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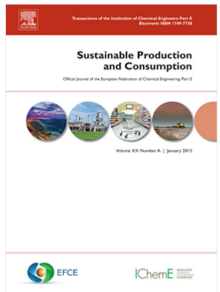

Reducing the exploration and production of oil: Reverse logistics in the automobile service sector

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Reducing the exploration and production of oil: Reverse logistics in the automobile service sector

Abstract

The improper disposal of used oil poses a significant threat to society and the environment. The present study adds value to the existing knowledge base by identifying and analysing the critical barriers to reverse logistics of used oil obtained from the automobile service stations in the developing economies context. An interpretive structural modelling methodology was applied for establishing the interrelationship between the identified barriers and to rank the barriers based on their driving power. The results of the study revealed that a barrier namely ‘inadequate government policies, organisational policies, and lack of top management commitment’ was the most significant. Findings of this study are intended to guide the decision and policy makers in understanding the reverse logistics barrier analysis so that the most significant barriers can be eliminated for the effective reverse logistics and enhancing the performance of the automotive oil manufacturing companies.

Keywords: *Reverse logistics; oil; sustainability; barriers, challenges, interpretive structural modelling; multi-criteria decision making.*

Abbreviations

RL	Reverse Logistics
ISM	Interpretive Structural Modelling
MCDM	Multi-Criteria Decision Making
MILP	Mixed Integer Linear Programming
BoP	The business of the Pyramid
SEM	Structural Equation Modelling
PRA	Product Recovery Activities
AIS	Artificial Immune System
PSO	Particle Swarm Optimization
ANOVA	Analysis of Variance
CSR	Corporate Social Responsibility
GRI	Global Report Initiative
AHP	Analytic Hierarchy Process
DEMATEL	Decision Making Trial and Evaluation Laboratory
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
ANP	Analytic Network Process
3PRLSP	Third Party Reverse Logistics Service Provider
SSIM	Structural Self–Interaction Matrix
TISM	Total Interpretive Structural Modelling
IRP	Interpretive Ranking Process

1 Introduction

1.1 Reverse logistics (RL)

Recently, the reverse supply chain or reverse logistics domain has received significant attention as it helps in balancing all three dimensions of sustainability, i.e. social, economic, and ecological (Choudhury et al., 2018; Nikolaou et al., 2012). It consists of a group of operations that start at the consumer point of the products collection and gets terminated at the reuse, reclaiming, remanufacturing, recycling, disposal, and reprocessing facilities (Alshamsi and Diabat, 2015; Govindan et al., 2012). It consists of all the processes included in the reducing, managing, processing, and disposing of non-hazardous or hazardous waste from the production, packaging, and usage of goods (Bouzon et al., 2015). RL focuses on the value recovered from a particular product after its disposal, and therefore it is the starting point of a new (reverse) supply chain (Guide et al., 2003a; 2003b). The ideal order of alternatives is a) reduction of waste- by increasing the durability of the product, b) reuse of waste- by remanufacturing the product, c) recovery of waste- by recycling the raw material, d) landfill waste-final option (King et al., 2006).

It may be noted that RL has considerable uncertainty, and the flow of material or product has less visibility as compared to the flow of forwarding supply chain and logistics. Moreover, management of the same becomes difficult due to the inexperience of many organisations with RL functions (Bai and Sarkis, 2013; Tibben-Lembke and Rogers, 2002). Supply uncertainty and timing are vital factors differentiating RL from the conventional logistics system (EI korchi and Millet, 2011). Profitability of RL has got multi-dimensions as it depends on the various factors, such as recovered quantities of products, innovation in technology for lowering the cost of the recovery process, and the market price of the products (Weil et al., 2012). Therefore, RL has become an important research topic in the area of sustainable supply chain management.

In the developed countries the products are gradually recycled, and reused, but, in the developing economies, the used products are sent to landfills, causing significant pollution, and financial losses. RL in the developing economies is an immature practice in the majority of industrial domains (Hsu et al., 2013; Lau and Wang, 2009). In this context as compared to developed economies where RL is a mandatory element in the supply chain, fewer research activities are carried out in the emerging economies as RL is still at a beginning stage

(Abdulrahman et al., 2014). In many emerging economies RL is considered as an undervalued activity of a supply chain (Gunasekaran and Ngai, 2012; Jindal and Sangwan, 2011). On the contrary, it is worth mentioning that active RL operations close the supply chain loop effectively and would help to increase sales, competitiveness, positive brand image, effective utilization of resources, strategic advantage, ecological protection, and reduce cost of operations (Govindan et al., 2013; Gunasekaran and Spalanzani, 2012; Neto et al., 2008; Tsai et al., 2009; Zhu et al., 2008).

India is struggling with the continuous increase in population, and it is one of the largest waste producers. Hence, Indian organisations are under tremendous pressure for adopting eco-friendly practices for the waste reduction, and less energy consumption (Al Zaabi et al., 2013). However, it is very alarming that, Indian industries are still in the beginning stages of the sustainable practices implementation like RL. The present study tries to bridge this research gap by identifying and modelling the barriers to the effective RL practices.

1.2 Overview of used oil of automotive service sector

The automobile sector is one of the most critical and most significant sectors in the world. It comprises a sequence of supply chain activities for the production and delivery of the vehicle. In the total cost of an automobile, logistics activities contribute a significant share. This complex system activates the need for managing both forward and reverse logistics (Chan et al., 2012).

Used oil is any synthetic or petroleum-based oil which gets contaminated after its use by chemical and physical impurities (EPA, 1997). During the routine use of oil, impurities like chemicals, water, metal particles, dirt get mixed with oil, and after a period, it becomes unfit to perform its intended activities. Then it should be replaced with re-refined or virgin oils, and the changed oil should not be disposed of illegally as it may contain heavy metals and toxic chemicals. Oil degrades slowly, and it can stick to anything from bird feathers to beach sand. The improper management of used oil contaminates waterways, oceans, lakes, groundwater, wastes a valuable resource, and poses a severe threat to marine life, plant & animal life. This shows the need for the active waste oil management. Not only recycling of used oil saves depleting resources but reduces oil imports (Jha, 2005; Mahalakshmi, 2015). The Union ministry of environment, forest and climate change have notified used oil as a hazardous waste, and it is being governed by the management and transboundary movement rules-2016 (Prakash, 2017).

The collection of used oils from the automotive service sector (two-wheelers, four-wheelers, heavy vehicles, and special purpose vehicles) includes-Crankcase oil (petrol and diesel engines), Natural gas-fired engine oil, Hydraulic power steering oil, Brake oil, Gear oil, and Cooling oil. Used oil is a valuable energy resource if it is properly recycled or managed. It can be recycled into a variety of products. Used oil after re-refining produces a high-quality base stock, which can be used for industrial fuels, lubricants, industrial oils, automotive oils, waste oil heaters. The by-product waste may be used as asphalt extender. It may be noted that the re-refining process of used oil consumes 70% less energy than refining crude oil (TCEQ). The used oil supply chain is shown in Figure 1, and Figure 2 illustrates the life cycle summary of the lubricants. Worldwide, 3700 tons of crude oil is refined out of which 1.0 % is used for the manufacturing of lubricant products (Boyde, 2002).

At present, around 1.5 million tonnes per year or 90% of used oil gets wasted in India due to improper disposal or used as a fuel for combustion without reprocessing, which adds 3.520 million tonnes of CO and CO_2 into the atmosphere. The used oil should be disposed within 90 days; else it can damage land and groundwater (Mahalakshmi, 2015; Prakash, 2017). One litre of used or waste oil contaminates one million litres of water, and if it poured on the soil, it could affect the soil fertility (Chan et al., 2012). It is very alarming that roadside garages let the used oil into sewers and drains, which is a significant threat to the environment. Due to lack of knowledge and ineffective governmental regulations used oil is sold to the industries in the replacement of light diesel oil and expensive furnace oil. Burning of used oil without refining or reprocessing increases levels of pollution considerably (Prakash, 2017). If all improperly disposed of used oil were recycled, it could provide approximately 60 million litres of high-quality motor oil. A little consideration will show that there is an urgent need to recycle the used oil to balance the environmental, economic, and social dimensions of sustainability. Also, RL helps to enhance the overall performance of the automotive oil manufacturing companies. To mitigate the issues mentioned above there is a need to address the following research questions.

RQ1: Which are the critical barriers to the effective RL of used automotive oil?

RQ2: How the shortlisted barriers are interrelated?

RQ3: Which are the most significant barriers to RL of used oil?

RQ4: How to overcome the barriers in the case sector?

