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ORIGINAL ARTICLE

Analyzing the drivers of end-of-life tire management using interpretive structural modeling (ISM)

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Abstract Due to industrialization and globalization, automotive sectors in both professional and societal applications have increased manufacturing and have resulted in higher production of virgin tires. These hikes in virgin tire production subsequently results in more end-of-life (EOL) tires, as well as lower quality, shorter tire lifespan, and a restricted availability of new model tires. Many developed nations have started to address EOL tire management issues through various strategies and codes of conduct, but because the environment is a global concern shared both by developed and developing nations, this study examines the issue of EOL tire management in India, a highly populated developing country. This paper proposes a framework to analyze the motivating factors of EOL tire management; it is validated in the Indian scenario with the assistance of a multi-criteria decision-making (MCDM) approach. Existing literatures are limited to the study of recycling and remanufacturing techniques. This study also provides the interrelationship between drivers and their respective influence with sound managerial implications. Finally, the paper concludes with the most influential driver of EOL tire management among all common drivers. We examine its limitations, and we shed light on the prospects of greater sustainability in EOL tire management in the future.

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1 Introduction

Increasing environmental concerns and global economic crises have pressured the engagement of the end-of-life tires (EOL) products management strategies to recover their value. Many EOL recovery strategies are evolving with relevant in-depth studies and research, and the management of EOL tires has become a popular debate topic among researchers and practitioners. The tire industry is an economic market giant. According to the port of global industry analysts (GIA), shipments of tires globally are going to reach 1.72 billion units by 2015 [1]. With tire productions growing as well—an expected hike of 5 % over 2011–2015 [2]—this increased production, due to higher demand and shorter life spans, will ultimately result in a greater number of EOL tires [3]. According to a report from the world business council of sustainable development (WBSCD), it is estimated that there are 1 billion EOL tires generated globally each year [4].

EOL tires and their management cover lots of definitions from both theoretical and virtual perspectives, but the most widely accepted definitions are provided by the WBSCD. EOL tires are defined as "a tire that can no longer be used for its original purpose; all tires including passenger car, truck, airplane, and agricultural, two-wheel and off-road tires result in ELTs; however, most ELTs result from car and truck tires." EOL tire management is defined as a "process beginning at point when a used tire is designated as an ELT up to its supply to an ELT recycling or recovery company." When the public began to focus on the environmental problems associated with waste generation in the 1990s [5], many studies emerged on tire recycling and remanufacturing. While there is value inherent in recovery options for used tires, they are not effective unless tires actually reach the recycling or remanufacturing

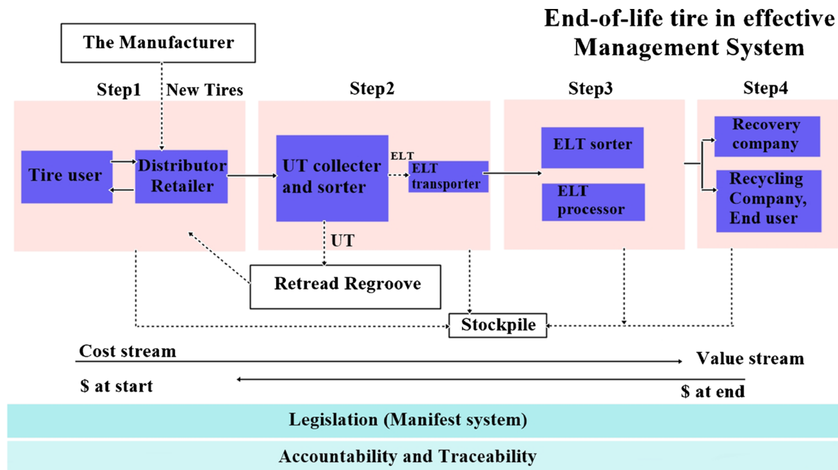


Fig. 1 One EOL tire management system (adapted from [4])

centers. One strategy for EOL tire management is shown in Fig. 1.

