource consumption also increasing as a result. Advancement in technology and increased production results in depletion of natural resources, causing severe damage to the environment

(Garza-Reyes et al., 2019). There is an increase in demand for resources such as minerals, water, land, energy and fuels (Zhang et al., 2019; Carmeli et al., 2020). Therefore, to tackle increasing resource demand, effective resource management policies and strategies need to be implemented. Circular economy (CE) is a concept to tackle such problems (Govindan and Hasanagic, 2018; Scarpellini et al., 2020). CE provides an ideal solution to meet the challenges presented by an increase in resource consumption and depletion of natural resources (Nadeem et al., 2019). Although CE is a new concept in ecology development, the core concept has been with us since the 1960s. Boulding (1966) suggested that the ecological system should be cyclic to maintain constant production on earth. In the 1990s, the idea of CE was also promoted by two environmental economists, Pearce and Turner (1990). They described a traditional economy system which does not focus on recycling strategies and forms an open system. They suggested using a closed system flow of material in which resources can be recycled or reused for other purposes; they named this CE.

CE can be defined as a closed loop in a system where materials and energy flow in a closed loop through multiple channels (Nadeem et al., 2017). The principle behind CE is the formation of a closed-loop of material flow, energy flow and waste. CE is now gaining more importance among researchers because of its triple bottom line (TBL) benefits. The main goal of CE is to recycle and reuse materials to reduce waste and also to minimise environmental impacts such as carbon footprint, water footprint and air acidification. Apart from environmental and economic benefits, CE increases product life through recycling and reuse of the product. Initially, 3R practices have been adopted in CE (Zhijun and Nailing, 2007; Su et al., 2013; Orazalin, 2020). 3R practice involves reducing, reuse and recycle. With the development of sustainable theories, 6R concepts have become more popular and have been adopted into CE (Kim and Goyal 2011; Govindan et al., 2016), 6R concepts include the initial 3R concepts along with recover, redesign and remanufacture. As well as CE, two more concepts have emerged in recent literature namely, Industrial Ecology (IE) and Extended Product Life (EPL) as noted by Gregson et al. (2015). IE is focused on minimising raw material use and resource consumption and promotes sustainable production; EPL is focused on minimising waste generation and enhancing utilisation techniques.

The Indian automobile sector is a leading competitor in the international automobile arena. Indian automobile companies are the world's fourth-largest manufacturers of passenger cars and seventh-largest manufacturers of commercial vehicles as presented in the report of Department for Promotion of Industry and Internal Trade (DPIIT) (Kumar et al., 2020).The growing demand for vehicles leads to the heavy fabrication of vehicles which consumes an enormous amount of water, energy and resources, thereby increasing carbon emissions. The CE model manages more efficient resource consumption. It minimises the need for raw materials by reutilising existing or waste material. The adoption of CE is very important nowadays in dealing with increasing waste and environmental pollution. Many studies are dedicated to CE because of its sustainable advantages. Recent studies are available on different perspectives of CE and over a wide range of applications. CE research has been conducted in different sectors, including the supply chain, manufacturing industries, service sectors, the automobile sector and so on. Many initiatives are presented in literature regarding the adoption of CE in recent years, but unfortunately, many emerging countries are not making any efforts to implement CE.

Roadblocks associated with CE implementation have not been studied in any depth in the Indian automotive sector. Deployment of sustainability initiatives such as the circular economy in the automotive sector can provide financial opportunities. So, there is a need to investigate potential roadblocks of implementing CE in emerging economies. CE has many potential benefits for the automobile sector; it is therefore important to adopt these concepts for the success of the Indian economy. From this viewpoint, this article supports the adoption of CE in Indian companies. For the successful adoption of CE into the sector, first, it is important to analyse roadblocks to achieve successful adoption. In this context, the present work addresses two research questions;

RQ1: What are the potential roadblocks in implementing CE concepts in Indian automobile companies?

RQ2: How can these roadblocks be analysed to identify a priority order to help in developing effective strategies for adopting CE in the Indian automobile sector?

As per the above-mentioned research questions, the following objectives are set for this study:

- To identify potential roadblocks to implement CE concepts in Indian automobile companies.
- To analyse and prioritize roadblocks of CE by calculating their weights.
- To propose business strategies and practical implications to adopt CE practices in the Indian automobile sector.

To fulfil these objectives, this works starts with the identification of potential roadblocks for the adoption of CE in the Indian automobile sector through an extensive literature review and in consultation with experts in the field. This study uses a Fuzzy TOPSIS method for analysis and prioritization of roadblocks under a vague environment. Fuzzy TOPSIS has been considered by many researchers for solving various prioritization problems (Ighravwe and Oke, 2017; Dhull and Narwal 2018; Falqi et al., 2019). To overcome the obstacles to CE implementation, the organisation must consider these roadblocks during the implementation period. Potential roadblocks have been discussed and recommendations have been suggested to mitigate any roadblocks. The contribution of this study is to prioritize the roadblocks for successful implementation of CE practices in the Indian automobile sector. Practical implications have been presented to help Indian automobile industries, decision-makers, research practitioners and government officials for successful adoption of CE practices.

This paper consists of six sections. Section 1 includes the introduction and motivation for this study. Section 2 contains a summary of the previous literature on CE. Section 3 includes a description of the adopted methodology for analysis. Section 4 includes a case study and results obtained, along with sensitivity analysis. Section 5 consists of discussions and implications. Conclusions, limitations, and future work are proposed in Section 6.

2. Previous literature

In this section, previous literature has been reviewed to support the present study. Recognising the trend in relevant literature, it is noted that most of the studies regarding CE has been conducted in the last four years; the concept is gaining much more importance nowadays given our methods of production in manufacturing industries.

2.1 Review of roadblocks to CE

In the current scenario, CE is firmly aimed towards sustainable development (Kirchherr et al., 2018; Demirel and Danisman, 2019). Most research studies have considered technological roadblocks as an important parameter hindering the implementation of CE. Kirchherr et al. (2018) analysed the CE roadblocks in the European Union (EU). They surveyed CE roadblocks in the EU resulting in 48 expert interaction and 208 survey respondents. Based on this survey result, they developed a CE roadblocks framework in which the roadblocks were identified around four key dimensions - namely cultural, regulatory, market and technological. The study revealed cultural roadblocks as the most influencing of these for CE implementation. Amongst cultural roadblocks, "lacking consumer interest and awareness" and "hesitant company culture" were found to be the key roadblocks. They suggested that in future, the framework could be refined by considering a greater sample size. CE is considered as an alternative to the traditional approach of "make-use-dispose" (Kumar et al., 2018). In the manufacturing sector, many organisations are striving hard to position themselves better, but appropriate strategies have not been identified for them in existing literature for CE implementation. Thus, Kumar et al. (2019) identified the opportunities and roadblocks to CE in manufacturing organisations via economic, legal, socio-political and environmental viewpoints. They adopted a survey questionnaire approach of more than 200 manufacturing companies operating in the EU and UK. The roadblocks and opportunities were identified through an extensive literature review with the key result highlighted. The study assessed "low level of public awareness on CE" and "lack of understanding of CE principles" as the most influencing roadblocks in the socio-political category. From the environmental perspective, "inadequate water resource systems" was identified as the biggest barrier. The authors advised identifying more potential roadblocks and conducting an analysis with a greater number of samples. In-depth interviews could also be conducted to obtain quantitative data. Ethirajan et al. (2020) analysed risks associated with CE initiatives in the SC of a manufacturing organization. Their study found 31 risks associated with CE initiatives and used a DEMATEL approach to analyse identified risks. Results reveal that a transparent process is the most crucial risk associated with CE initiatives in SC. Frei et al. (2020) analysed the adoption level of CE and sustainable practices in the retail return system. The study highlighted various barriers and challenges in adoption of CE and sustainable practices, while suggesting solutions to tackle those challenges. Moktadir et al. (2020) presented and analysed critical success factors (CSFs) of CE practices in the leather industry. The study identified CSFs of CE practices from a literature review and in consultation with domain experts. Authors used the best worst method (BWM) to analyse and prioritize CSFs and also used DEMATEL to identify cause and effect relationships among CSFs of CE practices. Results revealed that the most important CSF of CE practices is "top management commitment". The study helped the leather industry to minimize waste by adopting CE practices in the existing supply chain.

