Analysis of barriers to closed loop supply chain: A case of Indian automotive industry

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Abstract

Closed loop supply chain (CLSC) implementation has become imperative for organizations owing to resource scarcity and generation of toxic waste. However, CLSC implementation can be very challenging due to several barriers, especially in an emerging manufacturing hub such as India. This research identifies and analyzes the prominent barriers to CLSC implementation in the Indian automotive sector. Further, the paper also examines causal relationships between the barriers. A total of 22 barriers to CLSC implementation are identified from literature and subsequently, validated by industry experts. The finalized barriers are then evaluated by Analytical Hierarchy Process (AHP) and grey–Decision Making Trial and Evaluation Laboratory (DEMATEL) techniques. The study provides managers and policy makers with insights on the most prominent and causal barriers, and recommends strategies to overcome these barriers. The findings will help managers to frame short-term and long-term strategies to mitigate barriers to CLSC and contribute towards successful implementation of CLSC.

Keywords: Closed loop supply chain; barriers; AHP; grey - DEMATEL; India; automotive

1. Introduction

During the last century, development of industry and technology together with the global trade has enormously increased economic growth, which has resulted in increase in the living standards of human beings (Kok et al., 2013). The current economy works on the basis of linear model ('take, make, waste'), wherein the resources that are transformed into products end up as waste after their first useful life (Dervojeda et al., 2014). Therefore, the linear model is highly unsustainable (Ellen MacArthur Foundation, 2013). Furthermore, developing countries such as India, China, etc. are rapidly catching up with the living standards of the developed nations. This development can be attributed to increasing resource usage. It is expected that the global resource usage will increase three times by the year 2050. To address these issues, there is a need to shift to the systems that are regenerative or restorative. The circular economy (CE) can act as a paradigm wherein the resources that are used for production enter an infinite loop of reuse, remanufacturing and recycling. Closed loop supply chain (CLSC) implementation can help to realize the objectives of CE.

CLSC is "*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*" (Guide Jr. and Wassenhove, 2009). It has gained increased attention owing to environmental deterioration, customer awareness and government regulations (Pishvaee and Torabi, 2010; Ilgin and Gupta, 2010; Hong and Ke, 2011; Kenne et al., 2012; Govindan et al., 2015a; Özceylan and Paksoy, 2013). The focus of a CLSC is to recover value from the used products by integrating repair, reuse, refurbishing, remanufacturing and recycling operations (Thierry et al., 1995; Guide Jr. et al., 2003; Atasu et al., 2008; Metta and Badurdeen, 2013).

Remanufacturing is the highest degree of product recovery method as it upgrades the used products to the quality standard of new products (Raz et al., 2017; Huang et al., 2019). It has been a prominent business in the United States and has also been lately implemented by the organizations in European nations due to its profitable nature and legislative regulations being imposed by the European Union (EU) (Östlin et al., 2008). Implementation of CLSC provides firms with economic, environmental and social benefits (Wang and Huang, 2013; Diabat et al., 2013; Dervojeda et al., 2014).

CLSC implementation is quite challenging as there are several barriers in its implementation (Dora et al., 2016). Few barriers to CLSC implementation include major upfront investments, dependency on suppliers and retailers for collaboration, current product designs which are based on linear model, lack of information exchange systems, etc. (Kok et al., 2013; Dervojeda et al., 2014). In our knowledge, there has not yet been any study that has considered the comprehensive list of barriers to CLSC implementation and evaluated the most prominent barriers, and causal relationships between the barriers. We fill this gap in literature and analyze the prominent barriers by Analytical Hierarchy Process (AHP), and causal relationships between the barriers by Decision Making Trial and Evaluation Laboratory (DEMATEL) technique. AHP considers barriers to be independent of each other while DEMATEL considers inter-relationships among the barriers. Thus, AHP is used to prioritize the barriers and DEMATEL is used for examining the inter-relationships between the barriers. Further, to consider uncertainty and vagueness associated with the expert judgements, grey-systems theory is integrated with DEMATEL (Bai and Sarkis, 2013). Hence, results obtained using the AHP can be used to formulate short term

strategies, while findings obtained using grey DEMATEL can be used to frame long term strategies (Wu and Tsai, 2012; Mangla et al., 2016; Gandhi et al., 2016; Cui et al., 2019).

Indian automotive industry is currently fourth largest in the world and many firms are major exporters (IBEF, 2019). The sales of automobiles in domestic market witnessed an annual growth rate of 6.71% in the period between 2013 and 2019. Implementation of CE principles can help to keep several issues in check such as congestion, environmental pollution, greenhouse gas emissions, etc. There are several other benefits such as reduction of virgin materials, non-renewable resources and energy. There will be a potential to extract over 8 million tons of steel from end of life (EOL) vehicles in 2025, which represents an economic opportunity of nearly 2.7 billion dollars. This makes the implementation of CLSC practices an important and appealing prospect for the Indian automobile manufacturing industry (Darbari et al., 2019). Thus, this study is done in Indian automotive industry. The findings provide managers with insights on the most prominent and causal barriers, and strategies that need to be adopted to overcome these barriers. As multi-method approach is used, the paper provides recommendations to overcome short term and long term barriers. The findings can be useful for organizations that are planning to implement CLSC or those in the early stages of CLSC implementation, specifically in emerging economies. In nutshell, the major contributions of this paper are:

1. Identification of barriers to CLSC implementation in the Indian automotive sector

2. Examining the prominent categories of barriers and sub-barriers to CLSC implementation

3. Analysis of cause and effect groups of barriers to CLSC implementation

4. Provide strategies to overcome barriers in short term and long term

The remaining paper is structured as follows. Section 2 discusses the literature on CLSC and barriers to CLSC implementation. In Section 3, solution methodologies are discussed and in Section 4, an application is presented. Section 5 presents sensitivity analysis; Section 6 discusses managerial implications and Section 7 provides conclusions.

2. Literature review

2.1 CLSC implementation

The issues of resource scarcity and protection of environment have gained increased consideration throughout the world. The major issues involve how to minimize the generation of hazardous waste, prevent deterioration of environment caused by the generation of hazardous waste and recover valuable materials from the used products (Kannan et al., 2010). Products can be returned due to a number of reasons over the lifecycle, and can be classified as returns during the product lifecycle, end of use and EOL. CLSC implementation is viewed as an approach to achieve sustainable supply chain operations (Olugu and Wong, 2012), and resolve the above mentioned issues. CLSC management incorporates numerous strategies which aim to achieve greater efficiency (Geng et al., 2012).

The organizations have been focusing on zero waste management until now through the implementation of recycling processes (Dervojeda et al., 2014). However, reuse, repair, and remanufacturing activities can add most value. Examples of recovered products include automotive and electronics products, as these include high recoverable value as compared to other products (Easwaran and Üster, 2010). Few organizations that embrace the product recovery practices include Xerox, GM, Dell, HP, etc. However, product returns are of increasing concern

to industries and many industries do not view activities associated to product returns as favorable. Presently, only the small percentage of the value from used products is being recovered by the organizations around the world (Atasu et al., 2008).