Researchers study EOL tires aggressively because the entire manufacturing and sustainability spectrum is impacted (see, for instance, [3, 6, 7]), and much value can be reclaimed from EOL tires [8]. Because of these effects, much legislations have passed regarding EOL tire management in both developed and developing nations. Legislation remains in a preliminary stage in many developing countries due to poor governance, the lack of facilities, and proper monitoring. Hence, many researchers [3, 9–14] argue that there is a great need to manage EOL tires in developing nations before these tires becomes a more significant threat. In developing nations, India has one of the largest populations; its fast-growing market in automobiles rivals that of China. In recent years, cars have become a growing fashion in India; as a result, many multi-national industries launched their automobiles in India. Consequently, a tremendous hike in tire production has generated additional scrap. According to the report of SMB environmental projects in 2013 [15], a private green technology solution sector estimates claim that 1 million scrap tires are generated every year in India, but because there are no reverse logistics systems in place to collect EOL tires and because some rural areas of India have not yet acknowledged an awareness of the need for tire recycling, India's EOL tires issue will certainly invoke both widespread health and environmental problems. Some studies [16–18] discuss various concepts in EOL tire management but are limited to an analysis of their driving factors. Hence, this study explores the influencing or motivating factors of EOL tire management in an Indian context. This study also acts as a pioneering approach for other developing markets; they can analyze the drivers in EOL tire management relevant to their context. With these above considerations, this study attempts to responsibly analyze the drivers of EOL tire management with the aid of a proposed framework. The study was assisted by a literature review and opinions from industrial experts. We use interpretive structural modeling (ISM) as the solution methodology to analyze the problem we have framed within the Indian context.

The main objectives of this paper are:

- To identify the common drivers that affect the implementation of EOL tire management in an Indian context;
- To propose a framework to analyze EOL tire management drivers with the aid of ISM;
- To explain, with a case study in an Indian context, the essential drivers for EOL tire management implementation and to reveal their influence over one another; and
- To validate our results with the support of literature and feedback from industrial experts.

The remaining sections of the paper are organized as follows. Section 2 explores the concept of EOL tire management and its relevant drivers which were backed by an existing literature survey. The problem description, an overview of the case firm and their basic details, and their commitment towards the study are detailed in Section 3. The solution methodology is explained in Section 4, and Section 5 shows the application of the proposed model. The results and discussion of the study are provided in Section 6, followed by some managerial implications of the study which are given in Section 7. Section 8 offers our conclusion, limitations, and the future scope of the study.

2 Literature review

From the above discussion, it is already clear that the integration of EOL product management, including EOL tires, starts from about 1990. After this integration, many studies discussed the various recycling and remanufacturing methods of EOL tires or scrap tires, so we have considered here the EOL tire management and their relevant literatures.

In [5], they discussed the European standards of EOL tire management, especially with the focus of extended producer responsibility. They explored the relation between different parties like the government and private and academic institutions. Their perspectives on the integration of EOL tire management was founded on the evidence of a Portuguese case study, and their study discussed various EOL technologies like retreading, recycling, incineration (cement kiln), incineration (power plant), and legal landfill with their actors' infrastructure characterization. In [16], researchers compared and evaluated the best EOL tire treatment technology in a Chinese context; they considered four alternative technologies such as ambient grinding, devulcanization, pyrolysis, and illegal tire oil extraction. These alternatives were evaluated with the consideration of both economical and environmental perspectives using the life cycle analysis based on the Eco-indicator 99 with the aid of GaBi 4 software. This study provided a deep literature understanding of EOL tires in a Chinese scenario; they concluded that pyrolysis is the best, and illegal oil extraction is the worst among the alternatives. In [17], they discussed the challenges of the EOL tire management system with the evidence of a Spanish case study. This study revolves around Directive 2008/98/EC released by the European Union on the consideration of waste management and followed with extended producer responsibility. They discussed the effects and their integration of the virtual EOL tire management system in Spain with the abovementioned directive.

Reference [18] discusses pyrolysis as an alternative of EOL tire management. In [8], the researchers address the issues of the sustainable tire remanufacturing with an agent-based simulation modeling approach. Primarily, this paper focuses on the tire-retreading process with the proposed model of tire manufacturer, collector, retreader, and recycler. They argue that the retread process regains about 25 % of the market share. In [19], the study's focus is on the best EOL tire disposal process in terms of their environmental balance. They consider two alternatives for their study: a waste to energy process and using conventional fuel for the cement clink process. In the cement clink process, they take into account both cryogenic and mechanical pulverization processes. They evaluate that the fuel substitution in the cement clink is the better of the two alternatives obtained through the life cycle analysis based on the Eco-indicator 95 method. In [14], a method is proposed to absorb the vibration and noise with the material coming from EOL tires, and they provide the experimental details for this investigation of the damping characteristics. In [3], the various value recovery options are explored; for example, after getting the recycled fibers from the EOL tires, they tested the new fiber absorber developed from the used tires. From this study, they present a product with higher added value and lower cost.