2.2 Review on CE initiatives adoption in an automobile industry

Agyemang et al. (2018) adopted an exploratory method to establish the roadblocks and drivers of micro-level CE acceptance in Pakistan's automobile industry. Data had been collected by conducting surveys and interviews. Findings showed "profitability/market share/benefit", "cost reduction" and "business principle/concern for environment/appreciation" as the most influential drivers for CE implementation. Roadblocks such as "unawareness", "cost and financial constraint" and "lack of expertise" were found to be the top roadblocks for CE implementation. The major finding from the study focused on the reduction of the cost required for implementation; this roadblock was the reason why many organisations experienced delays in CE implementation. The study identifies the drivers and roadblocks of CE in Pakistan's automobile industry, giving a direction on how to conduct similar studies in different countries. Studies identified various enablers and roadblocks to CE and the difficulties of implementation of CE business models in small and medium enterprises (SMEs) (Rizos et al., 2016; Tura et al., 2019). In this study, various SMEs were nominated from GreenEcoNet, a web-based platform with experience of CE initiatives. The roadblocks "lack of support from supply and demand network" and "lack of capital" were recognised as influential roadblocks for CE implementation (Rizos et al. 2016).

CE is a concept developed to focus on maximising the use of resources and generating value by reusing and regenerating resources (Bernon et al., 2018). Initially, the CE concept was developed to aid the economic growth of China and other developed countries, but it can also be adopted in many developing countries to enhance their resource utilisation and make their manufacturing sectors more sustainable.

CE is an important concept for developing countries to minimise waste and to improve public health and environment conditions. Yet little attention has been given by developing countries to the implementation of CE concepts. Developing countries, such as India and Bangladesh, can exemplify the importance of CE by importing waste electronics product from developed countries like China for recycling and reuse (Amoyaw-Osei and Agyekum, 2011). This shows the overall benefits of CE in terms of the environment, the economy and social conditions. Table 1 shows a summary of previous literature.

Table 1: Summary of previous literature

Authors	**Contributions**
Geng et al. (2009)	Highlighted the initiatives taken by China in CE. Also highlighted the challenges associated with implementing CE.
Park et al. (2010)	Identified and analysed roadblocks and challenges in implementing CE.
Zhang et al. (2011)	Presented the issues associated with the remanufacturing process and also highlighted potential roadblocks.
Geng et al. (2012)	Reviewed the indicators of implementing CE in China. The study shows that indicators help in achieving the goals and outcomes of CE.
Su et al. (2013)	Presented the roadblocks and opportunities of deploying CE in China.
Rizos et al. (2016)	The paper presented an analysis of enablers and roadblocks in implementing CE in SMEs.
Singh and Ordoñez (2016)	Presented a survey to analyse the challenges in implementing CE.
Geissdoerfer et al. (2017)	Analysed the CE and sustainability concept, showing the similarities and differences between them.
Galvão et al. (2018)	Reviewed 195 articles about roadblocks and challenges of CE.
Kirchherr et al. (2018)	Presented a survey on roadblocks of CE in the European Union region.
Ranta et al. (2018)	Analysed and compared general and regional-based drivers and roadblocks of CE in China, US and Europe.
Agyemang et al. (2019)	Analysed the drivers and roadblocks in implementing CE in Pakistan based automobile industry.
Hart et al. (2019)	Reviewed and identified the roadblocks and drivers of CE in the built environment.
Kumar et al. (2019)	Presented a comprehensive review on CE and analysed the roadblocks of implementing CE in the UK and EU.
Tura et al. (2019)	Proposed a framework consisting of drivers and roadblocks of CE. The developed framework helped a firm to implement CE initiatives.
Bassi and Dias (2020)	Aimed to adopt CE practices in SMEs in the European region. They analysed the pattern of implementation of CE practices among different level firms.
Dey et al. (2020)	Analysed adoption of CE practices in SMEs to enhance sustainable development. The study highlights implementation benefits in terms of sustainable development and also presents challenges and opportunities of implementing CE practices in SMEs

Authors	Contributions
Frei et al. (2020)	Analysed adoption level of CE and sustainable practices in the retail return system.
Ethirajan et al. (2020)	Analysed risks associated with CE initiatives in SC of a manufacturing organization and also suggested business strategies to overcome identified risks.
Moktadir et al. (2020)	Identified and analysed CSFs of CE implementation in the leather industry.

2.3 Research gaps

The Indian automobile sector plays an important role in the growth of the Indian economy. Indian automobile factories contribute around 49% to the Indian manufacturing GDP and around 7.5% to the overall GDP of the country. Indian automobile companies and their supply chains also play an important role in employment as they employ around 32 million people. Indian automobile companies are the world's fourth-largest manufacturer of passenger cars and the seventh-largest manufacturer of commercial vehicles as presented in the report of Department for Promotion of Industry and Internal Trade (DPIIT). Increase in global warming and pollution levels pressurises all countries to improve their environmental policies to achieve sustainable development (Kumar et al., 2020). The automotive sector in India is increasing efforts in adopting sustainability initiatives such as CE; however, implementation is still uneven due to a lack of awareness of the roadblocks hindering it. Also, implementation of CE in the Indian automotive sector provides financial benefits in terms of less resource utilisation, less waste, agile production process etc. In this context, the implementation of CE concepts in Indian automobile companies leads to sustainable development and growth of the Indian economy. From the literature survey, it has been noted that many recent studies have concentrated on the identification of roadblocks and drivers of CE in both developed and developing countries, including China (Geng et al., 2009; Su et al., 2013), UK and EU (Kumar et al., 2019), Bangladesh (Moktadir et al., 2018) and Pakistan (Agyemang et al., 2019). Specific studies about the manufacturing sector in India are rare. Studies are also available in the identification of roadblocks of implementing CE, but very few studies look at prioritization and identification of the most influencing CE roadblocks. Therefore, this study attempts to fill this literature gap. This study presents the analysis of roadblocks of implementing CE in the Indian automobile sector. It enables industrial practitioners to formulate effective business strategies and supply chain planning for implementing CE in this important sector.

3. Methodology

In this section, the selected methodology for the analysis of roadblocks of CE is described; the reason for the selection of specified methodology has also been presented. In this study, a Fuzzy based technique for Order Preference by Similarity to Ideal Solution (F-TOPSIS) has been considered for analysing roadblocks of CE. Fuzzy logic was first presented by Zadeh in 1965. Fuzzy set theory can represent vague knowledge. Fuzzy set theory and the membership function are efficient in minimising vagueness in decision making and therefore Fuzzy set theory is included in MCDM applications to obtain realistic and optimised solutions for decision-making problems (Kaya et al., 2019). TOPSIS is a Multi-Criteria Decision Making (MCDM) method used in both theoretical and practical applications for analysis of alternatives based on certain criteria. The TOPSIS method was developed by Hwang and Yoon (1981). The principle behind the TOPSIS method is that it compares all alternatives with ideal solutions. In TOPSIS, there are two kinds of ideal solutions, the positive ideal solution (PIS) and negative ideal solution (NIS). PIS signifies maximisation of beneficial criteria and minimisation of non-beneficial criteria, whereas NIS signifies minimisation of beneficial criteria and maximisation of non-beneficial criteria (Dey and Chakraborty, 2016). TOPSIS compares each alternative with PIS and NIS and prioritises alternatives based on minimum geometrical distance with PIS and maximum geometrical distance with NIS. The best alternative possesses minimum distance with PIS and maximum distance with NIS. Several applications of Fuzzy TOPSIS can be seen in previous studies. Fuzzy TOPSIS has been considered as the best tool by many researchers for solving various prioritization problems e.g. prioritizing maintenance strategies for sustainable maintenance strategy in manufacturing systems (Ighravwe and Oke, 2017), ranking drivers of green supply chain management (Dhull and Narwal 2018), prioritization of knowledge management strategies (Akhavan et al., 2019), selection of concrete materials for sustainability (Falqi et al., 2019), selection of dry bulk carriers (Sahin et al., 2020) and sustainable electric vehicles model comparison (Samaie et al., 2020). Kolios et al. (2016) compared various MCDM techniques namely, Weighted Sum Method (WSM), Weighted Product Method (WPM), Analytical Hierarchy Process (AHP), Preference Ranking Organization Method For Enrichment