CLSC implementation can help to achieve economic and environmental benefits (Savaskan et al., 2004; Krikke et al., 2003). From the economic perspective, it helps to increase revenue, reduce production costs, lower buying costs for raw materials, etc. (Savaskan et al., 2004; Lee et al., 2009; Kadambala et al., 2017). CLSC implementation also provides firms with environmental benefits such as reduction in waste, virgin material usage, etc. (Garg et al., 2015; Jayaraman, 2006). Finally, CLSC implementation has some indirect benefits such as lesser sensitivity to price volatility, better relationship with the customers, creation of new jobs, etc. (Kok et al., 2013).

2.2 Barriers to CLSC implementation

Few authors have discussed about the potential barriers to CLSC implementation. Kok et al. (2013) discussed financial, institutional, infrastructural, societal and technological barriers to CE and provided few recommendations on steps that need to be taken. A survey conducted in the EU countries found 'Cultural barriers' to be the main barriers towards CE (Kirchherr et al., 2018). According to Dervojeda et al. (2014), major upfront investments and tendency of society for linear model are significant obstacles to CLSC implementation. Rizos et al. (2015) also cited upfront costs of implementation of green initiatives as significant barrier to CLSC implementation.

Govindan and Hasanagic (2018) classified 39 barriers to CLSC implementation into following eight clusters: "Governmental issues", "Economic issues", "Technological issues", "Knowledge and skill issues", "Management issues", "Circular economy framework issues", "Cultural and social issues" and "Market issues". According to their review, the barriers that have been most discussed in literature include customer perception towards remanufactured products, lack of awareness about CE and technological limitations of firms to make remanufactured products. Mangla et al. (2018) examined 16 barriers to CLSC implementation by Interpretive Structural Modelling (ISM). The findings indicate "lack of environmental laws and regulations" and "lack of preferential tax policies for promoting the circular models" to be the major barriers. This study considers 22 barriers to implementation of CLSC. The barriers are classified as 'Financial', 'Technological', 'Cultural', 'Managerial' and 'Regulatory' barriers. The list of barriers examined in this study is given in Table 1. The contribution of our study in comparison to other studies is also given in Table 2.

Table 1. Barriers to CLSC implementation

Category	Barrier	Description	References
Financial	High cost of transition from linear to CLSC	Costs of planning, R&D, infrastructure etc.	World Economic Forum (2018)
	Major upfront investment required for CLSC implementation	Upfront fixed investments that yield returns over a long term	Dervojeda et al. (2014), Rademaekers et al. (2011)
	Limited access to funding	Financial institutions are uncertain about returns on circular models, hence there is lack of funding	Dervojeda et al. (2014), Rizos et al. (2015)
	Total cost of products made from recycled materials is often higher	Due to collection costs and low recyclate quality, recycled materials are often costly than virgin materials	Kok et al. (2013), Kirchherr et al. (2018)
Technological	Low quality of remanufactured products	It is challenging to match the quality of products that are manufactured using recovered materials	Kirchherr et al. (2018), Ghisellini et al. (2016)
	Design challenges of products for reuse and recovery	It is challenging to design products for reuse, disassembly and remanufacturing	Ghisellini et al. (2016)

	Lack of metrics to measure extent of circulatory	There are lack of standardized metrics by which progress can be measured	World Economic Forum (2018)
	Lack of information exchange	Lack of information systems hinders exchange of materials	Kok et al. (2013), Rizos et al. (2015)
	Limited availability and quality of recycling material	There are limited number of used products available and available used products are of low quality	Kok et al. (2013)
	Challenges involved in separation of bio-material from techno-cycle	The changes that aim at circular economy can lead to challenges for separation of materials that belong to bio-cycle from those belonging in the techno-cycle	Kok et al. (2013), Ghisellini et al. (2016), Mishra et al. (2018)
Cultural	Lack of awareness	The awareness of people on significance of the CLSC is limited	Kok et al. (2013)
	Resistance to change	The current way of thinking inhibits shift towards CE	Dervojeda et al. (2014), Rizos et al. (2015)
	Perception of customers towards quality of reused materials	Customers generally have perception that refurbished products are not of good quality	Genovese et al. (2015), Weelden et al. (2016)
Regulatory	Recycling policies in waste management are ineffective to obtain high quality recycling	Recycling policies do not support high quality recycling	Kok et al. (2013), de Man and Friege (2016)
	Current laws in waste management do not support CLSC implementation	The current laws related to environment in some economies do not support CLSC implementation	Li and Yu (2011), Kok et al. (2013), Rizos et al. (2015)
	Complicated or inflexible regulatory structures	Policies and regulations were designed according to linear process and limit innovation in CE	World Economic Forum (2018)
	Financial governmental incentives support linear economy	The financial governmental incentives such as value added tax stimulate high material consumption above service, because labor is highly taxed, leaving materials relatively cheap.	Kok et al. (2013)
Managerial	Poor leadership and management towards implementation of CLSC	There is lack of interest to implement CLSC due to poor leadership and management	Shahbazi et al. (2016), Su et al. (2013)
	More priority to other issues in supply chain	Managers give more priority to other issue - e.g. expansion of market share	Shahbazi et al. (2016), Govindan and Hasanagic (2018)
	Organizational structure makes it challenging to implement CLSC	Organizational structures – e.g. inefficient bureaucracy act as a challenge	Liu and Bai (2014)
	No inventive schemes for managers to use recycled materials	Managers don't get incentives for taking initiatives towards implementation of CLSC	Kok et al. (2013)
	Lack of appropriate skills in personnel	The employees in organizations do not possess skills required for CLSC implementation	Liu and Bai (2014); Weelden et al. (2016); Rizos et al. (2015)

Table 2. Comparative studies on CLSC barriers

Study	Description	Country	Methodology
Kok et al. (2013)	Discussion of obstacles to CE	Netherlands	Interviews
Dervojeda et al. (2014)	Identification of barriers to CLSC	Multiple	Case studies
Rizos et al. (2015)	Identification of barriers to CE	-	Review
Wei et al. (2015)	Barriers to remanufacturing in CLSC	China	Survey
Zhang et al. (2017)	Barriers to remanufacturing in CLSC	China	Case studies
Kirchherr et al. (2018)	Analysis of barriers to CE	Europe	Survey
Mangla et al. (2018)	Identification of contextual interactions among barriers to CLSC	India	ISM
Govindan and Hasanagic (2018)	Classification of barriers to CLSC	-	Systematic review
Our study	Examine prominent barriers, and cause and effect groups of barriers	India	AHP and grey-DEMATEL

2.3 Research objectives

India is currently the second largest populated country, and accounts for nearly 18% of the

world's population. It is experiencing several deterioration of environment as 14 out of the 15

world's most polluted cities are from India, according to the recent report by the World Health

Organization (WHO). On one side, there is a quest to maintain the industrial growth to become a

fully developed economy but there is also a need to identify the business models that do not

aggravate the resource constraints. CLSC implementation can help to achieve the same as it

decouples growth and resource requirements (Ellen MacArthur Foundation, 2016). Through the

implementation of CE models, India has nearly half a trillion dollars' worth of economic

potential that can be unlocked by the year 2030. Suitable management of plastics waste can

create over 14 lakh jobs, a potential opportunity of 2 billion dollars (FICCI, 2018).