Reference [20] offers a literature review on various recycling practices in the well-known nations of the USA, Japan, and Korea. They explore the current status of the recycling techniques and then compare them with one another in that period. Recycling processes include retreading, recycling as crumb rubber, and combustion for thermal energy. In [21], a case study in Vermont considers scrap tire management, discussing the factors, facts, issues, policies, benefits, and other issues of scrap tire management. In [22], the life cycle budget for the tire production and the energy flows in the tire components are discussed. Also, other processes of recycling and the benefits of resource recovery from the scrap tires are examined. In [23], an investigation into the effects of foreign trade, international policy measures, and legislation on environmental pressures in the truck life cycle is explored. In [24], researchers made a study to select the best tire recycling process with the aid of a hybrid MCDM approach. They consider whole tires, cut tires, chipped tires, tire crumb, devulcanization, reclamation, and energy recovery as alternatives for their study. In [25], the authors attempt to identify the most efficient EOL tire recovery method with the assistance of AHP in a fuzzy environment. They chose all recovery methods used globally and selected the best method for a case study of Turkey because they argued that the recovery method used may be different in other nations depending on their economic, social, and legislative conditions. In [26], the EOL tire management in the European Union was reviewed. In this article, they revealed the process undergoing in EOL tire management in recent years among the European countries, and they reviewed the innovative organizational approaches used in the current realm and its possible ways of uses as raw materials or alternate fossil fuels. de Souza and D'Agosto [27] explored the reverse logistics of EOL tires in a Chinese sector by redirecting to the cement industry in their study. They proposed a value chain in scrap tire reverse logistics to verify financial benefits in distribution. The impact of extended producer responsibility (EPR) in tire waste is explored by Milanez and Bührs [28]; they further explained the development and implementation of EPR in Brazil with the consideration of theoretical aspects and case institutional aspects. Some literature resources integrate the life cycle analysis in EOL tire management decision-making; for example, reference [29] offers a life cycle analysis for two EOL tire treatment methods: material recovery and energy recovery with the prioritization of waste treatment in the USA. In this study, they used both attributional and consequential life cycle analyses to reveal the result that material recovery is more useful than energy recovery. In reference [30], a decision model called "life cycle activity analysis" is proposed; it combines life cycle analysis with activity analysis and integrates the two for eco-efficiency in decision-making. They consider two scenarios, landfill and EOL management of used tires, through the proposed model, and they find that the EOL activities include remanufacture, recycling, and heat generation in cement plants.

From the literature review described here, it is clear that very few studies explore EOL tire management, particularly since some of the literature resources focus mainly on remanufacturing and recycling techniques. The majority of the studies only consider alternatives of the EOL tire management, some with proposed models and some with potential recycling/remanufacturing processes. While these literature resources do provide some basic drivers of the EOL tire management such as directives and legislation, no previous work purely analyzes the drivers of EOL tire management, especially in an Indian context. Hence, this study provides a significant approach to this problem; it is a phenomenon that should be explored and extended further.

3 Problem description

Due to the momentous effect of EOL tire management in developed nations, many third parties become involved in the management through various strategies. Those third parties may include the government, non-government organizations, and the tire manufacturers themselves. However, in the context of developing countries, there are few third parties involved in these management operations. In our study, we considered a third party company in India that was actively involved in EOL tire management. This group took responsibility for collecting, sorting, and other operations. Their company manufactures rubber tires, and they employ an average of 90 workers. With the multi-stakeholder interest and especially with recent regulations such as extended producer responsibility, they organize EOL tire management activities. Hence, they want to implement effective EOL tire management through their whole supply chain to enjoy the benefits of this management. In order to address these issues, they needed to explore the influencing drivers of the EOL tire management, and they believed that this study would reveal the importance of EOL tire management in an Indian scenario. As a result, their business opportunities may increase. They approached our research team to support our work with eagerness. Our research team consists of decision makers with relevant industrial and academic experiences, and we approached the external auditor's assistance to avoid any bias in the research. Our proposed framework, shown in Fig. 2, starts from the goal of the study and continues with the identification and collection of drivers. The proposed model is applied to this sister concern with three phase methodologies, namely the identification and comparison of common drivers of EOL tire management, an analysis of the drivers within the ISM framework, and a validation of the results.