As mentioned earlier, RL of used oil is the need of time for balancing all three dimensions of sustainability. Hence, there is a significant need to identify and model the significant barriers to the effective RL of used oil. To achieve this overall aim of the research, the objectives are divided into a set of explicit target goals. The research objectives of this study are:

RO1: To identify the critical barriers to the effective RL of used automotive oil.

RO2: To identify the mutual relationship between the shortlisted barriers.

RO3: To identify the barriers having high influential power.

RO4: To identify the strategies for overcoming the barriers in the case sector.

The present study intends to contribute to the existing knowledge base by exploring the barriers to the effective RL of used oil of automotive service stations through a literature survey and expert opinions. Further, for the identification of the research gaps, papers published in the area of RL across various economies and different sectors have been reviewed. Also, different applications of Multi-Criteria Decision Making (MCDM) methodologies in the case domain were studied. Then, Interpretive Structural Modelling (ISM) methodology, which is an MCDM approach, was employed for identifying the interrelationship between the barriers and to explore the barriers having high driving power for their effective elimination.

This article is structured in the following sequence: sections 2 focuses on the literature review in the RL domain, whereas, in section 3, research methodology is detailed. Section 4 covers results of the study, implications are highlighted in section 5. Lastly, the conclusion of the study is detailed in section 6.

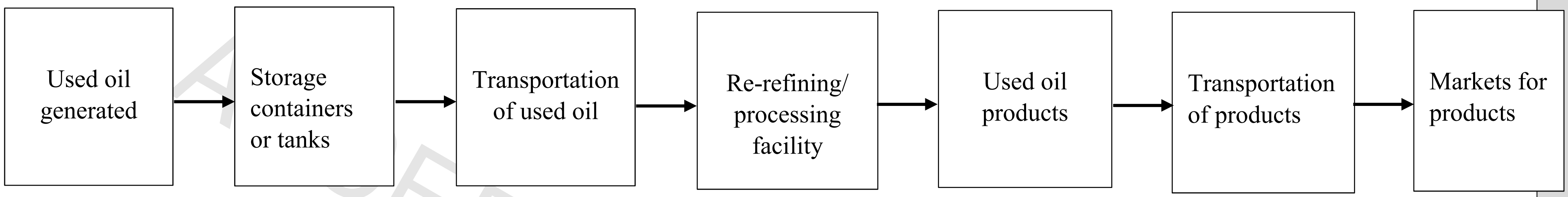

Figure 1. The used oil supply chain (Modified from DEC, 2007).

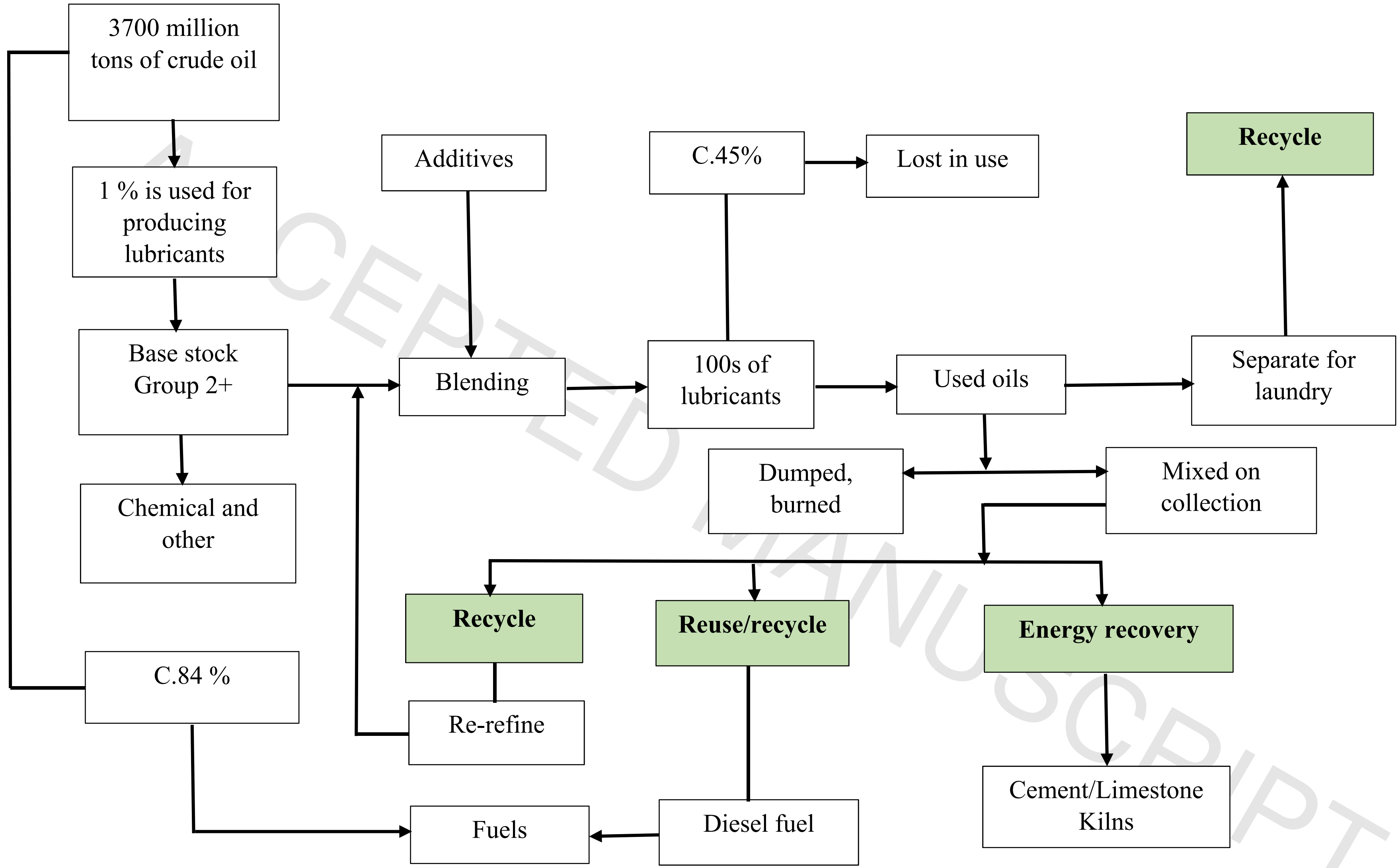

Figure 2. The life cycle of a summary of lubricants (adapted from Boyde, 2002; Fitzsimons, 2010).

2 Literature review

This section of the paper focuses on the papers published in the area of RL across various economies and different industries (Section 2.1). Additionally, various applications of the MCDM methodologies in RL domain have been discussed (Section 2.2). Then, the research gaps in the case domain have been identified (Section 2.3), and the shortlisted critical barriers have been detailed in Section 2.4.

2.1 Papers published in the area of reverse logistics

The papers published in the RL domain are detailed below, and the same are summarised in Table 1.

Ferri et al. (2015) proposed an RL network for the municipal solid waste management for solving the issues of managing the waste sustainably, i.e. by balancing all three dimensions of sustainability and taking into consideration the latest Brazilian policies by using the mathematical modelling approach. Abdulrahman et al. (2014) proposed RL implementation empirical model by identifying critical RL barriers on infrastructure, finance, policy, and management in the context of Chinese manufacturing industries using factor analysis. Alshamsi and Diabat (2015) proposed a mixed integer linear programming (MILP) approach for addressing complicated network configuration of a reverse logistics system, focusing on the optimal site selection, remanufacturing centres and inspection centres capacities. Bai and Sarkis (2013) introduced RL operational and strategic flexibility framework for decision makings, such as programmatic evaluation or process improvement.

Brix-Asala et al. (2016) took a holistic view of the ecological and social consequences of the business of the pyramid (BoP) of plastic water sachets. The case study highlighted opportunities and limitations of informal valorisation in RL activities. Chan et al. (2012) examined the RL activities of the automotive sector and proposed a framework for the same. González-Torre et al. (2010) identified and modelled the barriers to the RL implementation in the automotive sector using Structural Equation Modelling (SEM). Hazen et al. (2015) used goal setting theory and knowledge-based view for conceptualising the model that examined transactions from the inbound and outbound RL perspectives in a B2B context. Later, the model was tested by the least squares SEM.

Kapetanopoulou and Tagaras (2011) used statistical analysis for assessing the drivers and barriers in the Product Recovery Activities (PRA). It was found that the profitability and green image were the significant drivers, whereas the financial constraints, & complications of operations were the significant barriers for the useful PRA. Lai et al. (2013) verified whether RL practices hit the sustainability's triple bottom lines in the Chinese manufacturing sector using regression methods. Results revealed that, except social benefits, adoption of RL practices generated substantial ecological and economic gains. Nunes et al. (2009) introduced the concepts of RL and reverse distribution networks in the Brazilian construction and demolition waste domain. Silva et al. (2013) presented a case study on the reverse flow direction of returnable packaging for replacing the disposable packaging. It was found that returnable packaged system consumed 18.0 % less material than the disposable one, providing reduced cost, more protection for the products, reduction in working volume, and reduction of weight.