A review of the existing literature indicates that research in barriers to CLSC implementation is

relatively scant. Recently, Mangla et al. (2018) analyzed barriers to CLSC implementation using

the ISM. Firstly, the study considered limited barriers. Further, the authors' applied ISM that

finds inter-relationships among the barriers but neither quantifies nor ranks the barriers

(Mathiyazhagan et al., 2014). Also, ISM does not classify the barriers into cause and effect groups. Thus, there is a need for a comprehensive study that takes into consideration all the barriers and further, quantifies, ranks and categorizes the barriers into cause and effect groups. The ranking of barriers is useful to devise short term strategies, and causal relationships will help firms to formulate long term strategies (Mangla et al., 2016). In the view of the above discussion, this study has following objectives:

RQ1: What are the barriers to CLSC implementation in Indian automotive sector?

RQ2: What is the framework that should be used for the evaluation of barriers to CLSC?

RQ3: What are the prominent categories of barriers and sub-barriers to CLSC implementation?

RQ4: What are cause and effect relationships between the barriers to implementation of CLSC?

3. Solution methodology

In real life situations, people are supposed to make decisions in an environment in which there are conflicting criteria (Gölcük and Baykasoğlu, 2016). Multi-criteria decision making (MCDM) methods are commonly used in such situations (Dwivedi et al., 2018). In this study, AHP (Saaty, 1980) is used to evaluate the importance of barriers to CLSC implementation. Grey - DEMATEL is used to divide the barriers into cause and effect groups, and establish contextual relationships between the barriers (Luthra et al., 2018). ISM has also been used for developing structural models and find inter-relationships among barriers in several fields. However, as the number of variables or factors are increased, ISM becomes complex to apply and hence only a limited number of factors can be considered in developing an ISM model (Govindan et al., 2014). Further, ISM neither ranks the variables nor quantifies the variables (Mudgal et al., 2010). Analytic network process (ANP) can also be used, however it requires a very complex survey

procedure for non-expert's viewpoint (Harputlugil et al., 2011). Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used for evaluating the best choice from available alternatives (Dwivedi et al., 2018). Hence, TOPSIS is not an appropriate method for this study

AHP is considered better than other MCDM methods as it easier to use and has wide applicability (Harputlugil et al., 2011). It is a well- known and widely used decision making tool in business organizations (Govindan et al., 2014; Mathew et al., 2020). AHP decomposes, organizes and analyzes the problem, and converts the problem into a hierarchical structure, which allows decision maker to pay attention on criterion and sub-criterion during the process of weight allocation (Ishizaka and Labib, 2011). AHP generates weight for each criterion according to pairwise comparisons done by the decision maker. The higher weight indicates more importance of the corresponding criteria. AHP also involves a process to check internal consistency of pairwise comparisons through the calculation of internal consistency ratio. Further, AHP does not requires large sample size for analysis (Rahman et al., 2019).

DEMATEL determines causal relationships between the factors taken into consideration in a study (Fontela and Gabus, 1974; Jeng and Huang, 2015; Gölcüka and Baykasoglu, 2016), which can help firms in making long term strategies. DEMATEL is one of the most widely used method for analyzing interdependencies among the factors (Gölcük and Baykasoğlu, 2016; Duman et al., 2019; Singh et al., 2019). The integration of grey systems theory accounts for vagueness and uncertainty in judgements made by experts (Deng, 1989; Singh and Misra, 2019).

Many authors have applied AHP to analyze the barriers in other fields (Shi et al., 2008; Patil and Kant; 2014; Dang and Chu, 2016; Luthra et al., 2016; Bouzon et al., 2016; Yadav and Desai, 2017; Moktadir et al., 2019). Grey - DEMATEL has also been used to by a number of authors to analyze certain problems in many fields (Xia et al., 2015; Luthra et al., 2018; Bhatia et al., 2020). Hence, the combination of AHP and grey - DEMATEL is considered as an appropriate tool for achieving the aims of this study. In the next section, we discuss the formulation of the MCDM problem in detail. The MCDM techniques are also briefly described in Appendix 1 and Appendix 2.

3.1 Formulation of MCDM problem

3.1.1. AHP method

Firstly, a comparison matrix is created, involving comparison among the barriers / sub-barriers. An entry a_{jk} in the matrix represents importance of jth barrier relative to k^{th} barrier. The barriers are compared using the Saaty's scale given in Table 3.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & \cdots & a_{1(n-1)} & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & \cdots & a_{2(n-1)} & a_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{(n-1)1} & a_{(n-1)2} & a_{(n-1)3} & d_{(n-1)4} & \cdots & 0 & a_{(n-1)n} \\ a_{n1} & a_{n2} & \cdots & \cdots & \cdots & a_{n(n-1)} & a_{nn} \end{bmatrix}$$

Table 3. Scale of preference (Saaty, 1980)

Preference weight	1	3	5	7	9	2,4,6,8
Judgement	Equally important	Moderately important	Strongly important	Very strongly important	Extremely important	Intermediate values

Then, normalized comparison matrix is calculated, where each entry $\bar{a}_{jk}$ is calculated by Eq. (1)

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{i=1}^{n} a_{jk}} \tag{1}$$

The weights of each barrier / sub-barrier (w_j) are then calculated by taking the average of entries in each row of normalized comparison matrix (Eq. 2)

$$w_j = \frac{\sum_{i=1}^{n} \bar{a}_{jk}}{n} \tag{2}$$

Finally, consistency ratio (CR) is evaluated for each set of pairwise comparison (Eq. 3)

$$CR = CI / RI; \text{ CI: consistency index; RI: random index} \tag{3}$$

CI = (λ_{max} - n) / (n - 1); n: matrix of order n; λ_{max}: Maximum eigenvalue

RI values for matrices of different orders are given in Table 4. Preferably, CR should be less than 0.1 (Madaan and Mangla, 2015).

Table 4. RI values for matrix of order n

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

3.2.2 Grey-DEMATEL method

Firstly, a direct influence matrix is obtained, representing influence among the barriers

$$D = \begin{bmatrix} 0 & d_{12} & d_{13} & \cdots & \cdots & d_{1(n-1)} & d_{1n} \\ d_{21} & 0 & d_{23} & \cdots & \cdots & d_{2(n-1)} & d_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ d_{(n-1)1} & d_{(n-1)2} & d_{(n-1)3} & d_{(n-1)4} & \cdots & 0 & d_{(n-1)n} \\ d_{n1} & d_{n2} & \cdots & \cdots & \cdots & d_{n(n-1)} & 0 \end{bmatrix}$$

The matrix D is normalized using the CFCS (Converting fuzzy data into crisp scores) method explained below (Dou et al., 2014):

$\otimes A_{mn}^k$: Grey number of expert k (Influence of factor m on factor n)

$\underline{\otimes A_{mn}^k}$ and $\overline{\otimes} A_{mn}^k$: Lower and upper values of grey number $\otimes A_{mn}^k$, respectively.