Evaluation (PROMETHEE), Elimination Et Choix Traduisant La Realité (ELECTRE) along with TOPSIS for selection of offshore wind turbine installation problems. This research highlighted that the TOPSIS method predicts better optimum design alternatives than other MCDM tools. The reason for selecting Fuzzy TOPSIS method in this study is because it has several advantages over other MCDM methods. These include the ability to analyse the best alternatives quickly, good computational efficiency, can be easily adopted with a large number of criteria and alternatives, identifies both best and worst alternatives based on PIS and NIS and visualisation of the solution is easy as it compares alternatives with PIS and NIS through geometrical distance (Olson, 2004; Roszkowska, 2011; Çelikbilek and Tüysüz, 2020). The steps in Fuzzy TOPSIS are as follows:

1. The first step is the development of a decision matrix. A decision matrix is developed between alternatives and criteria. Then a decision matrix is developed by comparing alternatives with respect to each criterion.

$$X = \begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{matrix} C_1 & C_2 & \dots & C_n \\ \begin{bmatrix} ⓧX_{11} & ⓧX_{12} & \dots & ⓧX_{1n} \\ ⓧX_{21} & ⓧX_{22} & \dots & ⓧX_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ ⓧX_{m1} & ⓧX_{m2} & \cdots & ⓧX_{mn} \end{bmatrix} \end{matrix}$$

   Where,

   C_1, C_2,...C_n are n criteria, A_1, A_2,...A_m are m alternatives, and $ⓧX_{mn}$ are fuzzy numbers (p_{ij}, q_{ij}, r_{ij}) of mth alternative with respect to n^{th} criteria

2. The second step is to make a normalised decision matrix; normalisation makes each criterion comparable with others; equations 1 and 2 are used for normalisation.

$$X' = \begin{bmatrix} ⓧX'_{11} & ⓧX'_{12} & \dots & ⓧX'_{1n} \\ ⓧX'_{21} & ⓧX'_{22} & \dots & ⓧX'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ ⓧX'_{m1} & ⓧX'_{m2} & \cdots & ⓧX'_{mn} \end{bmatrix}$$

   Where, $ⓧX'_{mn}$ is the normalised rating of m^{th} alternative with respect to n^{th} criteria.

   If criteria belong to beneficial type,

$$ⓧX'_{ij} = \frac{ⓧX_{ij}}{X_j^{max}} = [\frac{p_{ij}}{r_j^{max}}, \frac{q_{ij}}{r_j^{max}}, \frac{r_{ij}}{r_j^{max}}] \quad (1 \leq i \leq m, 1 \leq j \leq n) \tag{1}$$

   If criteria belong to non-beneficial type,

$\otimes X'_{ij} = \frac{\otimes x_j^{min}}{x_{ij}} = [\frac{p_j^{min}}{p_{ij}}, \frac{p_j^{min}}{q_{ij}}, \frac{p_j^{min}}{r_{ij}}]$ (1 ≤ i ≤ m, 1 ≤ j ≤ n) (2)

3. The third step is to develop a weighted normalised grey decision matrix by multiplying the normalised decision matrix with the criteria weights. Equation 3 is used to calculate the weighted normalised grey decision matrix.

$$D = \begin{bmatrix} \otimes D_{11} & \otimes D_{12} & \cdots & \otimes D_{1n} \\ \otimes D_{21} & \otimes D_{22} & \cdots & \otimes D_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes D_{m1} & \otimes D_{m2} & \cdots & \otimes D_{mn} \end{bmatrix}$$

Where, $\otimes D_{ij} = \otimes X'_{ij} \times \otimes W_j$ (3)

$\otimes W_j$ is the weight of criteria for all $(1 \leq j \leq n)$

4. The fourth step is to identify ideal solutions. In this step, PIS and NIS are identified and are represented by I^+ and I^-. Equations 4 and 5 are used to analyse PIS and NIS.

$I^+ = \{(\max p_{i1}, \max q_{i1}, \max r_{i1}), (\max p_{i2}, \max q_{i2}, \max r_{i2}) \ldots (\max p_{in}, \max q_{in}, \max r_{in})\}$
(1 ≤ i ≤ m) (4)

$I^- = \{(\min p_{i1}, \min q_{i1}, \min r_{i1}), (\min p_{i2}, \min q_{i2}, \min r_{i2}) \ldots (\min p_{in}, \min q_{in}, \min r_{in})\}$
(1 ≤ i ≤ m) (5)

5. The fifth step is to calculate distance of each alternative from PIS and NIS and is represented by d^+ and d^- respectively. Equations 6 and 7 are used to calculate the distance of alternatives with PIS and NIS.

$d^+ = \sqrt{\frac{1}{3}\sum_{j=1}^{n}\{|p_{ij} - I^+|^2 + |q_{ij} - I^+|^2 + |r_{ij} - I^+|^2\}}$ (1 ≤ i ≤ m, 1 ≤ j ≤ n) (6)

$d^- = \sqrt{\frac{1}{3}\sum_{j=1}^{n}\{|p_{ij} - I^-|^2 + |q_{ij} - I^-|^2 + |r_{ij} - I^-|^2\}}$ (1 ≤ i ≤ m, 1 ≤ j ≤ n) (7)

6. The sixth and final step is to calculate the closeness value of all alternatives with respect to PIS. The ranking of alternatives is based on closeness value. Alternatives with high closeness value will be given more priority (Dey and Chakraborty, 2016). Equation 8 is used to calculate the closeness value of all alternatives.

Closeness (C) = $\frac{d^-}{d^- + d^+}$ (8)