Suyabatmaz et al. (2014) developed RL network design of a third-party logistics provider under uncertainty of supply regarding the number of returns, which was evaluated by using two-hybrid simulation analytical models. For checking the robustness of the model, a sensitivity analysis was also conducted. Ye et al. (2013) investigated the effects of institutional pressure, top management posture, and RL on the overall performance of the organisation. It was found that institutional pressure has a positive relationship with top management's position towards RL implementation, and product recovery has a significant positive influence on the organisations financial and ecological performance. Also, it was concluded that product returns setback the company's financial performance and has no effect on the environmental performance. Agrawal et al. (2016) explored the various disposition options and developed an approach for selecting the best one by employing graph theory and matrix approach. The results indicated that the company must reuse or repair and resell the returned mobile units as new in the current Indian business scenario. Also, recycling must be given preference over remanufacturing of the returned mobiles.

Guarnieri et al. (2016) analysed the e-waste RL decisions by using strategic options development analysis approach. Four clusters of actions for the implementation were found, namely strategic, ecological, financial, and social. Nikolaou et al. (2012) proposed a framework of performance indicators for the measurement of social responsibility of RL based on the social, economic, environmental aspects. Kumar et al. (2017) studied forward-reverse logistics model for maximising the total expected profit and also for obtaining an efficient route for the vehicle by employing an Artificial Immune System (AIS), and Particle Swarm Optimisation (PSO) algorithm. It was found that AIS is more efficient than the PSO. Wei et al. (2015) identified drivers and challenges of remanufacturing in the Chinese context. It was found that the ethical and ecological responsibility, strategic advantage, and customer orientation are the primary drivers, whereas, the customer recognition is the most significant barrier. Shaharudin et al. (2014) explored the hindrances to the product returns and recovery management among the Malaysian manufacturing sectors. It was found that the resource and economic constraints were essential barriers. Zailani et al. (2017) investigated the hindrances to the product return management among the automobile manufacturing industries in the Malaysian context. The surveyed data were analysed using PLS, and structural models highlighted that the resource barriers are the main impediments in the product return management process.

Table 1 Papers published in the RL domain.

Sr. No.	Author(s)	Year	Country	Area/sector/domain	Methodology
1	Ferri et al.	2015	Brazil	Solid waste management	Mathematical modelling
2	Abdulrahman et al.	2014	China	Manufacturing	Descriptive statistics, alpha coefficients, total item correlation, and Factor analysis
3	Alshamsi and Diabat	2015	UAE	Remanufacturing (Household appliances)	Mixed integer linear programming
4	Bai and Sarkis	2013	China	RL-flexibility	Rough set approach
5	Brix-Asala et al.	2016	Ghana	BoP projects	Case study
6	Chan et al.	2012	China	Automobile	Case study
7	González-Torre et al.	2010	Spain	Automobile	SEM
8	Hazen et al.	2015	USA	Defence supply chain	Goal setting theory, knowledge-based view, and partial least squares SEM
9	Kapetanopoulou and Tagaras	2011	Greece	Manufacturing	Non-parametric Chi-square test, Mann-Whitney U-tests, and Friedman two-way ANOVA.
10	Nunes et al.	2009	Brazil	Construction industry	Case study
11	Silva et al.	2013	Brazil	Machined engine heads packaging	Case study
12	Suyabatmaz et al.	2014	Turkey	RL network design	Hybrid simulation-analytical modelling
13	Ye et al.	2013	China	Manufacturing	Factor analysis, SEM
14	Agrawal et al.	2016	India	Mobile manufacturing	Graph theory and matrix approach
15	Guarnieri et al.	2016	Brazil	e-waste	Strategic options development analysis
16	Nikolaou et al.	2012	Greece	CSR	Triple bottom line and global report initiative (GRI)
17	Kumar et al.	2017	India	Manufacturing	AIS and PSO
18	Wei et al.	2015	China	Remanufacturing	Descriptive survey research
19	Shaharudin et al.	2014	Malaysia	Manufacturing	Quantitative and qualitative content analysis
20	Zailani et al.	2017	Malaysia	Automotive manufacturing	Partial least squares, SEM

2.2 Papers published in the RL domain using MCDM approach

Very lean literature is available in the RL domain using MCDM approach. Some of the papers published in the case domain using MCDM tools are detailed below and summarised in Table 2.

Bouzon et al. (2015) explored and analysed the interrelationship between the hindrances to the development of RL using ISM methodology focusing on the recovery of end of life products from the minerals and mining industry in the Brazilian context. After analysing it was found that policy-related barriers were most significant. Galvez et al. (2015) proposed an RL network design for a biogas plant using integrated MILP optimisation and Analytic Hierarchy Process (AHP). Govindan et al. (2012) analysed the third-party reverse logistics' selection criteria for the evaluation of the best service provider in the Indian tire manufacturing industry context using ISM approach. Ravi and Shankar (2005) identified the interrelationship between the significant challenges to the RL application in the automobile industries. It was found that lack of RL awareness, lack of top management commitment, and lack of strategic planning were considered to be the most significant barriers.

Zhu et al. (2015) introduced a methodology for identifying the relationship between the remanufacturing supply chain barriers using grey based Decision-making Trial and Evaluation Laboratory (DEMATEL) approach. The results highlighted that financial constraints, innovation, lack of quality standards, limited availability of the used truck engines, and lack of information for guaranteeing quality were the critical barriers. Bouzon et al. (2016) explored and analysed the RL barriers in the Brazilian electrical-electronics equipment industry sector using fuzzy Delphi and AHP approach. It was concluded that the related financial issues are the most important. Kannan et al. (2009) used ISM and fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for identifying the best third-party reverse logistics service provider based on the seven selection criteria. Mangla et al. (2016) identified and modelled critical success factors for RL in the Indian context using AHP and DEMATEL. It was found that global competitiveness is the significant factor.

Prakash and Barua (2015) employed fuzzy AHP and fuzzy TOPSIS for analysing and ranking the hindrances to RL implementation. A case study from an Indian electronics industry was considered. A sensitivity analysis was also carried out for checking the robustness of the methodology. Prakash and Barua (2016) employed fuzzy AHP for evaluating and ranking the selection criteria and VIKOR for the final selection of a third-party reverse logistics partner. Lastly, the sensitivity analysis was also performed.

Satapathy (2017) developed a model using ISM methodology for establishing the interrelationship among the hindrances to the effective implementation of recycling processes in the Indian plastic industries. After analysis, it was found that two barriers namely amount of scrap and toxic gas were the most significant hindrances. Akdoğan and Coşkun (2012) modelled RL drivers in the Turkish house appliance sector using AHP. The results of the study highlighted that there were disagreements regarding main parameters, financial factors, corporate citizenship and legislation. Govindan et al. (2013) applied AHP for analysing the selection/evaluation criteria and employed Analytic Network Process (ANP) for the selection of the third-party reverse logistics service provider (3PRLSP) in the Indian automobile sector. Govindan and Murugesan (2011) proposed a model by analysing seven criteria and thirty-four sub-criteria for the selection of 3PRLSP using fuzzy extent analysis for Indian battery manufacturing industries.

Kannan et al. (2014) analysed the interrelationship among the drivers of the end of life tire management using ISM approach in the Indian context. The results of the analysis revealed that four factors namely resource scarcity, codes of conduct, the extended responsibility of the producer, and ecological conservations were the most significant. Barker and Zabinsky (2011) presented an MCDM model for RL of manufacturing industries. The AHP was employed for the evaluation of attributes and sub-attributes, taking into consideration business relations and costs; for taking crucial decisions regarding the design of networks. Senthil et al. (2014) used hybrid MCDM approach for the evaluation and selection of 3PRLSPs. The AHP was utilised for obtaining the initial weights, and fuzzy TOPSIS was employed for the final ranking. For the confirmation of robustness of the model sensitivity analysis was also conducted.

Kannan et al. (2008) proposed a reverse supply chain model using AHP and fuzzy AHP for selecting collection centre location for RL. Sharma et al. (2011) analysed the interrelationship among the hindrances to the successful implementation of RL using ISM methodology. Results highlighted that among twelve barriers, two barriers were the most essential namely legal issues, and lack of awareness about RL. Samantra et al. (2013) developed a decision tool to design an effective policy of product recovery considering various parameters, using the concept of interval-valued fuzzy sets along with VIKOR.