The crisp values are calculated as:

$$\underline{\otimes} \bar{A}_{mn}{}^k = (\underline{\otimes} A_{mn}^k - \underset{n}{min} \underline{\otimes} A_{mn}^k) / \Delta_{min}^{max} \tag{4}$$

$$\overline{\otimes} \ \bar{A}_{\text{mn}}{}^k = (\overline{\otimes} \ A_{mn}^k - \underset{n}{min} \ \overline{\otimes} \ A_{mn}^k) \ / \ \Delta_{min}^{max} \tag{5}$$

where, $\Delta_{min}^{max} = \underset{n}{max} \ \overline{\otimes} \ A_{mn}^k - \underset{n}{min} \underline{\otimes} A_{mn}^k$

The total normalized crisp value and final crisp values are calculated as:

$$B_{mn}^k = \frac{(\underline{\otimes}\bar{A}_{\text{mn}}{}^k \ (1 - \underline{\otimes}\bar{A}_{\text{mn}}{}^k) + (\overline{\otimes} \ \bar{A}_{\text{mn}}{}^k * \overline{\otimes} \ \bar{A}_{\text{mn}}{}^k))}{(1 - \underline{\otimes}\bar{A}_{\text{mn}}{}^k + \overline{\otimes} \ \bar{A}_{\text{mn}}{}^k)} \tag{6}$$

$$C_{mn}^k = \underset{n}{min}\underline{\otimes} A_{mn}^k + B_{mn}^k \Delta_{min}^{max} \tag{7}$$

The next step involves calculation of normalized direct-relation matrix "N"

"N" is computed using the Eq. (8) and Eq. (9).

$$M = \frac{1}{\underset{1 \leq i \leq n}{max} \sum_{j=1}^{n} d_{ij}} \ ; \ \text{M: normalization factor} \tag{8}$$

$$N = M * D \tag{9}$$

Then, Total relation matrix "T" is calculated using Eq. (10)

$$T = N \ (I - N)^{-1} \ ; \ \text{I: Identity matrix} \tag{10}$$

The next step entails calculation of sum of rows and columns of "T"

$$R = \left[\sum_{j=1}^{j=n} m_{ij} \right]_{n \times 1} \ (\text{Sum of rows})$$

$$C = \left[\sum_{i=1}^{i=n} m_{ij} \right]_{1 \times n}' \ (\text{Sum of columns})$$

Finally, causal diagram is plotted on graph using $(R_i + C_i)$ (horizontal axis) and $(R_i - C_i)$ (vertical axis) values.

4. An Application

This section demonstrates an application and analyze the barriers in Indian automotive sector. The approach involves the four phases, discussed in the following sections. The outline of the approach is shown in Fig. 1.

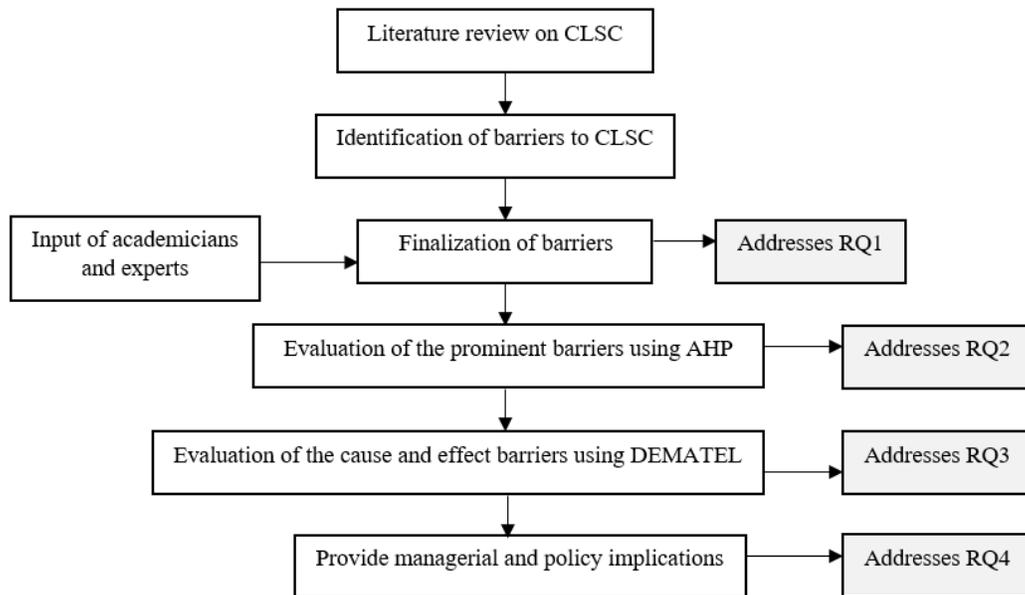Fig. 1. Framework of this study

4.1 Phase 1: Identification of barriers to CLSC

Firstly, barriers to CLSC implementation are identified from literature review (Table 1). A total of 22 barriers are shortlisted and considered for validation from industry experts. The barriers are classified into the following five categories: Financial, technological, cultural, managerial and regulatory barriers.

4.2 Phase 2: Validation of barriers to CLSC implementation

The barriers to CLSC shortlisted in phase 1 are validated by seven industry experts in Indian automotive sector. The profiles of experts are presented in Table 5. According to the inputs from experts, few barriers are eliminated in this phase. Finally, 17 barriers are considered for analysis in phase 3 and phase 4. The finalized barriers considered for the analysis are shown in Table 6. The hierarchical structure of barriers is shown in Fig. 2.

Table 5. Profile of industry experts

	Department	Experience	Position
Expert 1	Purchasing	9 years	Section Head
Expert 2	Purchasing	8 years	Section Head
Expert 3	Costing	19 years	Additional General Manager
Expert 4	Strategic sourcing	13 years	Supply chain manager
Expert 5	Design and development	11 years	Manager
Expert 6	Production Planning and control	20 years	Deputy General Manager
Expert 7	Marketing and sales	20 years	Vice President

Table 6. List of finalized barriers

| Category	Code	Barrier
Financial (FN)	FN1	High cost of transition from linear to CLSC
	FN2	Major upfront investment required for CLSC implementation
	FN3	Total cost of product made from recycled materials is often higher
Technological (TC)	TC1	Low quality of remanufactured products
	TC2	Limited availability and quality of recycling material
	TC3	Challenges involved in separation of bio-material from techno-cycle
Cultural (CL)	CL1	Lack of awareness
	CL2	Resistance to change
	CL3	Perception of customers towards quality of reused materials
Regulatory (RL)	RL1	Recycling policies in waste management are ineffective to obtain high quality recycling
	RL2	Current laws in waste management do not support CLSC implementation
	RL3	Complicated or inflexible regulatory structures
	RL4	Financial governmental incentives support the linear economy
Managerial (MG)	MG1	Poor leadership and management towards implementation of CLSC
	MG2	Higher priority of other issues in supply chain
	MG3	No inventive schemes for managers to use recycled materials
	MG4	Lack of appropriate skills in personnel

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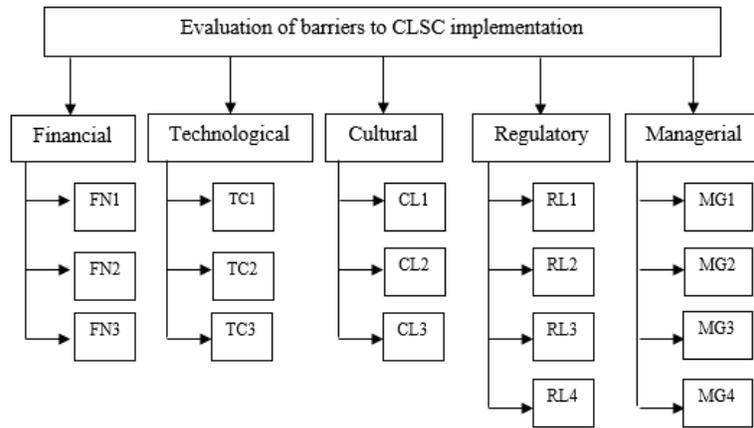
Fig. 2. Hierarchical structure of barriers

4.3 Phase 3: Evaluation of barriers using AHP

The barriers finalized in phase 2 are then evaluated using AHP. The relative importance of barriers is obtained using the input of industry experts. The pairwise comparisons between the barriers are done using the Saaty's scale (Appendix 3). The pairwise comparison matrices are given in Table 7. Table 8 presents overall ranking of barriers, which are based on global weights obtained using AHP.