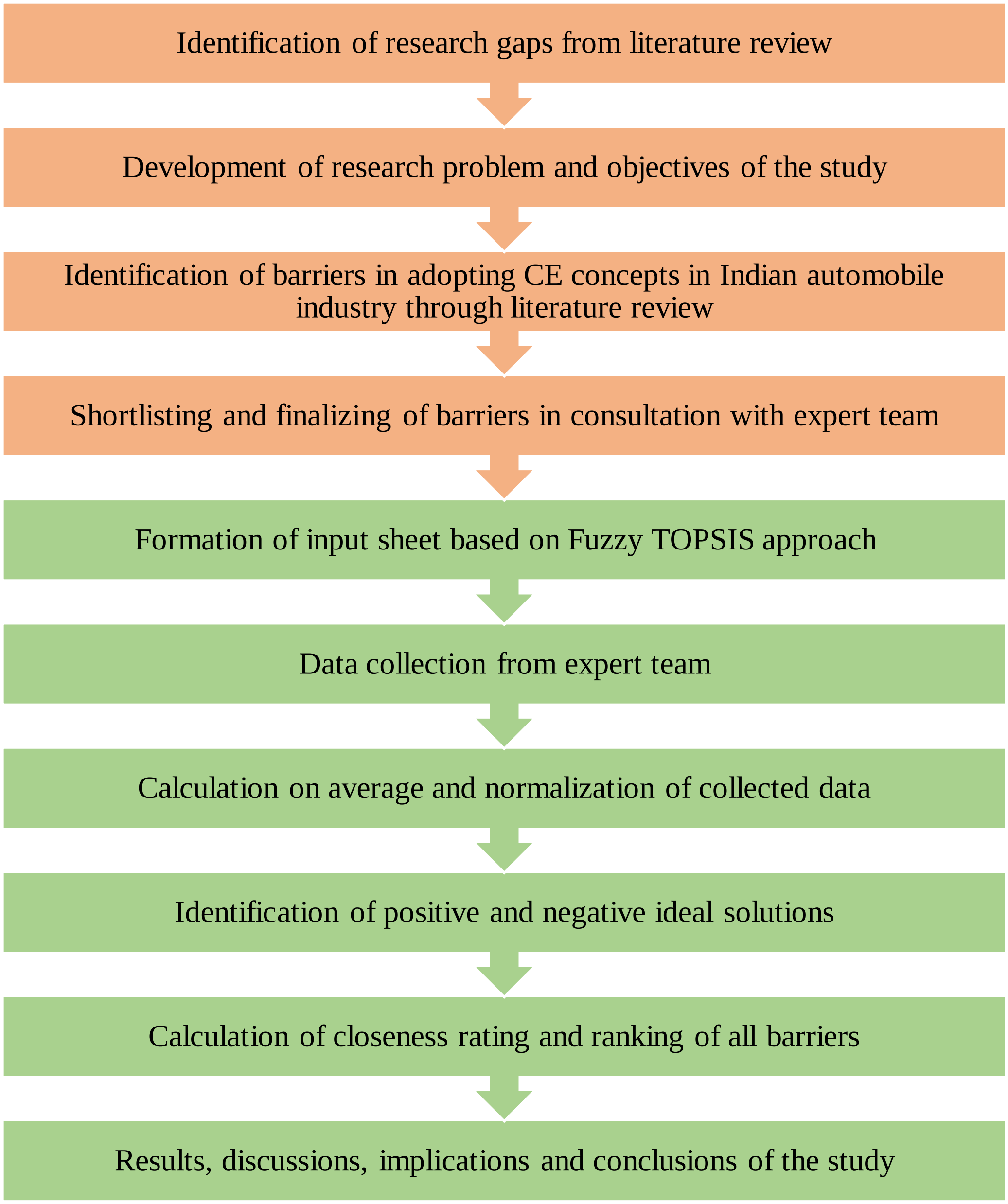

Figure 1: Methodology framework for the study

4. Analysis and results

In this section, an application and results are presented. Details regarding problem description, data collection, calculation and results obtained are presented and discussed. To achieve the research objectives of the work, the methodology framework shown in Figure 1 has been followed.

4.1 An Application

This work presents a case study into Indian automobile companies where the problem is to deal with roadblocks in adopting CE concepts. The automobile industry in India is under tremendous pressure from the government to minimize environmental pollution and heavy wastage. The adoption of CE concepts into the sector leads to minimization of industrial waste and landfills, thereby enabling sustainable development. However, for successful adoption of CE concepts, it is important to analyse the roadblocks. Therefore, this study presents an analysis of roadblocks in adopting CE in the Indian automobile sector. To gather in-depth knowledge of working practice, five experts from automobile companies have been consulted. A panel of five experts (one senior manager, one industrial engineer and three junior managers involved in sustainable manufacturing activities in their organizations) was set up. These experts have vast knowledge of the sector and all possess valuable industrial experience in the automobile industry.

4.2 Selection of roadblocks

Thirty-two potential roadblocks on the adoption of CE concepts in Indian automobile companies were identified from the literature review. The experts were consulted to check on the identified roadblocks. Consensus response was taken in discussion with all experts for shortlisting and finalising the identified roadblocks. The experts were also asked to suggest any other roadblocks which were not already listed. No other roadblocks were suggested; a finalized list of twenty roadblocks, the most important in the implementation of CE concepts, was drawn up. These are presented in Table 2 along with a description of each.

Table 2: Identified roadblocks for CE

S. No.	Roadblocks	Description of roadblocks	References
1.	Lack of funding for CE (B_1)	Funds are needed to make a shift from a linear economy to CE, especially in developing countries having a weaker economy	Rizos et al. (2016), Govindan and Hasanagic (2018), De Jesus and Mendonça (2018), Kirchherr et al. (2018), Tura et al. (2019), Ozkan-Ozen et al. (2020)
2.	Complexity in transformation for CE (B_2)	Complexity in transformation includes different contexts such as the supply chain for CE, certification and the make-up of	Govindan and Hasanagic (2018), Tura et al. (2019)

S. No.	Roadblocks	Description of roadblocks	References
		products.	
3.	Limited availability of reuse product (B_3)	Less availability of refurbished products; buyers may have fewer options to select refurbished products.	Govindan and Hasanagic (2018)
4.	Challenges in taking back (B_4)	Systems needed to develop take back strategies for implementing CE	Govindan and Hasanagic (2018), Tura et al. (2019), Bilal et al. (2020)
5.	Customer perspective towards the purchase of remanufactured product (B_5)	Customers are more focused on buying a new product rather than a remanufactured product.	Govindan and Hasanagic (2018)
6.	Lack of availability of a successful business model (B_6)	As successful business models of CE are limited, firms are not attracted to implementing CE	Govindan and Hasanagic (2018), Kirchherr et al. (2018), Tura et al. (2019), Ozkan-Ozen et al. (2020)
7.	Lack of flexibility of organisational structure to implement CE (B_7)	Most organisations in emerging economies do not have the flexibility to implement CE. Organisations need to have a flexible structure and supply chain to implement CE.	Govindan and Hasanagic (2018), Guldmann and Huulgaard (2020)
8.	Lack of knowledge towards CE (B_8)	Lack of knowledge about CE hinders implementation in organisations.	Govindan and Hasanagic (2018), De Jesus and Mendonça (2018), Tura et al. (2019), Guldmann and Huulgaard (2020)
9.	Lack of consumer knowledge about refurbished products (B_9)	Customers are not aware of refurbished products. In general, a customer thinks that a refurbished product is of lower quality than a new product	Govindan and Hasanagic (2018), Kirchherr et al. (2018), Bilal et al. (2020)
10.	Lack of awareness in society (B_{10})	Little awareness about the benefits of adopting and promoting CE.	Govindan and Hasanagic (2018), Kirchherr et al. (2018), Tura et al. (2019), Bilal et al. (2020)
11.	Maintaining the design of reuse	It is difficult and challenging to manage design for reuse products.	Govindan and Hasanagic (2018), Kirchherr et al.

S. No.	Roadblocks	Description of roadblocks	References
	product (B_{11})		(2018)
12.	High cost of eco-friendly material (B_{12})	The cost will increase when materials are selected with an eco-friendly profile.	Govindan and Hasanagic (2018)
13.	High production cost (B_{13})	Product cost will increase when implementing CE. In CE more focus is given on recycling and reuse of product, thus increasing cost.	Govindan and Hasanagic (2018), Tura et al. (2019), Jaeger and Upadhyay (2020)
14.	Limited technology for recycled material (B_{14})	Non-availability of adequate technology for recycled material.	Govindan and Hasanagic (2018), Tura et al. (2019), Bilal et al. (2020)
15.	Resistance to change in behaviour (B_{15})	It is difficult to change the mindset of people towards implementing CE.	Rizos et al. (2016), De Jesus and Mendonça (2018)
16.	Lack of government support (B_{16})	In emerging economies where cost is a major concern, government support is limited in adopting CE.	Rizos et al. (2016), Kirchherr et al. (2018), Ozkan-Ozen et al. (2020)
17.	Lack of support from distribution channel (B_{17})	Traditional distribution channels won't have much flexibility to adopt supply chain strategy for CE.	Rizos et al. (2016), Tura et al. (2019), Bilal et al. (2020)
18.	Low virgin material prices (B_{18})	Generally, virgin materials are available at lower prices compared to recycled material.	Kirchherr et al. (2018), Guldmann and Huulgaard (2020)
19.	Lacking the ability to deliver high quality remanufactured products (B_{19})	It is difficult to make a high-quality product with recycled or reuse parts.	Kirchherr et al. (2018), Govindan and Hasanagic (2018), Jaeger and Upadhyay (2020)
20.	Too few large-scale demonstration projects (B_{20})	Projects about the implementation of CE are unavailable, restricting implementation in a fully-fledged way.	Kirchherr et al. (2018)

4.3 Analysis of roadblocks

This analysis starts with a selection of criteria to examine roadblocks in implementing CE practices. From the literature review, three criteria have been selected, namely technical, economical, and cultural aspects (Mahpour, 2018; Kirchherr et al., 2018; Choudhary et al., 2020). The selected criteria play an important role in the adoption of CE practices in the automobile sector. However, the selection of criteria may vary from organization to organization. Therefore, selected experts' team were asked to validate the selected criteria and their consensus opinions were taken. Experts suggested that the selected criteria were significant and have practical relevance for the adoption of CE in the Indian automobile sector.