Table 2 Papers published in the RL domain using MCDM approach

Sr. No.	Author(s)	Year	Country	Area/sector/domain/Industry	Methodology used
1	Bouzon et al.	2015	Brazil	Machinery manufacturing	ISM
2	Galvez et al.	2015	France	Biogas plant	MILP and AHP
3	Govindan et al.	2012	India	Tire manufacturing	ISM
4	Ravi and Shankar	2005	India	Automobile industry	ISM
5	Zhu et al.	2015	China	Truck engine-Remanufacturing	DEMATEL
6	Bouzon et al.	2016	Brazil	Electrical-electronic equipment industry	Fuzzy Delphi and AHP
7	Kannan et al.	2009	India	Battery manufacturing	ISM and fuzzy TOPSIS
8	Mangla et al.	2016	India	Manufacturing	AHP and DEMATEL
9	Prakash and Barua	2015	India	Electronics industry	Fuzzy AHP and fuzzy TOPSIS
10	Prakash and Barua	2016	India	Electronics industry	Fuzzy AHP and VIKOR
11	Satapathy	2017	India	Plastic industry	ISM
12	Akdoğan and Coşkun	2012	Turkey	House appliance industry	AHP
13	Govindan et al.	2013	India	Automobile industry	AHP, Analytic Network Process (ANP)
14	Govindan and Murugesan	2011	India	Battery manufacturing Industry	Fuzzy extent analysis
15	Kannan et al.	2014	India	Tire manufacturing industry	ISM
16	Barker and Zabinsky	2011	USA	Manufacturing industries	AHP
17	Senthil et al.	2014	India	Plastic industry	AHP and Fuzzy TOPSIS
18	Kannan et al.	2008	India	Tire manufacturing industry	AHP and Fuzzy AHP
19	Sharma et al.	2011	India	Manufacturing	ISM
20	Samantra et al.	2013	India	Automobile industry	Interval valued fuzzy sets and VIKOR

2.3 Research Gaps

The developing economies like India have not entirely realised the reverse logistics implementation benefits. The adoption and implementation of the RL activities are not accessible from the industrial perspectives. In the developed countries much attention has been given to the same, but in countries like India, it is at a very nascent stage (Jindal and Sangwan, 2011; Prakash and Barua, 2015). From the above literature review, it may be inferred that not much of the research work is carried out in the RL of used oil, especially in the MCDM segment. To the best of the authors' knowledge, the present study is the first of its kind, highlighting the crucial barriers to the effective RL implementation activities of used oil in the context of Indian automotive service stations using ISM methodology, which is an MCDM approach. The ISM approach is a powerful methodology that helps 1. to present a complex structure in a simplified manner; 2. to transform less comprehensible mental models of a structure into explicit, visible models; 3. to identify structure within the system; 4. to interpret the embedded object; 5. to answer 'what' and 'how' in theory building (Sushil, 2012).

Unlike other MCDM tools like AHP, ANP, DEMATEL, etc., in the ISM tool, while analysing the factors the level of dominance or intensity of the relationship is not required, only the inter-linkage (driving and driven relationship) between the identified criteria is needed. It decreases the level of biases in the experts' judgments (Gardas et al., 2015). Hence, in the present study, ISM is employed for identifying the interrelationship among the identified barriers and modelling the same for identifying the most significant barriers, which need the maximum attention of the decision and policy makers for their effective elimination.

2.4 Identification of the critical barriers to the effective RL of used oil

Barriers are the hindrances which restrict a phenomenon to get implemented. In the present study, for identifying barriers to the effective RL of used oil, a literature survey was carried out using various search engines namely Science Direct (Elsevier), Emerald Insight, Springer, Taylor and Francis group, Inderscience online, IEEE explorer, Wiley online library, Google Scholar, and Google. The keywords used for the search were reverse logistics, barriers, hindrances, obstacles, pitfalls, challenges, constraints, used oil, waste oil, automotive sector, service stations, pollution, ecology, and reverse supply chain. Twelve barriers were identified after reviewing journal articles, short communications, book chapters, newspapers, white papers, magazines, conference proceedings, and by taking inputs from the experts of academia & industry. The experts' team comprised of three professors from the operations and supply chain management department, three supply chain and logistics managers, four research scholars of the domain, three general managers from the automotive service stations. A brainstorming session helped in eliminating two less significant hindrances, and the ten most crucial barriers were shortlisted for further analysis. The shortlisted barriers are discussed below-

1. *Inconvenience or lack of routine service pickup*

The collection of used oil is a big challenge, as the distance is directly proportional to the cost of collection (Mahalakshmi, 2015). Used oil is disposed of illegally or sold to unauthorised traders, due to improper oil collection facilities in the proximity of the service centres. Waste oil at a distance of 3-4 miles away from the certified collection centres is more likely to get disposed of improperly.

2. *Lack of knowledge and awareness of environmental impacts*

By using returned products companies do not want to compromise on the end product quality. Hence policies of going for only virgin products constitute a significant barrier (Lindhqvist, 2000; Ravi and Shankar, 2005). Lack of knowledge of effective waste oil management and unawareness among the various members of the system regarding the adverse effects on the ecology causes much pollution. The top management should ensure that all the employees are trained sufficiently to follow the policies of pollution prevention. Also, car users should be imparted knowledge on waste oil management by conducting special seminars. The manpower should be trained immediately after they are hired, and at regular intervals after that (Bouzon et al., 2015; 2016; CSBMP Handbook, 2014; Govindan et al., 2014; González-Torre et al., 2004; 2010; Kapetanopoulou and Tagaras, 2011; Kungu and Simuyu, 2012; Prakash and Barua, 2015; Ravi and Shankar, 2005).

Used oil should not be dumped on the ground, roads, or in the trash. It may contain additives and heavy metals, it has the potential to contaminate water, soil, and have harmful effects on the local ecology. It contains harmful contaminants such as lead, and benzene. Used oil should not be mixed with carburettor cleaner, antifreeze, solvents, chemicals, pesticides, paint thinner, petrol, brake cleaner, as mixing with these liquids may make oil non-recyclable. The containers that were used to store hazardous liquids should not be used to store used oil, and whenever there is a need, drip pan may be provided (Kungu and Simuyu, 2012; TCEQ). RL activity is the joint responsibility of the customers and the producers for minimising the waste generation (Bouzon et al., 2015; 2016). The customers should be made responsible by making them sign a form of spills prevention (CSBMP Handbook, 2014).

3. *The high cost of legal disposal of oil*

Policies of hazardous waste are linked to the improper disposal of used oil. The regulations that increase legal disposal cost encourage illegal oil dumping or selling it to illegal buyers. To encourage people, the fee charged for providing used oil disposal facility should be significantly lower than the fine for illegal dumping (Cerullo, 2000; Sigman, 1999).

4. *Inadequate government policies, organisational policies, and lack of top management commitment*

It includes ineffective strict government regulations and policies, organisational philosophy for the useful RL activities. It is the most significant barrier as it is intended to influence all other barriers. The management barriers comprise organisational planning and strategy, training and hiring the workforce, installation of a system for measuring the performance, learning best practices and implementing the same. It also includes internal and external stakeholder's views (Abdulrahman et al., 2014; Bernon et al., 2013; Bouzon et al., 2015; 2016; Chaabane et al., 2012; Chan et al., 2012; Chung and Zhang, 2011; González-Torre et al., 2010; Kapetanopoulou and Tagaras (2011); Koh et al., 2012; Lau and Wang, 2009; Mintzberg, 1973; Prakash and Barua, 2015; Rahman and Subramanian, 2012; Ravi and Shankar, 2005; Rogers and Ronald, 1999; Shaharudin et al. (2014); Tan and Hosie, 2010; Wei et al., 2015; Zhou et al., 2007).

5. *Lack of integration between the vehicle manufacturers and re-refiners*

A practical and efficient integration between the vehicle manufacturers and re-refiners would help in the proper legal disposal of the oil (Mahalakshmi, 2015). As the authorised service stations abide by the rules and regulations set by the manufacturers, therefore, the legal disposal aspect should be strictly proposed. Service centres should be asked to maintain the documents of the oil disposals, and periodic audits may be conducted to verify the same. Also, collaboration with the re-refiners makes the service stations to handover the used oil to re-refiners legally, avoiding illegal selling to the buyers (Bouzon et al., 2015; 2016; Chan et al., 2012; Mahalakshmi, 2015).