Table 7. Pairwise comparison matrices

Categories of barriers							
Barriers	FN	TC	CL	RL	MG	Weight	Ranking
FN	1	0.2	0.5	0.25	0.166	0.048	5
TC	5	1	0.166	0.143	0.111	0.061	4
CL	2	6	1	0.5	0.333	0.166	3
RL	4	7	2	1	1	0.323	2
MG	6	9	3	1	1	0.400	1
Financial barriers							
Barriers	FN1		FN2		FN3	Weight	Ranking
FN1	1		1		0.5	0.240	2
FN2	1		1		0.33	0.209	3
FN3	2		3		1	0.549	1
Technological barriers							
Barriers	TC1		TC2		TC3	Weight	Ranking
TC1	1		0.25		0.2	0.093616	3
TC2	4		1		0.333	0.279688	2

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TC3	5	3	1	0.626696	1
Cultural and social barriers					
Barriers	**CL1**	**CL2**	**CL3**	**Weight**	**Ranking**
CL1	1	1	1	0.32748	2
CL2	1	1	0.5	0.259921	3
CL3	1	2	1	0.412599	1
Regulatory barriers					
Barriers	**RL1**	**RL2**	**RL3**	**RL4**	**Weight**	**Ranking**
RL1	1	1	0.5	0.25	0.120539	4
RL2	1	1	1	0.333	0.154035	3
RL3	2	1	1	0.2	0.161219	2
RL4	4	3	5	1	0.564207	1
Managerial barriers					
Barriers	**MG1**	**MG2**	**MG3**	**MG4**	**Weight**	**Ranking**
MG1	1	0.2	0.166	1	0.083243	4
MG2	5	1	0.25	0.5	0.173221	3
MG3	6	4	1	3	0.567497	1
MG4	1	2	0.333	1	0.176039	2

Table 8. Overall ranking of barriers

Category	Relative weight	Sub-barriers	Relative weights	Global weight	Rank
Financial	0.04838	FN1	0.240211	0.011621	15
		FN2	0.209844	0.010152	16
		FN3	0.549946	0.026606	13
Technological	0.060954	TC1	0.093616	0.005706	17
		TC2	0.279688	0.017048	14
		TC3	0.626696	0.0382	11
Cultural	0.166308	CL1	0.32748	0.054463	6
		CL2	0.259921	0.043227	9
		CL3	0.412599	0.068619	5
Regulatory	0.323851	RL1	0.120539	0.039037	10
		RL2	0.154035	0.049884	8
		RL3	0.161219	0.052211	7
		RL4	0.564207	0.182719	2
Managerial	0.400507	MG1	0.083243	0.03334	12
		MG2	0.173221	0.069376	4
		MG3	0.567497	0.227287	1
		MG4	0.176039	0.070505	3

4.4 Phase 4: Analysis of barriers using grey - DEMATEL

Grey-DEMATEL is used for classifying the barriers into cause and effect groups. The input of

three experts is considered for analysis. However, three experts are considered as sufficient for

DEMATEL analysis. Many studies which have applied DEMATEL used responses from four or

lesser number of experts (Zhu et al., 2014; Xia et al., 2015; Govindan et al., 2015b; Bhatia and

Srivastava, 2018). The direct relation matrix of expert 1 is shown in Table 9. The comparison is done by experts using linguistic terms given in Appendix 3. The total relation matrix is given in Appendix 4 (Calculated by giving equal weights to all the experts). The prominence and cause / effect values of barriers are given in Table 10.

Table 9. Direct relation matrix (Expert 1)

	FN1	FN2	FN3	TC1	TC2	TC3	CL1	CL2	CL3	RL1	RL2	RL3	RL4	MG1	MG2	MG3	MG4
FN1	N	H	H	L	H	VH	L	L	L	L	L	VH	VH	H	H	L	H
FN2	H	N	VH	VH	VH	H	VH	H	H	VH	H	H	VH	H	H	H	H
FN3	H	VH	N	H	VH	H	H	VH	H	L	H	H	H	VH	VH	H	L
TC1	H	H	VH	N	H	H	H	L	VL	L	L	VL	VL	L	H	VH	H
TC2	VH	H	VH	VH	N	H	H	H	H	H	H	H	L	H	L	VL	H
TC3	VH	H	H	H	L	N	H	H	H	L	VL	H	H	H	L	H	H
CL1	H	H	H	L	H	L	N	VH	H	H	H	VH	H	H	L	H	H
CL2	H	L	VL	N	VL	N	H	N	H	H	VH	H	L	L	H	L	L
CL3	VH	H	L	VL	N	VL	H	H	N	L	H	VH	H	L	H	H	L
RL1	H	L	L	H	H	H	L	L	H	N	H	L	H	L	H	H	L
RL2	H	H	H	VL	L	L	H	H	VH	H	N	L	H	L	H	H	L
RL3	H	H	H	VL	L	N	H	VH	H	L	VH	N	L	L	H	L	L
RL4	VH	L	L	H	N	N	H	VH	H	VL	L	H	N	N	VH	H	L
MG1	H	H	H	L	N	VL	L	H	H	H	L	H	L	N	H	VH	H
MG2	VH	L	H	L	L	N	N	H	VH	H	L	L	L	H	N	L	L
MG3	H	H	L	L	H	L	L	H	L	VL	H	L	H	L	H	N	L
MG4	N	H	H	L	H	VH	L	L	L	L	L	VH	VH	H	H	L	H

Table 10. Prominence and cause/effect values

Barrier	R	C	R + C	R - C
FN1	4.90	5.98	10.88	-1.07
FN2	6.05	5.02	11.07	1.03
FN3	5.80	5.18	10.98	0.62
TC1	4.84	4.50	9.34	0.34
TC2	5.63	3.99	9.61	1.64
TC3	5.33	3.52	8.84	1.81
CL1	5.92	5.12	11.05	0.80
CL2	4.41	6.09	10.50	-1.69
CL3	4.59	5.33	9.92	-0.74
RL1	5.08	4.76	9.84	0.31
RL2	5.18	5.48	10.66	-0.30
RL3	5.19	5.25	10.44	-0.06
RL4	4.72	5.65	10.37	-0.93
MG1	4.82	5.02	9.83	-0.20
MG2	4.28	5.87	10.14	-1.59
MG3	4.58	5.59	10.18	-1.01
MG4	5.33	4.30	9.64	1.03