The considered roadblocks are compared with three criteria, namely technical, economical, and cultural aspects. For comparison, data has been collected from experts. An input sheet was prepared based on a Fuzzy TOPSIS approach and sent to all experts from the team. The input sheet was issued to ten experts but because of Covid-19, we received responses from only six experts. This data was collected using a fuzzy scale shown in Table 3. The collected input data is presented in Appendix Table A1. The average rating of roadblocks concerning all considered criteria is shown in Table 4.

The ranking of roadblocks of CE for the Indian automobile sector has been analysed using the Fuzzy TOPSIS method. A decision matrix has been constructed by collecting the data from experts using fuzzy numbers in the form of TFN through linguistic variables. The decision matrix compares all considered roadblocks with selected criteria. The normalised decision matrix and weighted normalised decision matrix were then formed. For each criterion, PIS and NIS have been identified and using the Euclidean distance method, the geometrical distance of each alternative from PIS and NIS has been calculated. The ranking of the roadblocks has been listed by calculating the closeness rating of all roadblocks with the PIS.

Table 3: Linguistic scale used in this study

For roadblocks rating		**For Criteria weights**	
Linguistics	**Fuzzy Number**	**Linguistics**	**Fuzzy Number**
Very Low	(0,0,1)	Highly Unimportant	(0,0,0.1)
Low	(0,1,3)	Unimportant	(0,0.1,0.3)
Medium Low	(1,3,5)	Fairly Unimportant	(0.1, 0.3, 0.5)
Medium	(3,5,7)	Fair	(0.3, 0.5, 0.7)
Medium High	(5,7,9)	Fairly Important	(0.5, 0.7, 0.9)
High	(7,9,10)	Important	(0.7, 0.9, 1)
Very High	(9,10,10)	Highly Important	(0.9, 1, 1)

Table 4: Average rating of Roadblocks

Roadblocks	**Technical**	**Economical**	**Cultural**
Weights of roadblocks	**(0.34,0.54,0.74)**	**(0.82,0.96,1)**	**(0.46,0.66,0.84)**
B_1	(7.4,9,9.8)	(5,7,8.6)	(1.8,3.8,5.8)
B_2	(7,8.8,9.8)	(2.2,4.2,6.2)	(5.8,7.8,9.2)
B_3	(2.6,4.6,6.6)	(6.2,8.2,9.6)	(8.2,9.6,10)
B_4	(5,7,8.6)	(7.8,9.2,9.8)	(5,7,8.8)
B_5	(3.8,5.8,7.8)	(8.2,9.6,10)	(5.4,7.4,9)
B_6	(5,7,8.6)	(7.8,9.4,10)	(5,7,8.8)
B_7	(6.6,8.4,9.6)	(5,7,8.8)	(7.4,9,9.8)
B_8	(7,8.8,9.8)	(5.4,7.4,8.8)	(7.4,9,9.8)
B_9	(3.8,5.8,7.8)	(7.8,9.4,10)	(8.2,9.6,10)
B_{10}	(3.8,5.8,7.8)	(7.8,9.4,10)	(8.2,9.6,10)
B_{11}	(7.8,9.4,10)	(5.8,7.8,9.4)	(8.2,9.6,10)
B_{12}	(6.2,8,9.2)	(7.8,9.4,10)	(2.6,4.6,6.6)
B_{13}	(7.4,9.2,10)	(7.8,9.4,10)	(2.6,4.6,6.6)
B_{14}	(8.2,9.6,10)	(5.8,7.8,9.4)	(4.2,6.2,8)
B_{15}	(3.8,5.8,7.8)	(6.6,8.4,9.6)	(7.8,9.4,10)
B_{16}	(6.2,8,9.2)	(5.8,7.8,9.2)	(5.4,7.4,9)
B_{17}	(5.8,7.8,9.4)	(6.2,8,9.4)	(5,7,8.6)
B_{18}	(3.8,5.8,7.8)	(7.8,9.4,10)	(3.4,5.4,7.4)
B_{19}	(8.6,9.8,10)	(7.4,9,9.8)	(7,8.8,9.8)
B_{20}	(5,7,8.6)	(4.2,6.2,8)	(4.6,6.6,8.4)

After establishing the average rating of all roadblocks in the three categories, normalisation of data has been carried out using equations 1 and 2. Weights of each category have been multiplied by the normalised rating to get weighted normalised ratings of all roadblocks as mentioned in equation 3. Normalised ratings and weighted normalised ratings are shown in Table 5.

Table 5: Normalised and weighted normalised rating of roadblocks of CE

Roadblocks	**Normalised rating**			**Weighted normalised rating**		
	Technical	**Economical**	**Cultural**	**Technical**	**Economical**	**Cultural**
B_1	(0.74,0.9,0.98)	(0.5,0.7,0.86)	(0.18,0.38,0.58)	(0.251,0.486,0.725)	(0.41,0.672,0.86)	(0.083,0.251,0.487)
B_2	(0.7,0.88,0	(0.22,0.42,	(0.58,0.78,	(0.238,0.475,	(0.180,0.403	(0.267,0.515,

	.98)	0.62)	0.92)	0.725)	,0.62)	0.773)
B_3	(0.26,0.46,0.66)	(0.62,0.82,0.96)	(0.82,0.96,1)	(0.088,0.248,0.488)	(0.508,0.787,0.96)	(0.377,0.633,0.84)
B_4	(0.5,0.7,0.86)	(0.78,0.92,0.98)	(0.5,0.7,0.88)	(0.17,0.378,0.636)	(0.639,0.883,0.98)	(0.23,0.462,0.739)
B_5	(0.38,0.58,0.78)	(0.82,0.96,1)	(0.54,0.74,0.9)	(0.129,0.313,0.577)	(0.672,0.922,1)	(0.248,0.488,0.756)
B_6	(0.5,0.7,0.86)	(0.78,0.94,1)	(0.5,0.7,0.88)	(0.17,0.378,0.636)	(0.639,0.902,1)	(0.23,0.462,0.739)
B_7	(0.66,0.84,0.96)	(0.5,0.7,0.88)	(0.74,0.9,0.98)	(0.224,0.453,0.71)	(0.41,0.672,0.88)	(0.340,0.59,0.823)
B_8	(0.7,0.88,0.98)	(0.54,0.74,0.88)	(0.74,0.9,0.98)	(0.238,0.475,0.725)	(0.443,0.71,0.88)	(0.340,0.59,0.823)
B_9	(0.38,0.58,0.78)	(0.78,0.94,1)	(0.82,0.96,1)	(0.129,0.313,0.577)	(0.639,0.902,1)	(0.377,0.634,0.84)
B_{10}	(0.38,0.58,0.78)	(0.78,0.94,1)	(0.82,0.96,1)	(0.129,0.313,0.577)	(0.639,0.902,1)	(0.377,0.634,0.84)
B_{11}	(0.78,0.94,1)	(0.58,0.78,0.94)	(0.82,0.96,1)	(0.265,0.507,0.74)	(0.476,0.749,0.94)	(0.377,0.634,0.84)
B_{12}	(0.62,0.8,0.92)	(0.78,0.94,1)	(0.26,0.46,0.66)	(0.210,0.432,0.68)	(0.639,0.902,1)	(0.119,0.304,0.554)
B_{13}	(0.74,0.92,1)	(0.78,0.94,1)	(0.26,0.46,0.66)	(0.251,0.496,0.74)	(0.639,0.902,1)	(0.119,0.304,0.554)
B_{14}	(0.82,0.96,1)	(0.58,0.78,0.94)	(0.42,0.62,0.8)	(0.279,0.518,0.74)	(0.476,0.749,0.94)	(0.193,0.409,0.672)
B_{15}	(0.38,0.58,0.78)	(0.66,0.84,0.96)	(0.78,0.94,1)	(0.129,0.313,0.577)	(0.541,0.806,0.96)	(0.359,0.62,0.84)
B_{16}	(0.62,0.8,0.92)	(0.58,0.78,0.92)	(0.54,0.74,0.9)	(0.211,0.432,0.68)	(0.476,0.749,0.92)	(0.248,0.488,0.756)
B_{17}	(0.58,0.78,0.94)	(0.62,0.8,0.94)	(0.5,0.7,0.86)	(0.197,0.421,0.696)	(0.508,0.768,0.94)	(0.23,0.462,0.722)
B_{18}	(0.38,0.58,0.78)	(0.78,0.94,1)	(0.34,0.54,0.74)	(0.129,0.313,0.577)	(0.639,0.902,1)	(0.156,0.356,0.622)
B_{19}	(0.86,0.98,1)	(0.74,0.9,0.98)	(0.7,0.88,0.98)	(0.292,0.529,0.74)	(0.607,0.864,0.98)	(0.322,0.581,0.823)
B_{20}	(0.5,0.7,0.86)	(0.42,0.62,0.8)	(0.46,0.66,0.84)	(0.17,0.378,0.636)	(0.344,0.595,0.8)	(0.212,0.436,0.706)

Next step in the TOPSIS method is to identify ideal solutions. For each criterion, PIS and NIS have been identified. PIS signifies the best solution for particular criteria whereas NIS signifies the worst solution for particular criteria. Each criterion has a PIS and NIS. Equations 4 and 5 are used to identify PIS and NIS for all criteria. PIS and NIS of all criteria are presented in Table 6.