6. *Inconsistent quality of oil*

For the roadside or unauthorised garages, constructing fences or other physical barriers would help in controlling dust that may enter into the oil while carrying out the maintenance activity (CSBMP Handbook, 2014). As there are different hydraulic systems in a vehicle for example- brake oil, power steering oil, gear oil, engine oil. All these types of oils should not be mixed as they have different chemical and physical properties and mixing of the same would make the refining process complicated. It may also be noted that the quality of the used oil may not be the same of the vehicles of the same make or similar models, as it depends on the various other factors such as driving habits, driving environment, engine condition, etc. The waste oil containers should be stored in a safe and convenient place, and the members should make sure that foreign particles will not enter into the same. The containers should be labelled appropriately as per the hazard and content of the fluid in it.

7. *Improper maintenance practices causing spillage of oil*

The workforce of the service stations should be trained to inspect storage and work areas for the leakage signs. Periodic inspections for spills, leaks, mal-functioning, corroded or worn parts should be carried out effectively. Valves, tanks, seals, containers, and hosepipes should be checked regularly. All the preventive maintenance procedures suggested by the vehicle manufacturers should be strictly followed as per the training manual instructions (CSBMP Handbook, 2014).

8. *Lack of finance*

Lack of finance affects the support activities of RL, effective training programs, monitoring systems, tax policies, handling, and storage facilities. It may be noted that the lack of modern disposal method is mainly due to lack of funds, especially for the unauthorised garages. It also includes uncertainty related to financial issues, lack of economy of scale, etc. (Abdulrahman et al. 2014; Bouzon et al., 2015; 2016; Chan et al., 2012; González-Torre et al., 2010; Kapetanopoulou and Tagaras, 2011; Kungu and Simuyu, 2012; Lau and Wang, 2009; Ravi and Shankar, 2005; Rogers and Ronald, 1999; Shaharudin et al. (2014); Tan and Hosie, 2010; Zhou et al., 2007; Zhu et al., 2015).

9. *Lack of institutional support towards the waste management activities.*

The leading central institutions dealing with environmental management and solid waste management are inefficient in ensuring effective used oil management (Kungu and Simuyu, 2012).

10. *Lack of proper infrastructure and technology*

Unavailability of the proper infrastructure and technology in the organisation for the collection of data regarding the generation of used oil v/s consumption of new oil by the service stations is a significant barrier. It also includes the lack of coordination and support from various members, lack of planning and forecasting capability, etc. (Bernon et al., 2013; Bouzon et al., 2015; 2016;

González-Torre et al., 2010; Kungu and Simuyu, 2012; Lau and Wang, 2009; Ravi and Shankar, 2005; Rogers and Ronald, 1999; Shaharudin et al. (2014); Tan and Hosie, 2010; Zhou et al., 2007). Also, the organised inventory of the waste oil and used oil needs to be maintained (CSBMP Handbook, 2014).

3. Research methodology

The primary objective of this study is to propose a new structural model of significant barriers to the effective RL practices of used oil obtained from the automobile service stations. The outcome of this study is intended to guide the policymakers in reviewing their policies towards the active RL activities. The introduction to ISM approach and steps involved in the same are detailed below.

3.1 Introduction to ISM methodology

An interpretive structural modelling (ISM) approach is an MCDM tool that helps in analysing the interrelationships between the factors/variables (Warfield, 1974). Also, it identifies the order and direction of the relationship (Diabat and Govindan, 2011; Gardaset al., 2017a; Hawthorne and Sage, 1975; Jha et al., 2018; Ravi and Shankar, 2005).

Steps involved in the ISM approach are given below (Kannan and Haq, 2007; Malone, 1975; Mudgal et al., 2009; Raut et al., 2018a)-

1. Barriers to the RL practices of used oil were identified.
2. The interrelationship between the identified barriers was established, and the same was tabulated in the structural self-interaction matrix (SSIM).
3. The SSIM was then transformed into a binary matrix known as an initial reachability matrix (IRM).
4. The IRM was then modified to final reachability matrix (FRM) by adding transitive links. The transitivity rule means if a criterion ‘P’ influences ‘Q’, and ‘Q’ affects ‘R’, then ‘P’ can influence ‘R’.
5. The level partitioning of FRM was then carried out.
6. From the FRM a directed graph (digraph) was drawn, and the links of transitivity were removed.
7. Lastly, the final digraph was transformed into a hierarchical structure by replacing node numbers with the criteria statements.

4 Results of the study

Various stages leading to the elaboration of the ISM hierarchical model and results of the same are detailed below.

4.1 Critical barriers to the effective RL of used oil

The shortlisted barriers to the RL of used automotive oil were identified through literature review and expert opinions. They are listed in section 2.4 of the manuscript.

4.2 Development of SSIM

For establishing the mutual relations among the critical barriers, all the thirteen experts from the academia and industry (indicated in section 2.4) were contacted and were asked to fill up the SSIM table individually. The following four symbols were used for showing the direction of influence between the criteria (*i* and *j*). 'O'- no relationship; 'X' - both influence each other; 'V' – element *i* causes element *j*; 'A' – element *j* causes element *i*. After receiving thirteen SSIM tables, the 'law of majority' was used to fill the final SSIM (Table 3).

4.3 Formation of reachability matrix

For the development of IRM from the SSIM, following guidelines were used. If the SSIM has the value 'V' for i, j; then IRM will have i, j value as 1, and the value of j, i will be 'zero'. If the SSIM has the value 'A' for i, j; then IRM will have i, j value of 'zero', and the value of j, i will be 1. If the SSIM has the value 'X' for i, j; then both i, j and j, i values will have 1. For i, j value of 'O' the IRM will have both i, j and j, i as 'zero'. The IRM for the present case study is shown in Table 4. The FRM (Table 5) was formulated from the initial reachability matrix by applying the rules of transitivity as mentioned in step 4 of section 3.1.

4.4 Level Partitions

From the final reachability matrix, the reachability, and antecedent sets were identified for each barrier (Kannan et al., 2009). A barrier having both the sets identical was eliminated and was given the top (first) position in the hierarchical structure (Mandal and Deshmukh, 1994; Raut et al., 2017a). Similarly, all the criteria were iterated for obtaining various levels. Level partitioning of the critical barriers is shown in Table 6.

Table 3 Structural self-interaction matrix (SSIM) of the barriers

S. N	Critical barriers	10	9	8	7	6	5	4	3	2
1	Inconvenience or lack of routine service pickup	A	A	A	O	A	A	A	X	A
2	Lack of knowledge and awareness of environmental impacts	V	A	V	V	V	A	A	V	
3	The high cost of legal disposal	O	A	A	A	A	A	A		
4	Inadequate government policies, organizational policies, and lack of top management commitment	V	V	V	V	V	V			
5	Lack of integration between the vehicle manufacturers and re-refiners	V	X	V	V	O				
6	Inconsistent quality of oil	O	A	A	A					
7	Improper maintenance practices causing spillage of oil	A	A	A						
8	Lack of finance	X	A							
9	Lack of institutional support towards the waste management activities.	V								
10	No data collection of used oil generation v/s new oil consumed by service stations.	---								

Table 4 Initial reachability matrix of the barriers

S. N.	Critical barriers	1	2	3	4	5	6	7	8	9	10
1	Inconvenience or lack of routine service pickup	1	0	1	0	0	0	0	0	0	0
2	Lack of knowledge and awareness of environmental impacts	1	1	1	0	0	1	1	1	0	1
3	High cost of legal disposal	1	0	1	0	0	0	0	0	0	0
4	Inadequate government policies, organizational policies, and lack of top management commitment	1	1	1	1	1	1	1	1	1	1
5	Lack of integration between the vehicle manufacturers and re-refiners	1	1	1	0	1	0	1	1	1	1
6	Inconsistent quality of oil	1	0	1	0	0	1	0	0	0	0
7	Improper maintenance practices causing spillage of oil	0	0	1	0	0	1	1	0	0	0
8	Lack of finance	1	0	1	0	0	1	1	1	0	1
9	Lack of institutional support towards the waste management activities.	1	1	1	0	1	1	1	1	1	1
10	No data collection of used oil generation v/s new oil consumed by service stations.	1	0	0	0	0	0	1	1	0	1

Table 5 Final reachability matrix of the barriers

S. N.	Critical barriers	1	2	3	4	5	6	7	8	9	10	Driving Power
1	Inconvenience or lack of routine service pickup	1	0	1	0	0	0	0	0	0	0	**2**
2	Lack of knowledge and awareness of environmental impacts	1	1	1	0	0	1	1	1	0	1	**7**
3	High cost of legal disposal	1	0	1	0	0	0	0	0	0	0	**2**
4	Inadequate government policies, organizational policies, and lack of top management commitment	1	1	1	1	1	1	1	1	1	1	**10**
5	Lack of integration between the vehicle manufacturers and re-refiners	1	1	1	0	1	1*	1	1	1	1	**9**
6	Inconsistent quality of oil	1	0	1	0	0	1	0	0	0	0	**3**
7	Improper maintenance practices causing spillage of oil	1*	0	1	0	0	1	1	0	0	0	**4**
8	Lack of finance	1	0	1	0	0	1	1	1	0	1	**6**
9	Lack of institutional support towards the waste management activities.	1	1	1	0	1	1	1	1	1	1	**9**
10	No data collection of used oil generation v/s new oil consumed by service stations.	1	0	1*	0	0	1*	1	1	0	1	**6**
	Dependence Power ⟶	**10**	**4**	**10**	**1**	**3**	**8**	**7**	**6**	**3**	**6**	**58**