The barriers with the positive (R – C) values are known as causal barriers. The barriers TC3, TC2, FN2, MG4 and CL1 are found to be the most important causal barriers to CLSC

implementation. These barriers should be eliminated in the long term (Cui et al., 2019). The barriers with negative (R – C) values are known as effect barriers. The analysis reveals RL4, MG3, FN1, MG2 and CL2 to be the major effect barriers. The causal relationships among the barriers are presented in Fig. 3. Though, there exists a number of relationships among the barriers, we depict only those relationships which are above a certain value 'x'. The value of 'x' is calculated by: μ + σ, where μ denotes average of values of total relation matrix and, and σ denotes standard deviation. These values (more than x) are given in bold in Total relation matrix (Appendix 4).
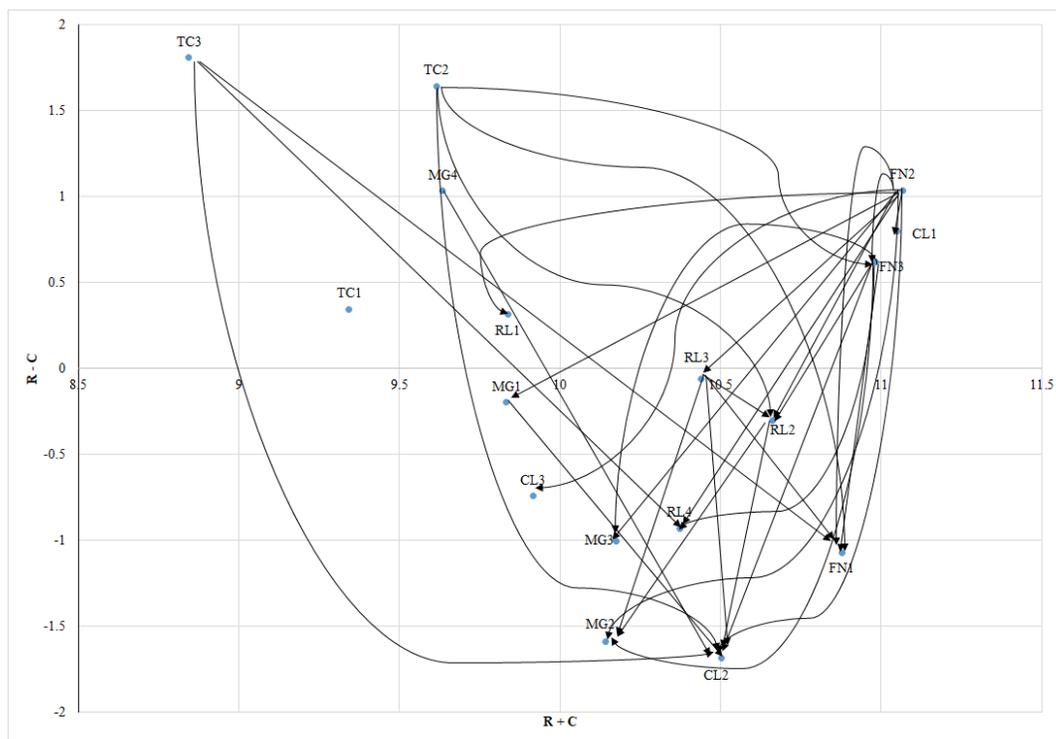
Fig. 3. Causal relationships diagram

5. Sensitivity analysis

In MCDM analysis, vagueness of data, inaccuracy and judgements of the experts may affect the results (Moktadir et al., 2019). Further, changes in relative weights can result in change in

rankings of variables (Mangla et al., 2017). Sensitivity analysis is done to check the robustness of findings (Changes in rankings, and cause and effect groups of barriers). In this study, using AHP, managerial barriers (MG) is ranked as the most important of all categories of barriers. Thus, the weight of managerial barriers is varied from 0.1 to 0.9, with each increment of 0.1. The change in weights of other categories of barriers is done simultaneously. The weights of different categories of barriers using sensitivity analysis are shown in Table 11.

As a result of changes in weights of categories of barriers, weights and rankings of sub-barriers are also changed. When managerial barrier is assigned the weights from 0.4 – 0.9, MG3 holds the first rank. When the weight is varied from 0.4 – 0.6, RL4 has the second rank, MG4 has the third rank and MG2 has the fourth rank. During the variation of the weight from 0.7 – 0.9, MG4 gets the second rank and MG2 gets the third rank. Hence, it can be concluded that managerial barriers need to be focused most in the short run for implementation of CLSC. The rankings of sub-barriers using sensitivity analysis are given in Table 12.

Table 11. Weights of category of barriers using sensitivity analysis

Barriers	Normal	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FN	0.0483	0.0726	0.0645	0.0564	0.0484	0.0403	0.0322	0.0242	0.0161	0.0080
TC	0.0609	0.0915	0.0813	0.0711	0.0610	0.0508	0.0406	0.0305	0.0203	0.0101
CL	0.1663	0.2496	0.2219	0.1941	0.1664	0.1387	0.1109	0.0832	0.0554	0.0277
RL	0.3238	0.4861	0.4321	0.3781	0.3241	0.2701	0.2160	0.1620	0.1080	0.0540
MG	0.4005	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Total	1	1	1	1	1	1	1	1	1	1

Table 12. Ranks of sub-barriers using sensitivity analysis

Barrier	Normal	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FN1	15	13	15	15	15	15	15	15	15	15
FN2	16	15	16	16	16	16	16	16	16	16
FN3	13	10	10	12	13	13	13	13	13	13
TC1	17	16	17	17	17	17	17	17	17	17
TC2	14	11	13	14	14	14	14	14	14	14

TC3	11	8	9	11	11	12	12	12	12	12
CL1	6	3	4	4	6	6	7	7	7	7
CL2	9	6	7	9	9	10	10	10	10	10
CL3	5	2	3	3	5	5	6	6	6	6
RL1	10	7	8	10	10	11	11	11	11	11
RL2	8	5	6	6	8	9	9	9	9	9
RL3	7	4	5	5	7	7	8	8	8	8
RL4	2	1	1	1	2	2	2	4	5	5
MG1	12	17	14	13	12	8	5	5	4	4
MG2	4	14	12	8	4	4	4	3	3	3
MG3	1	9	2	2	1	1	1	1	1	1
MG4	3	12	11	7	3	3	3	2	2	2

The sensitivity analysis is also performed for the results obtained using grey - DEMATEL. Three experiments (ET1, ET2, ET3) are performed to check the robustness. In ET1, first expert is assigned a weight equal to 0.5, and other experts are assigned equal weights (0.25). Similarly, other experiments are done by assigning higher weights to other experts. The (R + C) rankings show that barriers CL1, FN2, FN3 and FN1 have the highest prominence values (Table 13). The (R − C) rankings show barriers TC6, TC5, FN2 and MG4 to be causal and RL4, MG3, FN1, MG2 and CL2 to be the effect barriers (Table 13). Thus, the results are relatively robust to expert evaluations and can be used for decision making.