The identified drivers of EOL tire management in phase I are analyzed with the ISM methodology, then we consider the notions of the case industrial managers in phase II. Once the results are obtained, the results are revealed to the case industrial managers to get their feedback and to allow them to know the impact of the study which is detailed in phase III. The drivers of EOL tire management are listed in Table 1.

4 Solution methodology

Interpretive structural modeling is one of the multi-criteria decision-making (MCDM) tools best suited for complex engineering problems. In terms of ISM, various mathematical foundations were found in previous literatures [37], but a theoretical and logical explanation was provided only by Warfield [38]. Many researchers applied ISM in their study due to its potential benefits of converting a complex problem into a simple and evident model with better insights [39]. Our knowledge and understanding of the first integration of ISM in management application were done by the study of Mandal and Deshmukh [40] with the vendor selection problem. After this integration, many studies have analyzed various factors in applications with the aid of ISM methodology. For instance, the most famous applications of ISM are in supplier selection [40–42], policy analysis [43–46], and other general issues [47, 48]. Some existing studies integrate the ISM with other MCDM tools to solve problems; for instance, see references [41, 49]. Some studies [50, 51] also use other MCDM methods such as AHP, ANP, etc. to analyze and to rank the given criteria for the chosen problem, but the interactions between the attributes are analyzed only by the ISM. Hence, in this consideration, for this study, we chose ISM as a solution methodology.

In our problem, the aim of the paper is to analyze the drivers of EOL tire management. The various steps involved in the methodology of ISM are discussed below (adapted from [52]):

Step 1 Identification and collection of attributes/criteria affecting the implementation of EOL tire management.
Step 2 Conceptual relationship is developed among the drivers that were collected from step 1.
Step 3 Development of structural self-interaction matrix (SSIM), a pairwise comparison of drivers.
Step 4 Formation of reachability matrix from the SSIM which was obtained in the previous step and checked for transitivity.
Step 5 Partition of reachability matrix into levels.

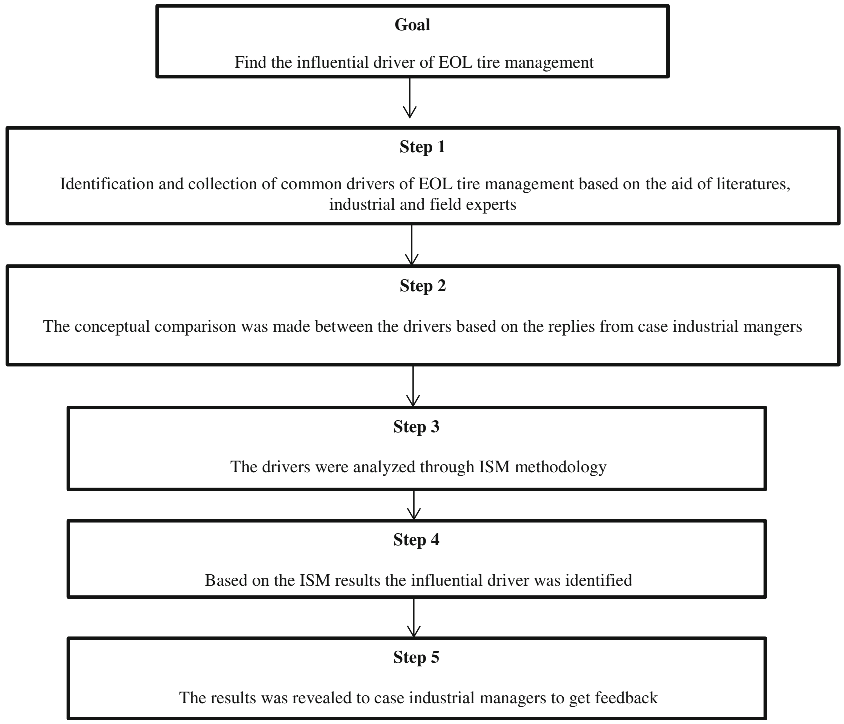


Fig. 2 Proposed framework for analyzing the influential driver of EOL tire management in an Indian scenario