Table 6 Level partitions of the reachability matrix
Iteration I to Iteration VII

S. N	Reachability Set	Antecedent Set	Intersection	Level
1	1,3	1,2,3,4,5,6,7,8,9,10	1,3	**I**
2	1,2,3,6,7,8,10	2,4,5,9	2	**V**
3	1,3	1,2,3,4,5,6,7,8,9,10	1,3	**I**
4	1,2,3,4,5,6,7,8,9,10	4	4	**VII**
5	1,2,3,5,6,7,8,9,10	4,5,9	5,9	**VI**
6	1,3,6	2,4,5,6,7,8,9,10	6	**II**
7	1,3,6,7	2,4,5,7,8,9,10	7	**III**
8	1,3,6,7,8,10	2,4,5,8,9,10	8,10	**IV**
9	1,2,3,5,6,7,8,9,10	4,5,9	5,9	**VI**
10	1,3,6,7,8,10	2,4,5,8,9,10	8,10	**IV**

4.5 Formation of the ISM model

From the FRM a structural model (digraph) was developed (Figure 3), and by removing the transitive links from the same a final hierarchical model was structured (Figure 4).

4.6 MICMAC Analysis

This approach analyses and explains the evaluation criteria based on their driving and dependence power. The driving power (influential power) of a particular criterion is calculated by taking the sum of all the 1's in the row, and dependence power by taking the sum of all 1's of the column (Raut et al., 2017b). The driving and dependence power values of all the criteria are shown in Table 5. The power matrix (driving and dependence power diagram) is shown in Figure 5. It has four segments namely driving, linkage, dependent, and autonomous. The autonomous cluster comprises the barriers having low driving and low dependence power; the dependent segment consists of barriers having low driving and high dependence power; linkage cluster consists of barriers having high influential power and high dependency. Lastly, the barriers of the driving cluster are very significant as they have high influential and weak dependence power (Raut et al., 2018b; Sage, 1977). It is worth mentioning that the driving cluster attracts the significant attention of the decision/policy makers.

The critical barriers to the RL of waste oil identified through literature review and opinion of experts were modelled by employing an ISM methodology which is an MCDM approach. The various levels (VII) of the developed structural model are shown in Figure 4. The top three barriers in the hierarchical model, namely inconvenience or lack of routine service pickup (B1), the high cost of legal disposal (B3), (level I) and inconsistent quality of oil (B6) (level II) are less significant as compared to the barriers below them. These are the barriers which are getting influenced by rest of the barriers of the hierarchy. The intermediate barriers (level III to level V) in the increasing order of their influence are -improper maintenance practices causing spillage of oil (B7) (level III), lack of finance (B8), no data collection of used oil generation v/s new oil consumed by service stations (B10) both these barriers are in the level IV followed by lack of knowledge and awareness of environmental impacts (B2) in level V. The intermediate barriers are moderately significant and are driven by the most critical barriers of the level VI and VII. The most significant barriers, driving all other barriers above them are lack of integration between the vehicle manufacturers and re-refiners (B5), lack of institutional.

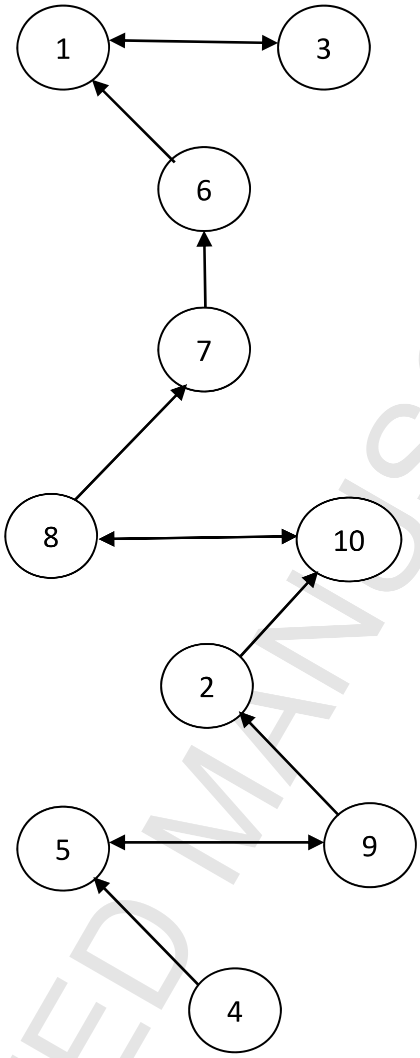

Figure 3 Final digraph depicting relationship among the barriers

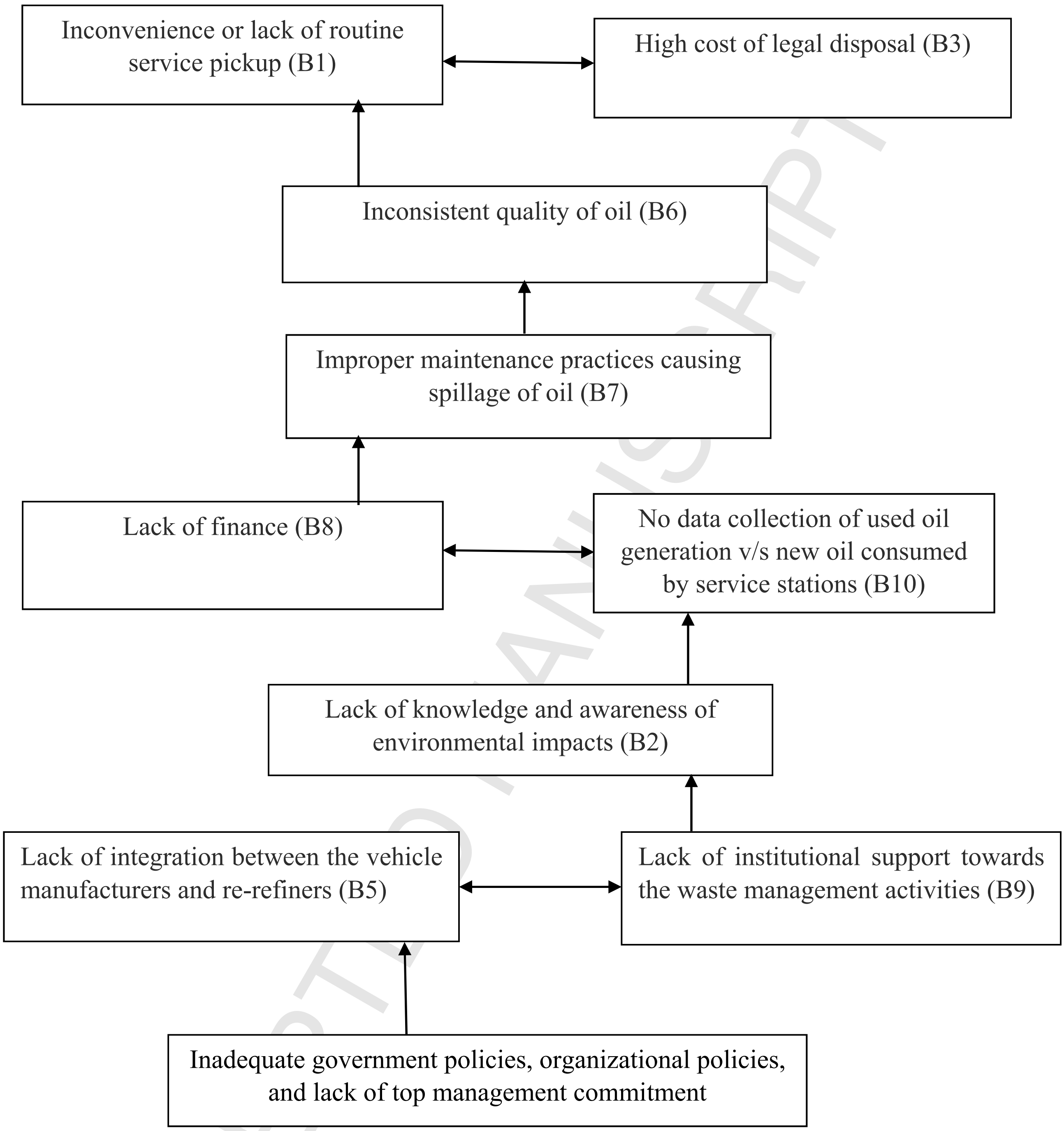

Figure4 ISM based model for critical barriers.