Table 13. Sensitivity analysis (DEMATEL analysis)

R + C ranks				R - C ranks			
Equal weights	ET1	ET2	ET3	Equal weights	ET1	ET2	ET3
FN2	FN2	FN2	FN2	TC3	TC3	TC3	TC3
CL1	FN3	FN3	FN3	TC2	TC2	TC2	TC2
FN3	FN1	CL1	CL1	FN2	FN2	MG4	FN2
FN1	CL1	FN1	RL2	MG4	MG4	FN2	MG4
RL2	RL2	RL2	CL2	CL1	CL1	CL1	CL1
CL2	CL2	CL2	RL4	FN3	FN3	FN3	FN3
RL3	RL3	RL3	FN1	TC1	TC1	TC1	TC1
RL4	RL4	RL4	RL3	RL1	RL1	RL1	RL1
MG3	MG2	MG3	MG3	RL3	MG1	RL3	RL3
MG2	MG3	MG2	MG2	MG1	RL3	MG1	MG1
CL3	CL3	CL3	RL1	RL2	RL2	RL2	RL2
RL1	MG4	MG1	MG1	CL3	CL3	CL3	CL3
MG1	RL1	RL1	CL3	RL4	MG3	RL4	RL4
MG4	MG1	MG4	TC2	MG3	RL4	FN1	MG3
TC2	TC2	TC2	MG4	FN1	FN1	MG3	FN1

TC1	TC1	TC1	TC1	MG2	MG2	MG2	MG2
TC3	TC3	TC3	TC3	CL2	CL2	CL2	CL2

6. Discussion and managerial implications

This section provides recommendations for managers and policy makers to overcome the barriers. Firstly, we discuss the results from AHP and thereafter results from grey - DEMATEL. From AHP analysis, 'managerial barriers' is found to be the most prominent category of barriers to CLSC implementation. 'Regulatory barriers' and 'Cultural barriers' are found to be the next important categories of barriers. Our result differs from that of Kirchherr et al. (2018), who found cultural barriers to be more prominent in the context of European nations (Hesitant company culture). The possible reason could be that the companies are traditionally operating in a linear system and they are into the state of inertia. They may find it difficult to collaborate with other companies for implementing CLSC. On the other hand, in Indian context, managers are not incentivized or their performance is not mapped by the stakeholders for the extant of CLSC implementation. The possible reason for the lack of incentivization could be no strict regulatory environment in developing countries such as India. In fact, based on a holistic review of CE in China, Su et al. (2013) also identified weak economic incentives and poor enforcement ability of legislation as key barriers for CE implementation. MG3, RL4, MG4 and MG2 (see table 6 for description) are found to be the most prominent sub-barriers. These barriers need to be addressed in the short run for successful implementation of CLSC.

The barrier, "No inventive schemes for managers to use recycled materials" (MG3) holds the first position. Mangla et al. (2018) also found this as to be one of the important barrier to implementing CLSC. Implementation of CLSC involves commitment from leadership and supports from managers, as it involves bringing major changes in an organization (Jayaraman et

al., 1999). Managers will only be interested to take painstaking efforts if they are provided with some extra benefits. We may invoke the agency theory to explain the reason for the utmost importance this barrier. The CLSC practices may sacrifice the short-term profitability of the company for prospective growth in the future. However, the agents (Managers in the company) are concerned with this inherent risk associated with CLSC implementation. Moreover, this may lead to an agency problem between the principals (stakeholders in our case who demands for CLSC implementation) and the agents. Therefore, incentives need to be provided to managers to align the goals to resolve the agency problem. The top management in an organization may consider this issue and provide managers with extra benefits for their efforts towards the implementation of CLSC.

The barrier, "Financial governmental incentives support the linear economy" (RL4) holds the second position. The result agrees with Zhang et al. (2017) and Mangla et al. (2018), who found lack of government support and lack of preferential tax policies as key barriers to CLSC, respectively. In this regard, policy makers need to provide initial financial support to organizations to implement CLSC practices. This also has implications for Indian government, as to how it can formulate its regulatory framework so as to stimulate adoption of CLSC practices with a long term enduring focus (Sharma et al., 2016; Shi et al., 2019; Bhatia and Srivastava, 2019). The other important barriers are "Lack of required skills by employees" (MG4) and "Higher priority of other issues in supply chain" (MG2). Companies need to build the necessary tactical capabilities and capacities to adopt CLSC practices and gain competitive advantage (Xia et al., 2015). Tactical capabilities can be built by imparting skills to employees through training. Infact, empirical studies in the extant literature also establish the need to inculcate necessary

skills in employees to adopt sustainability practices. An empirical study of Spanish automotive industry by Sarkis et al. (2010) also concludes that training plays an important mediator role for adoption of environmentally oriented reverse logistics practices. Top leadership of firms need to set clear priorities to managers and impart relevant skills to employees.

From DEMATEL analysis, it is found that TC3, TC2, FN2, MG4, CL1, FN3 and TC1 are the important causal barriers and these need to be in addressed in the long run. It can be observed that technological barriers are major barriers in CLSC implementation, which is different from the finding by Kirchherr et al. (2018), who found technological barriers to be least critical in the context of European countries. This is probably due to the reason that firms in developing nations such as India are behind on adoption of technologies in comparison to the developed nations such as European countries, USA, etc. (Castellacci, 2008). On the other hand, the finding that barrier FN2 ("Major upfront investment required for CLSC implementation") is one of the major barrier, agrees with the findings of Abdulrahman et al. (2014), Xia et al. (2015), Rizos et al. (2015) and Kirchherr et al. (2018). This implies that the firms around the world consider 'major upfront costs for implementing CLSC' as one of the major barrier to CLSC implementation.

The barrier, "New challenges to separate the bio-material from the techno-cycle" (TC3) is the most important causal barrier. There are three reasons for it to be biggest barrier in CLSC implementation. Firstly, existing products are not designed to keeping in mind their recycling and reuse. Secondly, separation technologies have limited capabilities to sort out waste streams. Finally, end product user is not educated enough to dump the recyclable and non-recyclable

waste separately. "Limited availability and quality of recycling material" (TC2) is the second most important causal barrier. Similar finding is obtained by Xia et al. (2015) in the context of remanufacturing of automotive parts in China. To eliminate TC2, policy makers need to develop channels for collecting the used products, so that used products are available in good amount for the further processes. "Lack of required skills by employees" (MG4) is another important causal barrier. The skills and expertise cannot be gained by employees in a short period of time. Thus, as stated earlier, management needs to start now and continuously impart relevant skills to employees. "Lack of awareness" (CL1) is another barrier that will need to be addressed (Wei et al., 2015; Kirchherr et al., 2018). Policy makers and managers should increase awareness among customers about remanufactured products (Bhatia and Srivastava, 2018). "Total cost of product made from recycled materials is often higher" (FN3) and "Low quality of remanufactured products" (TC1) are the other causal barriers. The "Cost" and "Quality" are two important parameters for customers to buy the product. If the product made by recycled material are costly and of low quality, then certainly they act as barriers to CLSC implementation. All in all, business organizations need to make strategies to tackle these short term barriers and long term barriers to successfully implement CLSC.

7. Conclusions, limitations and future work

Resource scarcity, deterioration of environment and increased generation of toxic waste has made execution of CLSC practices necessary for firms. However, there are several challenges to implementation of a CLSC. This requires not only the organizations to act but also needs support from government, customers and society. This research identifies key barriers to CLSC implementation, evaluates the prominent barriers, and identifies the causal relationships among

the barriers. The AHP findings indicate 'Managerial barriers' as the most prominent category of barriers and 'Regulatory barriers' as the second most important category of barriers. The findings from grey - DEMATEL indicate 'technological barriers' to be the important causal barriers. The findings can be useful for organizations that are planning to implement CLSC practices or those in the early stages of CLSC implementation, in emerging economies. The organizations can draft the strategies to eliminate the barriers, for short term and for long term. We also provide implications for managers and policy makers, and suggest recommendations to eradicate the barriers to CLSC implementation.