Table 1 Common drivers of EOL tire management in an Indian scenario

S. no.	Drivers	Definition	References
1	Extended producer responsibility (D1)	In a famously debated act by the government, manufacturers are pressured to take responsibility of their product throughout its whole life cycle (including after its EOL)	[4, 5, 8, 18, 23]
2	Codes of conduct (D2)	Regulations, legislations, and other governmental initiatives concerned with environmental and waste management are considered as the drivers for codes of conduct	[4, 5, 8, 18, 23]
3	Stakeholder pressure (D3)	Pressures exist from various stakeholders such as government, auditors, banks, customers, suppliers, employees, etc.	[4, 5]
4	Eco design (D4)	In recent design and manufacturing environments, all products are produced with aim of considering their ecological impact through their eco design and green manufacturing	[23] Enterprise interview
5	Value recovery (D5)	EOL tires have many useful materials such as fiber, rubber, etc. which can be used for other useful applications	[4, 5, 8, 18]
6	Resource scarcity (D6)	Every time virgin tires are manufactured, in addition to other materials, we exploit rubber, and tire manufacturing consumes more rubber than any other process. Thus, there can be a chance of resource scarcity in future	[4, 5, 18]
7	Recycling and remanufacturing options (D7)	Many recycling and remanufacturing strategies are identified and are still evolving towards continuous improvement by the researchers. This serves as a better option for EOL tires than landfills.	[3–5, 16, 31]
8	Health issues (D8)	In rainy seasons (mostly in tropical areas), EOL tires are a breeding place for mosquitoes and other flies. These insects cause major diseases and lead to many health problems.	[3–5, 16, 31, 23]
9	Increasing landfill (D9)	Illegal landfills became a major threat in land leaching; organic elements in the tire became dangerous when they decay. In addition, the fertility of the soil decreases	[4, 18, 23, 32, 33]
10	Environmental conservations (D10)	If EOL tires burn, poisonous gases are released that are dangerous for the environment. Other issues like soil fertility, resource depletion must also be considered. Due to this fact, huge pressures are exerted to conserve the environment from EOL tires	[3–7, 16, 18, 31–33]
11	Reverse logistics (D11)	Reverse logistics is the one of the tools to achieve EOL tire management	[34]
12	Cost benefits (D12)	Recently government initiatives provide tax exemptions for EOL tire management activities. There will also be huge economic benefits from the value of their recovery	[6, 17, 32, 35, 36]

Step 6 Development of diagraph with removed transitive links.

Step 7 By replacing the nodes with statements, we convert the diagraph into ISM.

Step 8 Check for inconsistencies, and if necessary, make modifications.

The above steps are applied in the next section with our consideration of the problem. The framework of the ISM methodology with regard to our problem is shown in Fig. 3.

5 Application of proposed model

The proposed model is applied to the case mentioned in the above sections. This framework application has three phases, namely identification and comparison of common drivers of EOL tire management, an analysis of the drivers with ISM, and validation of the results.

Phase I Identification and comparison of common drivers of EOL tire management

This phase consists of identifying and collecting the common drivers that affect the implementation of EOL tire management. According to this data collection, our research team made a two-step approach. Initially, we approached industrial and field experts who are relevant to our problem and case. Our research team considered 12 field experts who have sound knowledge in tire manufacturing and environmental management. In addition to those 12, we also contacted 20 large scale sectors through mail, telephonic inquiries, and direct meetings. Moreover, we surveyed existing literatures in the leading journals such as Springer, Elsevier, and Emerald, and some locally made case studies were also considered for identifying the drivers. Our goal was to reveal the gap between the "state-of-the-art" and virtual worlds. Once the common drivers were collected, we then approached the individual industry and field experts with these drivers to ensure the collected drivers were sufficient for the study. From their replies and suggestions, the common drivers of EOL tire management are identified. The experts suggested that we consider only the main drivers, but all other drivers were grouped under these drivers. We have listed these results in Table 1.

Phase II Analysis of the drivers with ISM

After the drivers are collected and identified, the drivers are analyzed with the assistance of ISM methodology as explained in the previous section. As per the ISM methodology, the following steps are applied to analyze the drivers with the case company perspective.