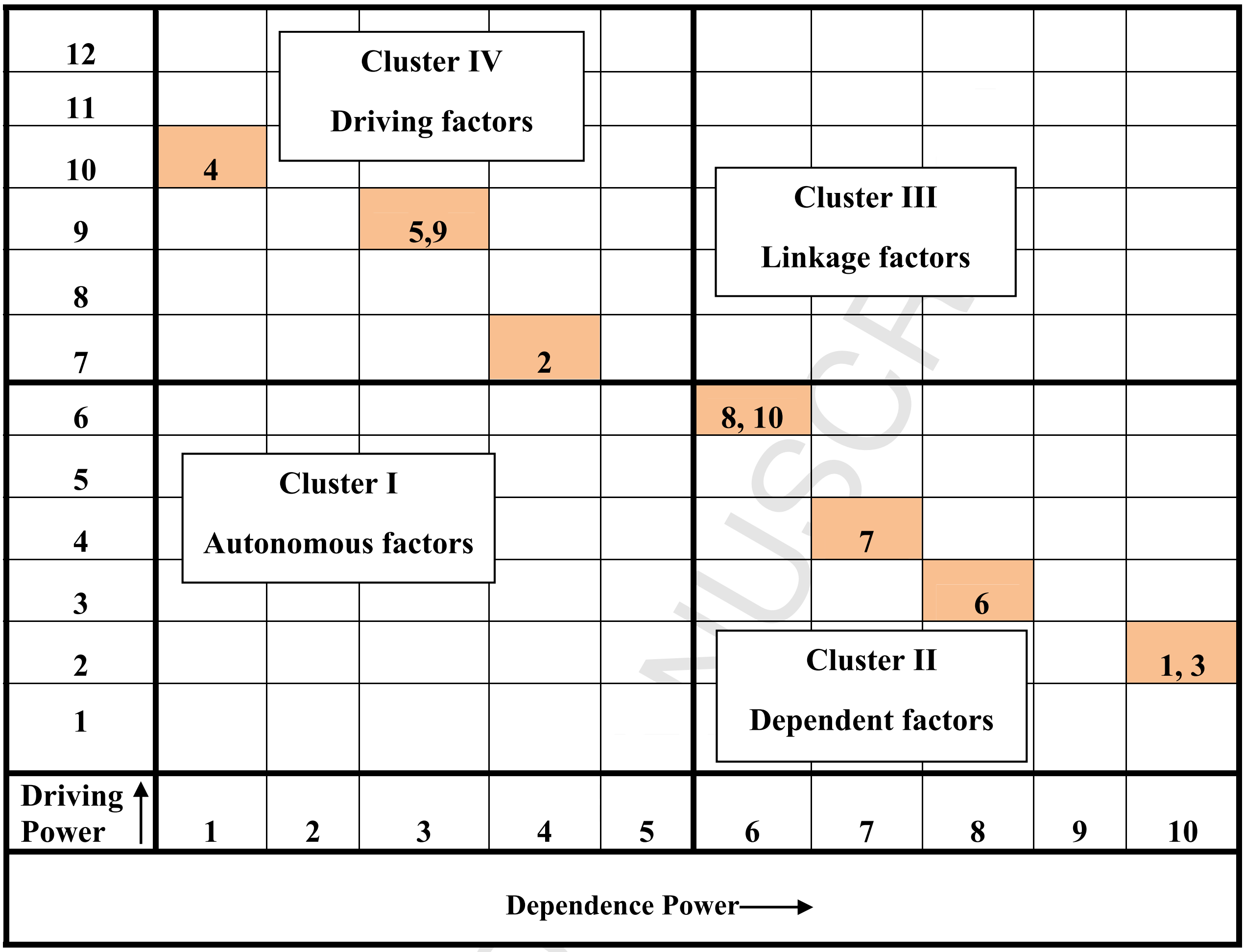

Figure 5 The Power matrix.

support towards the waste management activities (B9), and Inadequate government policies, organisational policies, and lack of top management commitment(B4).

Figure 5 shows the matrix of driving and dependence power of fourteen significant barriers to the reverse logistics of used oil in the automotive service sector. The cluster I consist of the barriers having weak driving and dependence power. It may be noted that not a single barrier fell in the first cluster. The dependent barriers having weak driving and high dependence power are shown in cluster II, these are less significant as they are dependent on the other barriers. Out of ten identified barriers, six barriers are from this cluster. Cluster II barriers in the descending order of their driving power are lack of finance (B8), no data collection of used oil generation v/s new oil consumed by service stations (B10), improper maintenance practices causing spillage of oil (B7), inconsistent quality of oil (B6), inconvenience or lack of routine service pickup (B1), and high cost of legal disposal (B3). Cluster III is for the barriers having high driving and high dependence power. These are the linkage barriers, and it may be noted that none of the barriers fell in this category. The driving barriers cluster is comprised of four barriers namely inadequate government policies, organizational policies, and lack of top management commitment (B4), lack of integration between the vehicle manufacturers and re-refiners (B5), lack of institutional support towards the waste management activities (B9), and lack of knowledge and awareness of environmental impacts (B2). It is worth mentioning that the barriers of the cluster IV are most significant as they are having high driving power and low dependence power.

In the past research activities, Abdulrahman et al. (2014), González-Torre et al. (2010), Lau and Wang (2009), Mintzberg (1973),Ravi and Shankar (2005), and Tan and Hosie (2010) stated that lack of top management commitment and lack of knowledge and trained manpower are the significant barriers. Abdulrahman et al. (2014), Bouzon et al. (2015), González-Torre et al. (2010), Lau and Wang (2009), and Tan and Hosie (2010) stated that the lack of government policies are the essential hindrances. Abdulrahman et al. (2014), Ferguson and Browne (2001), González-Torre et al. (2010), Kapetanopoulou and Tagaras (2011), Lancioni (1994), Lau and Wang (2009), JimWu and Cheng (2006), Shaharudin et al. (2014), Tan and Hosie (2010), and Zhao et al. (2006) found that cost considerations are the critical barriers to the RL implementation. Abdulrahman et al. (2014), Bernon et al. (2013), González-Torre et al.(2010), Lau and Wang (2009), Rahman and Jim Wu (2011), Tan and Hosie (2010), and Zhou et al. (2007) concluded that lack of infrastructure and technology (data collection and storage) is a significant barrier. Bernon et al. (2013), and Chan et al. (2012) stated that the supply chain integration is needed for the effective RL implementation. All of these research findings are very much in parallel with the present study findings. However, the results of Bouzon et al. (2015) are contradicting which stated that management related issues are less significant. One reason for this is that the weights of the barriers vary significantly from one enterprise to another, and from one place to another.

5. Implications of the study

Due to increased material costs, growing international regulatory pressures, scarcity of resources, and global warming, not only the organisations but also the entire supply chains are being forced to realise the importance of the sustainable practices such as RL. Implementation of RL practices gives the organisations a competitive edge in the global competitive environment. In India automotive sector is the leading one having significant potential for recycling or reusing the used oil. Reverse logistics is attracting many organisations all over the globe due to legal, economic, social, and environmental issues. As RL closes the supply chain's loop, it can address issues of resource depletion. Effective RL practice demands the proper coordination among the various levels of the workforce. The barriers involved in the RL implementation are the significant challenges for the industries all over the globe, especially for the emerging economies.

Presently, India is the fourth largest lubricating oil consumer in the world. Annually around 15, 00,000 tons are consumed, out of which 75.0 % is the engine oil. It may be noted that automotive service stations currently don't have to return the oil to the oil organisations (Mahalakshmi, 2015). In India, the automotive service industry is largely unorganised, and the prices of used oils keep regularly fluctuating as local traders are controlling them. As the organisations rarely implement RL practices as an outcome of proactive planning measure and from the developed model, it may be inferred that the governmental organisations have a significant role to play in the elimination of the barriers by formulating the stringent rules and regulations. Also, the government can bridge the gap between the institutions and the industries in improving the effectiveness of the RL activities. There is an extensive need for developing motivational laws, incentives or some benefits may be offered to the industries for encouraging them to implement RL practices (Bouzon et al., 2015). Also, the government needs to formulate strict policies for waste disposal, integrating the vehicle manufacturers, service providers, and re-refiners. It will also help to control the unregulated used oil prices (Mahalakshmi, 2015).