Table 6: Ideal solutions

Ideal solution	Technical	Economical	Cultural
Positive ideal solution (I^+)	(0.292,0.529,0.74)	(0.672,0.922,1)	(0.377,0.634,0.84)
Negative ideal solution (I^-)	(0.088,0.248,0.488)	(0.18,0.403,0.62)	(0.083,0.251,0.487)

TOPSIS compares each alternative with PIS and NIS and prioritises alternatives based on minimum geometrical distance with PIS and maximum geometrical distance with NIS. The geometrical distances of all roadblocks with PIS and NIS have been calculated using equations 6 and 7 respectively. The final step of TOPSIS is to calculate the closeness value of all alternatives with respect to PIS. The ranking of alternatives is based on closeness value. The alternative with high closeness value will be given more priority. Equation 8 is used to calculate the closeness rating of all roadblocks. The geometrical distance of all roadblocks with PIS and NIS, closeness rating of all roadblocks and ranking of roadblocks are presented in Table 7.

Table 7: Closeness rating and ranking of roadblocks

Roadblocks	D+	D-	CC	Rank
B_1	0.6048	0.4621	0.4331	19
B_2	0.6138	0.4565	0.4265	20
B_3	0.3721	0.6968	0.6519	15
B_4	0.3015	0.7672	0.7179	8
B_5	0.3045	0.7632	0.7148	9
B_6	0.2921	0.7798	0.7275	6
B_7	0.3141	0.7594	0.7074	10
B_8	0.2707	0.8001	0.7472	5
B_9	0.2043	0.8619	0.8084	4
B_{10}	0.2044	0.8619	0.8085	3
B_{11}	0.1752	0.8984	0.8368	2
B_{12}	0.3954	0.6716	0.6294	16
B_{13}	0.3446	0.7274	0.6785	11
B_{14}	0.3587	0.715	0.6659	12

B_{15}	0.2989	0.7719	0.7209	7
B_{16}	0.3611	0.7116	0.6634	13
B_{17}	0.3684	0.7074	0.6576	14
B_{18}	0.4447	0.624	0.5839	17
B_{19}	0.0969	0.9703	0.9092	1
B_{20}	0.5863	0.4831	0.4518	18

The graphical representations of closeness rating of all roadblocks are presented in Figure 2.

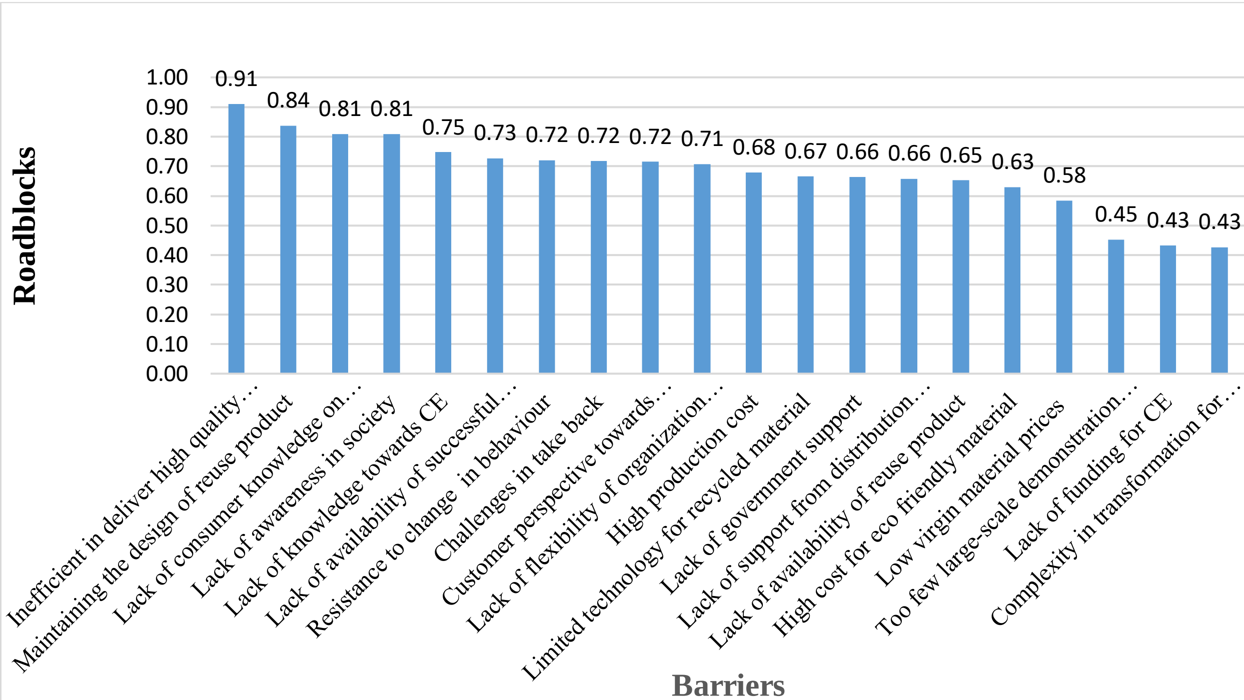

Figure 2: Graphical representation of closeness ratings of roadblocks

4.4 Sensitivity Analysis

Sensitivity analysis is an important approach for the validation of the developed model. It is necessary to analyse the working behaviour of the developed model under different working conditions (Kumar et al., 2019). Several researchers have used a sensitivity analysis approach to analyse a developed model and to validate the developed model (Mangla et al., 2017; Kumar et al., 2019). Hence in this study, changes have been made in experts' input to analyse the variations in results and to conduct sensitivity analysis.

From the data, it can be seen that economic criteria has higher weighting. Therefore, it is important to analyse the variation in results by changing the weights of economic criteria. In the presented sensitivity analysis, weights of economic criteria are changed in a systematic manner from 0.44 to 0.04 (0.44*0.9=0.40, 0.44*0.8=0.35, 0.44*0.7=0.31, 0.44*0.6=0.26, 0.44*0.5=0.22, 0.44*0.4=0.18, 0.44*0.3=0.13, 0.44*0.2=0.09, 0.44*0.1=0.04) respectively.