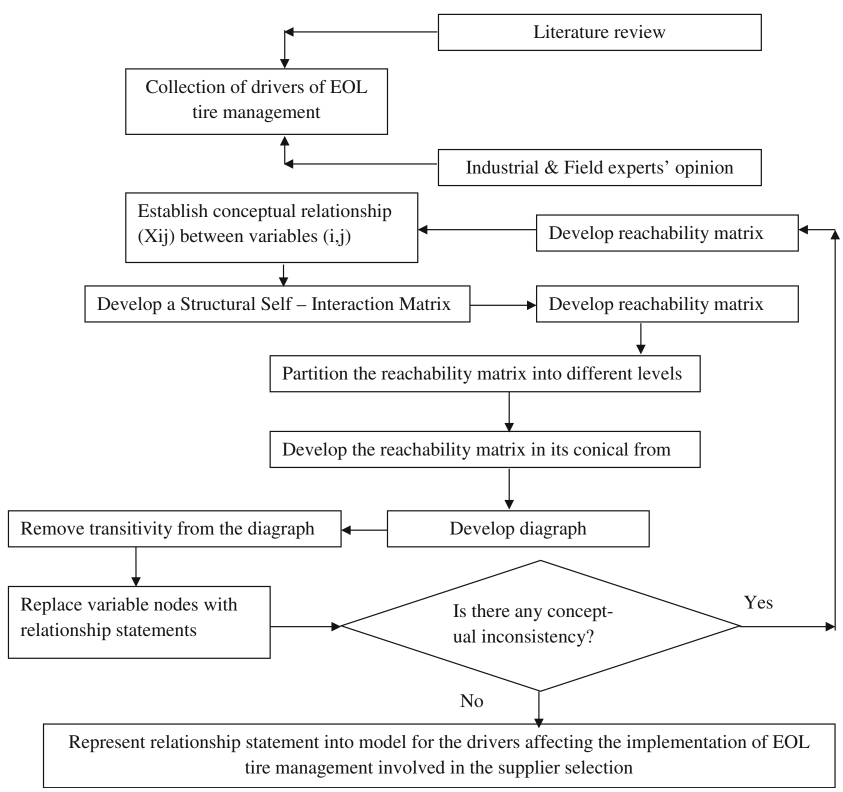


Fig. 3 Flow chart for the ISM methodology respective to our study (Modified from Kannan et al. [49])

(a) SSIM development

The structural self-interaction matrix (SSIM) is developed with the conceptual relationship between each attribute. The collected drivers were provided to the case industrial managers, and depending on their reply, a pairwise comparison was made among the collected drivers. The pairwise comparison consists of four symbols to indicate the influence of one driver over another. The four symbols are listed below with its relevant definition.

‘V’ Issue i influences issue j
‘A’ Issue j influences issue i
‘X’ Issues i and j influence each other
‘O’ Issues i and j are unrelated

The pairwise comparison among the drivers from the case industrial managers’ perspective is shown in Table 2.

(b) Formation of reachability matrix:

There are two reachability matrices derived in this formation: an initial reachability matrix and a final reachability matrix.

Initial reachability matrix: Once the SSIM is developed, then from the SSIM, the reachability matrix is derived. An initial reachability matrix is shown in Table 3, where the symbols are replaced with the numbers ‘0’ and ‘1.’ The principles of replacing the numbers with the principles are mentioned below.

- If the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 0.
- If the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 1.
- If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 1.
- If the (i, j) entry in the SSIM is O, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 0.

Final reachability matrix: The initial reachability converts to the final reachability matrix by applying the transitivity rule. The transitivity rule states that if an attribute ‘A’ is related to ‘B’ and ‘B’ is related to ‘C’, then A is surely related to ‘C.’ According to this rule, the final reachability matrix is formed and shown in Table 4. In the final reachability matrix, the driving power and dependence power are calculated. The sum of the row is

Table 3 Initial reachability matrix

Element	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	1	1	0	1	0	0	0	1	1
4	0	0	0	1	0	0	0	0	0	0	0	0
5	0	0	0	1	1	0	0	0	0	0	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1
7	0	0	0	1	1	0	1	0	0	0	1	1
8	0	0	1	1	1	0	1	1	0	0	1	0
9	0	0	1	1	1	0	1	1	1	0	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1
11	0	0	0	1	0	0	1	0	0	0	1	1
12	0	0	0	1	0	0	0	0	0	0	0	1