The authors suggest the following strategies or measures for the effective RL practices of used oil of the automotive service sector-

Oil needs to be stored in tanks or containers that are in excellent condition and should be labelled as used oil. The tanks should be kept out of the weather. The oil containers or tanks may be reused. All the records (bills or invoices, shipping documents) of the used oil tanks should be strictly maintained. As soon as the used oil has been removed from the vehicle, the same needs to be transferred from the quarter barrels or drain pans in the designated storage area immediately. For preventing the spills accidentally, the drip pans should never be left outside and should be prevented from the rainfall. All the maintenance activities should be carried out indoors. Automakers need to have proper integration with the various supply chain members. Also, they can involve a third-party reverse logistics service provider for the same. For visualising the RL implementation benefits, training programs have to be conducted for the dedicated staff. The same information can be conveyed to the customers so that they would know which part of the car can be retrieved, recycled, remanufactured, etc. In the training session the misconception of the poor-quality product should be addressed (Bouzon et al., 2015).

There is a significant need to carry out environmental audits on authorised and non-authorized garages.

A service station or garage owners should responsibly manage the used oil on their premises, and adequate funds need to be allocated for the same. Service stations must sell used oil to authorised recyclers only. Also, it should be made mandatory for the retail outlets to sell new oil only after collecting the used oil. The illegal dumping needs to be discouraged by charging significant fines, the same should be advertised. The people should be encouraged for reporting illegal dumping of used oil to the identified institutions. The effective RL implementation leads to oil imports reduction, yielding profits to the organisations, safeguards ecology, and increases employment in the region, thus balancing social dimension. The results of the present study have a considerable contribution to the RL of used oil of automotive service stations. Understanding the barriers and their intensity is very much necessary for taking decisions on their elimination process, and it is the first step towards the effective RL implementation.

The reduction of barriers to the implementation of RL practices in the Indian automobile service stations helps in achieving sustainability, which is the need of time. The hindrances to RL implementation is an MCDM problem having a considerable significance. In the present study, a methodological framework for the identification and modelling the ten critical barriers to RL has been proposed using ISM tool. The prime objective of the present study is to help the policy and decision makers to understand the level of significance of the identified barriers and to guide them in the formulation of effective policies for the reduction of wastage of used oil and to recycle the same. The time required for the effective implementation of the techniques or the strategies (short-term or long-term) and planning for the same may be evaluated. It is worth mentioning that reduction or elimination of the barriers to the RL implementation will reduce the cost of the oil, provide ecological protection, improve the competitiveness of the organisation, increase profits, increase market share, etc.

6. Conclusion

The present study has addressed four research questions and achieved four research objectives mentioned in the introduction section of this article. In this study, the ten critical barriers to the RL of used oil of automotive service centres from an Indian context were explored by literature review and expert opinions. An Interpretive structural modelling methodology was employed for identifying the interrelationship between the barriers. Also, the hindrances to having high driving power were identified. The findings of the study revealed that three factors, namely inadequate government policies, organizational policies, and lack of top management commitment (B4), lack of integration between the vehicle manufacturers and re-refiners (B5), and lack of institutional support towards the waste management activities (B9) are the most significant among ten factors, and these factors need immediate attention of the decision and policymakers.

The established interrelationship among the ten identified barriers depends solely on the inputs given by the invited experts, and it may be noted that these judgments could be biased. For eliminating or reducing this limitation and to improve the reliability of the developed hierarchical model or for validation, the shortlisted barriers may be analyzed by employing other MCDM tools individually or some of the methodologies may be applied along with the ISM approach (Gardas et al., 2017b; 2018; Mishra et al., 2018; Narkhede et al., 2017; Raut et al., 2017c; Sasananan et al., 2016). The suggested tools for the same are – Total Interpretive Structural Modelling (TISM), AHP, ANP, Interpretive Ranking Process (IRP), DEMATEL, SEM, etc. Experts weights vary significantly from one sector to another. Hence, results of the present study apply to the case domain under study only and cannot be made generic to other sectors. Also, for the effective application of ISM methodology, the person should have good knowledge of the tool and should have the capability to interpret the data. In the present study, ten significant barriers to RL of used oil were analysed, but there could be other significant barriers which were not taken into consideration in the evaluation process. Considering more criteria in other research activities would provide better results. However, it may also be noted that inclusion of more factors in the model development would make the analysis tedious and complicated. In further studies, authors may employ SEM methodology for validating the ISM approach results statistically (Pawaskar et al., 2017; Priyadarshinee et al., 2017).

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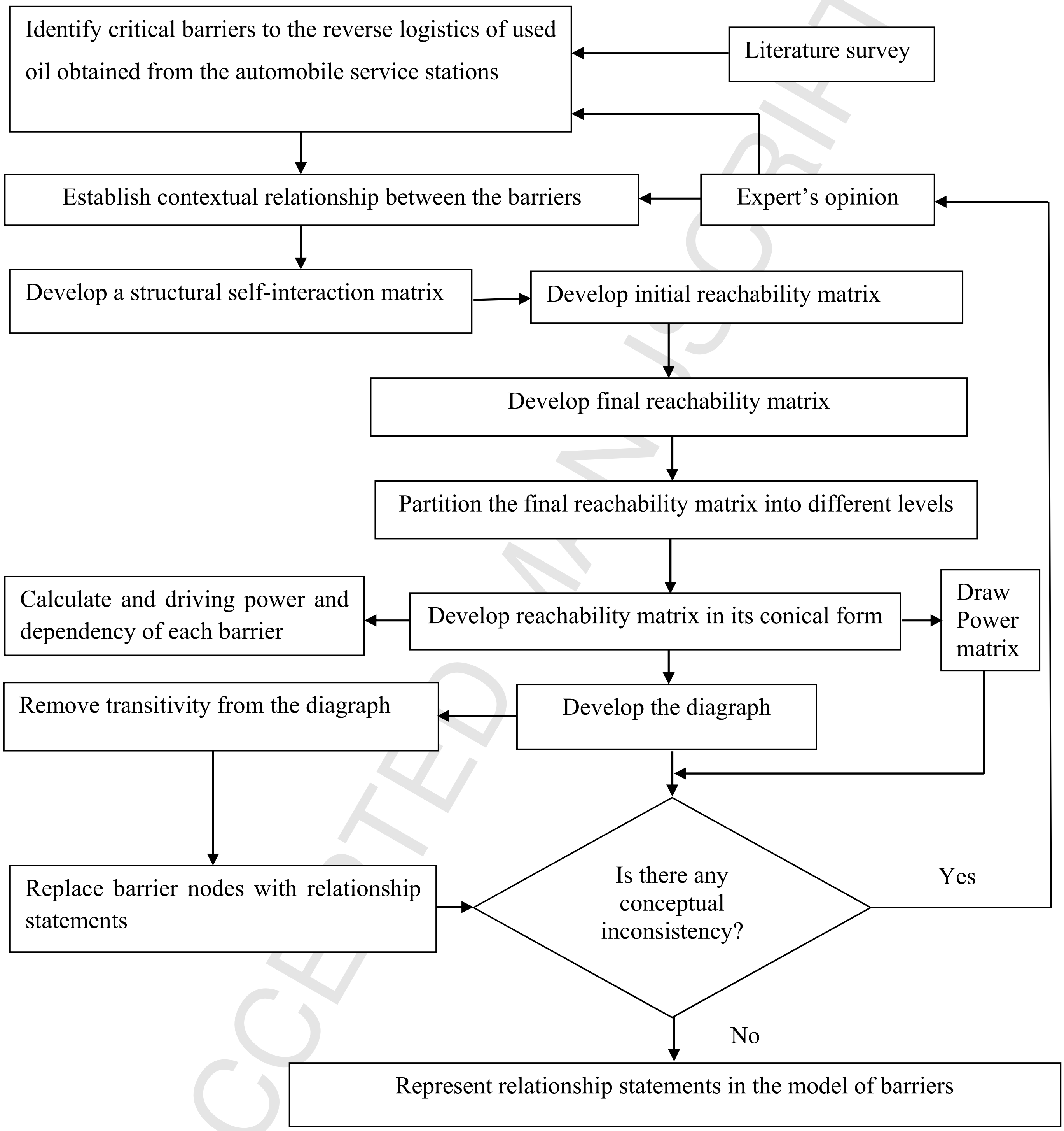

Graphical Abstract

Highlights

- Reverse logistics supply chain domain has received significant attention
- Barriers identified through an extensive literature review and expert opinions.
- An interpretive structural modeling methodology was employed.
- The MICMAC analysis was used to find driving power and dependency of all the barriers.
- ‘Inadequate policies, and commitments’ was found to be the most significant barrier.