Table 8: Criteria weights when varying economical (E) criteria weight

Criteria	**Incremental Changes**									
	Normal	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**	**Run 9**
Technical	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39	0.41	0.43
Economical	**0.44**	**0.40**	**0.35**	**0.31**	**0.26**	**0.22**	**0.18**	**0.13**	**0.09**	**0.04**
Cultural	0.31	0.33	0.36	0.38	0.40	0.43	0.45	0.48	0.50	0.52

Table 9: Data prepared for sensitivity analysis by varying E criteria weight from 0.44 to 0.04 through incremental change

Roadblocks	**Normal**	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**Run 7**	**Run 8**	**Run 9**
B_1	19	20	20	20	20	19	19	18	18	18
B_2	20	18	17	15	14	9	7	5	5	5
B_3	15	13	13	13	11	12	12	12	12	12
B_4	8	9	10	10	13	14	14	14	14	14
B_5	9	11	12	14	15	15	15	15	15	15
B_6	6	8	9	9	12	13	13	13	13	13
B_7	10	6	4	4	4	4	4	4	4	4
B_8	5	3	3	3	3	3	3	3	3	3
B_9	3	4	5	5	5	5	5	6	6	6
B_{10}	4	4	5	5	5	5	5	6	6	6
B_{11}	2	2	2	2	2	2	1	1	1	1
B_{12}	16	16	16	17	18	18	18	19	19	19
B_{13}	11	15	15	16	16	16	17	17	17	17
B_{14}	12	14	14	12	10	11	10	10	10	10
B_{15}	7	7	7	7	7	7	8	8	8	8
B_{16}	13	10	8	8	8	8	9	9	9	9
B_{17}	14	12	11	11	9	10	11	11	11	11
B_{18}	17	17	18	19	19	20	20	20	20	20
B_{19}	1	1	1	1	1	1	2	2	2	2
B_{20}	18	19	19	18	17	17	16	16	16	16

After changing economic criteria weight, changes have been calculated in other criteria weights as presented in Table 8. The ranking of each roadblock has then been calculated based on respective changes in criteria weights as presented in Table 9. From Table 9, it can be found that maximum changes occur in barrier 2 i.e. ‘complexity in transformation for CE’. Finally, the results of sensitivity analysis are plotted in the graph shown in Figure 3.

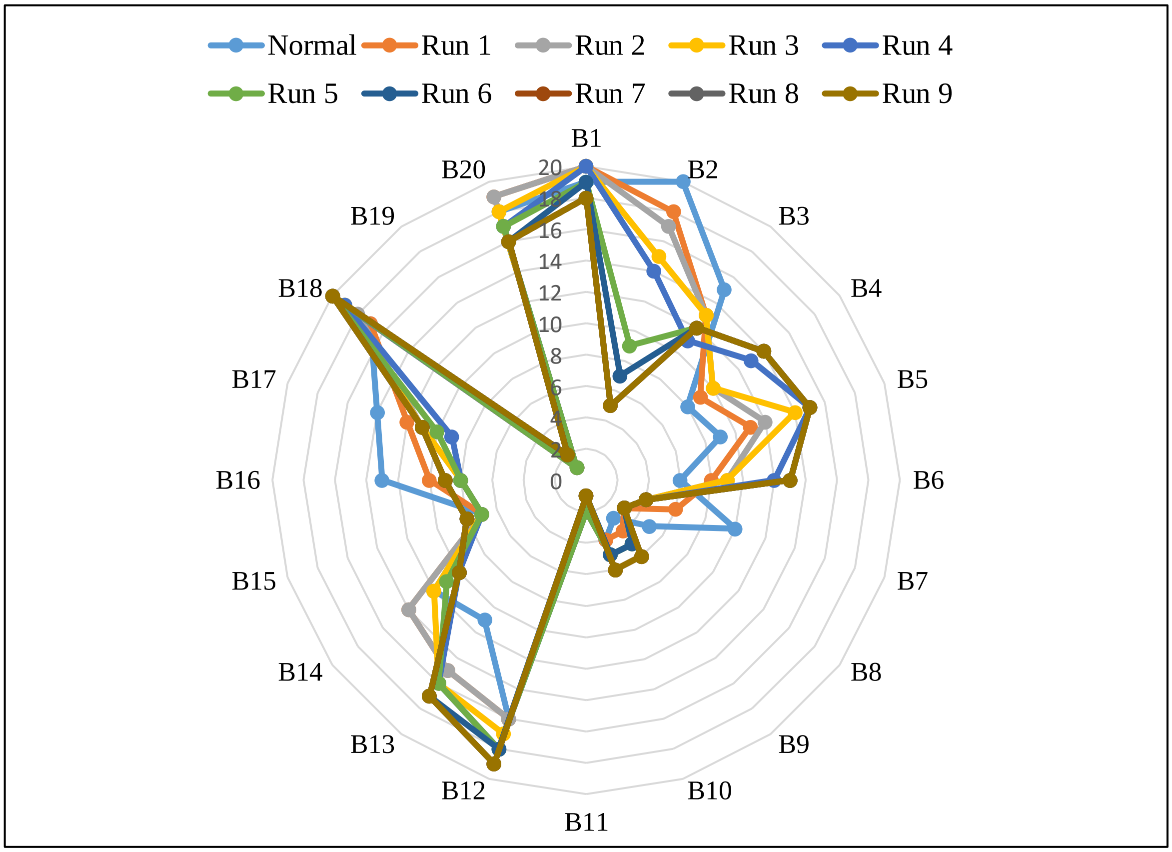

Figure 3: Sensitivity Analysis Result

Results reveal that the major identified roadblocks in adopting CE concepts in the Indian automotive industry are ‘lacking ability to deliver high quality remanufactured products (B_{19})’, ‘maintaining the design of reuse product (B_{11})’, ‘lack of awareness in society (B_{10})’ and ‘lack of consumer knowledge about refurbished products (B_9)’. This study will help the Indian automobile industry, decision-makers, research practitioners and government officials in the identification of potential roadblocks of implementing CE.

5. Discussion of Findings

This study includes a comprehensive literature review for identification of potential roadblocks of implementing CE in the context of the Indian automobile sector; it has adopted Fuzzy TOPSIS for analysing the considered roadblocks. As discussed in section 4.3, three important criteria - technical, economical, and cultural - have been considered for the analysis of twenty roadblocks to CE. The criteria were selected based on the importance of roles in the adoption of CE practices. The three criteria identified are crucial for decision-makers in analysing roadblocks in implementation planning. The criteria were further validated through the opinions of the experts consulted, given their practical knowledge within the industry.

The roadblocks to implementing CE having highest closeness value will be given as top priority. The results concluded that barrier 'lacking ability to deliver high quality remanufactured products (B_{19})' is ranked first among all considered roadblocks. The ability to deliver high quality remanufactured products requires good technology implementation (Kirchherr et al., 2018). The study from the European Union regarding roadblocks to a circular economy identified this as a technical barrier, but the least pressing one, due to the existence of good technological foundations (Kirchherr et al., 2018). The potential benefits of delivering high quality remanufactured products include high market value, decreased waste disposal and reduced extraction of resources (Galvão et al., 2018). Remanufactured products also reduce societal pressure during the implementation of sustainability initiatives (Galvão et al., 2018). This result should motivate Indian automobile companies to improve their technical foundations as this will provide a higher quality of remanufactured products. Recommendations are highlighted to draw attention to disruptive technologies such as IoT and additive manufacturing for smooth circular economy practices in the automobile industry (Arora et al., 2018).

The barrier "maintaining the design of reuse product (B_{11})" is ranked second in hindering adoption of the circular economy. Considering business model innovation, managing the design of reused products is a key aspect for the transition towards CE (Kirchherr et al., 2018; Kumar et al., 2019). The reuse product, if properly managed, enhances the productivity of an organization and delivers financial benefits (Kumar et al., 2019). A failure in the design of reuse products hinders the ability of the automobile industry to reuse and recycle (Agyemang et al., 2018).

The barrier "lack of awareness in society (B_{10})" stands at third place among all roadblocks. Although CE provides many opportunities, the awareness level about CE in society is still poor

(Guo et al., 2017; Kumar et al., 2019). The barrier "lack of consumer knowledge about refurbished product (B_9)" is ranked fourth. Customer inclination towards the use of refurbished products can be increased with the consent of original equipment manufacturers (Govindan and Hasanagic 2018). Thus, customer knowledge about the environmental advantages of refurbished products should be widely promoted to improve the uptake in buying these products. Government regulatory bodies should focus on creating awareness among consumers and highlight the significance of CE (Agyemang et al., 2018). Next, the barrier "lack of knowledge towards CE (B_8)" is ranked fifth among all roadblocks. Although only ranked fifth in this study, Govindan and Hasanagic (2018) mention this roadblock as a particularly important barrier to proceed with CE implementation. Improving knowledge about CE can help in attracting suppliers and customers to using remanufactured products (Govindan and Hasanagic 2018; De Jesus and Mendonça 2018; Tura et al., 2019).