The study has few limitations. The verification of barriers with the aid of statistical approach such as Structural equation modeling (SEM) is very interesting future research proposition. Future studies can also study the prominent barriers in other industries and compare the results with those obtained from this research. Furthermore, in practical MCDM problems, decision makers tend to use linguistic preference information instead of numerical information. Zhang et al. (2016) proposed a novel linguistic based computational approach by using the extended linguistic hierarchies. Yu et al. (2019) proposed a minimum adjustment-based approach for consensus in MCDM with multi-granular hesitant fuzzy linguistic term sets. Zhang et al. (2019) developed an algorithm to represent a linguistic distribution assessment using a hesitant linguistic distribution. The readers are encouraged to refer the Yu et al. (2019), Zhang et al. (2019) and Zhang et al. (2016) for detailed discussion.

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Appendix 1: AHP method

Step 1. Problem formulation: This step comprises identifying barriers to CLSC implementation from literature review and input of industrial experts.

Step 2. Pairwise comparisons of barriers: This step involves pairwise comparisons between barriers using the judgement of industry experts. The comparisons between the barriers are done using the Saaty's scale, given in Table 3.

Step 3. Computation of relative importance weights: This step involves calculation of eigen values and eigen vectors. The relative weights of the factors involved in the study are then calculated using eigen values and eigen vectors.

Step 4. Evaluation of consistency ratio: Finally, evaluations (pairwise comparisons between criteria) made by the decision makers are checked for consistency.

Appendix 2: Grey - DEMATEL method

Step 1. Direct relation matrix "D": It represents influence levels between the finalized barriers. It is represented as follows:

$$D = \begin{bmatrix} 0 & d_{12} & d_{13} & \cdots & \cdots & d_{1(n-1)} & d_{1n} \\ d_{21} & 0 & d_{23} & \cdots & \cdots & d_{2(n-1)} & d_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ d_{(n-1)1} & d_{(n-1)2} & d_{(n-1)3} & d_{(n-1)4} & \cdots & 0 & d_{(n-1)n} \\ d_{n1} & d_{n2} & \cdots & \cdots & \cdots & d_{n(n-1)} & 0 \end{bmatrix}$$

Step 2. Normalization of "D": CFCS (Converting fuzzy data into crisp scores) method is used for converting grey numbers to crisp numbers (Dou et al., 2014). This is explained in detail in Section 3.1.2.

Step 3: Normalized direct-relation matrix "N"

$M = \dfrac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} d_{ij}}$; M: normalization factor

$N = M * D$

Step 4: Total relation matrix "T"

$T = N (I - N)^{-1}$; I: Identity matrix

Step 5: Calculation of sum of rows and sum of columns of "T"

$R = \left[\sum_{j=1}^{j=n} m_{ij} \right]_{n \times 1}$; R: sum of rows of "T"

$C = \left[\sum_{i=1}^{i=n} m_{ij} \right]'_{1 \times n}$; C: sum of columns of "T"

Step 6: Causal diagram

In causal diagram, $(R_i + C_i)$ and $(R_i - C_i)$ values are plotted on horizontal and vertical axis, respectively.

Appendix 3: Grey linguistic scale for direct relation matrix

Linguistic assessment	Grey number
No influence (N)	(0, 0)
Very low influence (VL)	(0, 0.25)
Low influence (L)	(0.25, 0.50)
High influence (H)	(0.50, 0.75)
Very High influence (VH)	(0.75, 1)

Appendix 4: Total relation matrix

	FN1	FN2	FN3	TC1	TC2	TC3	CL1	CL2	CL3	RL1	RL2	RL3	RL4	MG1	MG2	MG3	MG4
FN1	0.29	0.31	0.31	0.25	0.23	0.23	0.27	0.34	0.28	0.26	0.29	0.31	0.35	0.29	0.32	0.32	0.25
FN2	**0.42**	0.30	**0.37**	0.33	0.31	0.25	**0.36**	**0.40**	**0.36**	**0.36**	**0.38**	**0.37**	**0.41**	**0.36**	**0.40**	**0.39**	0.30
FN3	**0.41**	0.33	0.29	0.33	0.30	0.27	0.33	**0.41**	0.34	0.31	**0.36**	0.34	**0.38**	0.35	**0.41**	**0.36**	0.29
TC1	0.32	0.28	0.32	0.22	0.25	0.22	0.29	0.32	0.29	0.27	0.30	0.27	0.30	0.28	0.33	0.33	0.27
TC2	**0.39**	0.33	**0.36**	0.33	0.22	0.26	0.34	**0.39**	0.34	0.32	**0.37**	0.34	0.35	0.32	0.34	0.35	0.28
TC3	**0.39**	0.32	0.33	0.29	0.25	0.18	0.32	**0.36**	0.32	0.28	0.31	0.32	**0.36**	0.31	0.35	0.35	0.28
CL1	**0.39**	0.35	0.34	0.29	0.27	0.24	0.30	**0.43**	**0.37**	0.34	**0.38**	**0.39**	**0.40**	0.34	**0.40**	**0.39**	0.32
CL2	0.30	0.25	0.25	0.19	0.18	0.15	0.28	0.27	0.29	0.27	0.32	0.30	0.29	0.26	0.32	0.28	0.22
CL3	0.33	0.27	0.26	0.22	0.18	0.17	0.29	0.34	0.24	0.26	0.30	0.31	0.30	0.27	0.32	0.30	0.23
RL1	0.34	0.28	0.29	0.28	0.27	0.24	0.30	0.34	0.33	0.24	0.33	0.31	0.33	0.29	0.34	0.33	0.24
RL2	0.35	0.30	0.30	0.25	0.24	0.21	0.32	**0.38**	0.34	0.30	0.28	0.32	0.35	0.30	**0.36**	0.34	0.24
RL3	**0.37**	0.30	0.32	0.25	0.24	0.18	0.32	**0.39**	0.33	0.29	**0.36**	0.27	0.34	0.30	**0.37**	0.32	0.24
RL4	0.35	0.27	0.29	0.26	0.18	0.16	0.29	0.34	0.30	0.24	0.30	0.31	0.26	0.26	0.34	0.33	0.24
MG1	0.33	0.28	0.30	0.24	0.20	0.18	0.29	**0.36**	0.31	0.27	0.30	0.29	0.30	0.24	0.34	0.34	0.26
MG2	0.31	0.26	0.26	0.23	0.18	0.15	0.25	0.31	0.28	0.25	0.27	0.25	0.28	0.27	0.25	0.28	0.21
MG3	0.32	0.27	0.27	0.23	0.22	0.19	0.27	0.34	0.27	0.24	0.30	0.27	0.32	0.28	0.33	0.25	0.22
MG4	**0.37**	0.30	0.33	0.32	0.26	0.26	0.31	**0.38**	0.34	0.28	0.33	0.30	0.33	0.32	0.35	0.35	0.23