One interesting result found in this study concerns the "low virgin material prices (B_{18})" barrier. Kirchherr et al. (2018) found low virgin material prices to be the most influential barrier hindering CE in the European Union. However, in this study, it is identified as the least pressing barrier due to the use of metal products (Malik et al., 2015). The ranking order of analysed roadblocks has been shown in Table 7.

5.1 Implications of the research

The present study analyses twenty crucial roadblocks hindering CE implementation in Indian automobile companies. The identified order of the roadblocks has research, managerial, policymaking and academic implications. This study will help the entire Indian automobile sector, as well as decision-makers, research practitioners and government officials in the identification of potential roadblocks.

CE is difficult to implement, yet this study, in identifying potential roadblocks, will be helpful for companies wishing to proceed. The most pressing roadblocks in the study will strongly motivate industrial managers to adopt CE practices. As many managers are not aware of the CE concept, whole organizations are not in a position to adopt CE practices. Managers and policymakers cannot take a lead in implementing CE unless they are well aware of its roadblocks. This study will help to kick start adoption practices. CE implementation is not a short term measure but requires a long-term undertaking to gain sustainable benefits (Kirchherr et al., 2018). CE implementation in the automobile industry is made easier if managers concentrate on the priority order of roadblocks.

The present study recognises the importance of various environmental issues related to the automotive sector. The top four roadblocks are ‘lacking ability to deliver high quality remanufactured products (B_{19})’, ‘maintaining the design of reuse product (B_{11})’, ‘lack of awareness in society (B_{10})’ and ‘lack of consumer knowledge about refurbished products (B_{9})’. This study will help Indian automobile companies, decision-makers, research practitioners and government officials to focus on specific potential roadblocks of implementing CE. Reuse products, if properly managed, enhance the productivity of an organization and deliver benefits to customers, the company itself and the wider society (Kumar et al., 2019).

To relax the environmental burden from automotive organizations, the Indian government can promote awareness of the order of roadblocks along with CE implementation. Together with ISO 4001 certification, the government can motivate manufacturers to proactively implement CE by focusing on the roadblocks suggested. In addition to this, senior-level managers can publicise projects related to CE practices and their benefits to create enthusiasm among workers. Wider coverage within society can encourage acceptance for adopting circular products. The results obtained confirm the advantages of CE implementation in automotive organizations. Companies can include CE initiatives in their long-term vision, mission and plans for a smooth adoption.

6. Conclusions

Sustainability is vitally important for companies in today’s industrial scenario. To achieve sustainability in an organisation, CE has emerged as a promising route to be followed. CE is an important concept for developing countries, aiming to minimise waste and to improve health and environmental conditions. Not enough attention is given by developing countries to the implementation of CE concepts. Even though various researchers have conducted studies related to CE, roadblock analysis to ensure smooth implementation is still considered as an avenue for industrial research. This article supports the adoption of CE in the Indian automobile industry. For the successful adoption of CE, it is important to analyse all potential roadblocks. Thus, the present study focuses on the analysis of CE roadblocks from technical, economic, and cultural perspectives for successful implementation. Potentially critical CE roadblocks were identified through an extensive literature search and validated using expert opinions. This article uses a

Fuzzy TOPSIS methodology for analysis and prioritization of roadblocks. The study motivates key stakeholders of an organisation to focus on the main CE roadblocks; namely ‘lacking ability to deliver high quality remanufactured products (B_{19})’, ‘maintaining the design of reuse product (B_{11})’, ‘lack of awareness in society (B_{10})’ and ‘lack of consumer knowledge about refurbished product (B_{9})’ in transforming from a linear economy into CE. To overcome the obstacles to CE implementation, an organisation must consider these roadblocks. There are various MCDM techniques that can be used for prioritisation; fuzzy TOPSIS is believed to be the best technique to make these decisions.

6.1 Unique contributions of the research

The important contributions of the presented study are:

- This study has filled a gap in existing literature; very few studies were available about identification and analysis of roadblocks to adopting CE concepts in automobile sectors in emerging economies such as India.
- The presented work has finalized twenty potential roadblocks from the literature review after consultation with an expert team from Indian automobile companies.
- This study used a Fuzzy TOPSIS method for analysis and prioritization of roadblocks in a vague environment. An important contribution of this study is a consideration of three important criteria, namely technical, economical, and cultural; these are crucial for decision-makers in analysing roadblocks in implementing CE.

The present study has limitations in terms of several roadblocks. The present study is conducted in an emerging country by consulting experts from Indian automobile companies. This study can be extended to other countries with limited modifications. The present study uses the TOPSIS methodology in a fuzzy environment for analysis of twenty CE roadblocks. Future studies may be performed using an integrated solution methodology for the analysis of more CE roadblocks. Since the current study is limited to automobile organisations, further research may consider different industrial sectors. Also, we suggest performing comparative analysis among industries regarding CE initiatives. Comparative analysis of CE levels among industries can be undertaken as future studies. While focusing on roadblocks identified and analysing them for prioritization, this study has not developed the relative influence of roadblocks with each other. Furthermore, the research approach is quantitative i.e. based on expert opinion; the generalized statements cannot be claimed regarding identified roadblocks in a different context. But the results obtained will help other organizations to identify potential roadblocks and to prioritize them using MCDM techniques. The development of a structural model is suggested as future research to better understand the inter-relationships among roadblocks.

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Appendix

Table A1: Input sheet prepared by collecting data from experts.

Criteria	**Technical**					**Economical**					**Cultural**				
Experts	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**
Criteria weights	F	F	FI	F	F	HI	I	HI	HI	I	FI	F	F	FI	I
Roadblocks Rating	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**	**E1**	**E2**	**E3**	**E4**	**E5**
Lack of funding for CE	H	VH	H	MH	VH	MH	M	M	H	H	ML	M	ML	ML	M
Complexity in transformation for CE	VH	H	H	H	MH	M	ML	M	M	ML	H	H	H	MH	M
Lack of availability of reuse product	M	M	ML	M	M	H	MH	H	MH	H	H	VH	VH	H	VH
Challenges in taking back	H	H	MH	M	M	VH	VH	H	VH	MH	H	MH	M	MH	MH
Customer perspective towards the purchase of a remanufactured product	MH	M	M	MH	M	VH	VH	H	VH	H	MH	H	M	MH	H
Lack of availability of a successful business model	M	H	MH	H	M	VH	H	H	H	VH	H	MH	M	MH	MH
Lack of flexibility of organizational structure to implement CE	MH	MH	VH	H	H	H	MH	M	MH	MH	VH	H	H	VH	MH
Lack of knowledge towards CE	VH	H	H	H	MH	H	H	M	H	M	MH	VH	H	H	VH
Lack of consumer knowledge on refurbished product	MH	M	M	M	MH	VH	H	H	VH	H	VH	VH	H	VH	H
Lack of awareness in society	MH	M	M	MH	M	VH	VH	H	H	H	H	VH	VH	VH	H
Maintaining the design of reuse product	VH	H	H	H	VH	H	MH	H	MH	MH	VH	H	VH	H	VH
High cost of eco-friendly material	VH	H	H	MH	M	VH	VH	H	H	H	M	ML	ML	M	MH
High production cost	H	H	VH	H	H	VH	H	VH	H	H	M	ML	M	M	M
Limited technology for recycled material	VH	H	VH	VH	H	H	MH	H	MH	MH	M	M	MH	H	M
Resistance to change in behaviour	M	M	MH	MH	M	H	VH	MH	H	MH	VH	H	H	VH	H
Lack of government support	VH	H	H	MH	M	H	H	MH	H	M	H	MH	MH	M	H
Lack of support from the distribution channel	MH	H	MH	H	MH	VH	H	MH	MH	MH	MH	M	H	M	H
Low virgin material prices	M	MH	MH	M	M	VH	H	H	H	VH	M	M	MH	M	M
Inefficient in delivering high quality remanufactured products	VH	H	VH	VH	VH	MH	VH	H	H	VH	H	MH	H	VH	H
Too few large-scale demonstration projects	H	H	M	MH	M	M	H	M	M	MH	M	MH	M	H	MH