Table 2 Structural self-interaction matrix (SSIM)

Drivers	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2
Extended producer responsibility (D1)	V	V	X	V	V	V	X	V	V	V	X
Codes of conduct (D2)	V	V	X	V	V	V	X	V	V	V	
Stakeholder pressure (D3)	V	V	A	A	A	V	A	V	V		
Eco design (D4)	A	A	A	A	A	A	A	A			
Value recovery (D5)	V	V	A	A	A	A	A				
Resource scarcity (D6)	V	V	X	V	V	V					
Recycling and remanufacturing options (D7)	V	X	A	A	A						
Health issues (D8)	O	V	A	A							
Increasing landfill (D9)	V	V	A								
Environmental conservations (D10)	V	V									
Reverse logistics (D11)	V										
Cost benefits (D12)											

Table 4 Final reachability matrix

Element	1	2	3	4	5	6	7	8	9	10	11	12	Driving Power
1	1	1	1	1	1	1	1	1	1	1	1	1	12
2	1	1	1	1	1	1	1	1	1	1	1	1	12
3	0	0	1	1	1	0	1	0	0	0	1	1	6
4	0	0	0	1	0	0	0	0	0	0	0	0	1
5	0	0	0	1	1	0	1	0	0	0	1	1	5
6	1	1	1	1	1	1	1	1	1	1	1	1	12
7	0	0	0	1	1	0	1	0	0	0	1	1	5
8	0	0	1	1	1	0	1	1	0	0	1	1	7
9	0	0	1	1	1	0	1	1	1	0	1	1	8
10	1	1	1	1	1	1	1	1	1	1	1	1	12
11	0	0	0	1	1	0	1	0	0	0	1	1	5
12	0	0	0	1	0	0	0	0	0	0	0	1	2
Dependence	4	4	7	12	10	4	10	6	5	4	10	11	

called the driving power and the sum of the column is called the dependence power.

(c) Partitions of matrix into levels:

The final reachability matrix, obtained from the previous step, is partitioned into different levels based on the three sets, namely the reachability set, the antecedent set, and the intersection set. The reachability set contains the criterion itself and the other criteria it may influence. The antecedent set contains the criterion itself, and the other criteria which may influence to achieve this criterion. The common criteria present in both reachability set and antecedent set is called the intersection set. Once we obtained these three sets, the criteria that are common in the reachability and intersection sets are designated as level I. For instance, in our case, in Table 5 (first iteration), eco design (D4) is the only criterion which is common in both reachability and intersection sets, so it is designated as level I. By further iterations, the full ranks of the influencing drivers were analyzed.

(d) ISM model formation

By computing all the iterations which were explained in the previous steps, the full rank vector of drivers of EOL tire management were analyzed and are shown in Table 6, and with the assistance of the rank, the ISM model is framed which is shown in Fig 4.

Phase III Validation of the result

The final phase of the study is the validation of the results; the obtained results are communicated with the case industrial managers and other field experts. In our results, there are no complications. In fact, if complications are exhibited, then the study needs to be reconsidered with the abovementioned model framework. The responses

Table 5 Level partition of drivers of EOL tire management (iteration I)

S. no.	Drivers	Reachability set	Antecedent set	Intersection	Level
1	Extended producer responsibility (D1)	1,2,3,4,5,6,7,8,9,10,11,12	1, 2, 6, 10	1, 2, 6, 10	
2	Codes of conduct (D2)	1,2,3,4,5,6,7,8,9,10,11,12	1, 2, 6, 10	1, 2, 6, 10	
3	Stakeholder pressure (D3)	3,4,5,7,11,12	1, 2, 3, 6, 8, 9, 10	3	
4	Eco design (D4)	4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	4	I
5	Value recovery (D5)	4, 5, 7, 11, 12	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	5, 7, 11	
6	Resource scarcity (D6)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 6, 10	1, 2, 6, 10	
7	Recycling and remanufacturing options (D7)	4, 5, 7, 11, 12	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	5, 7, 11	
8	Health issues (D8)	3, 4, 5, 7, 8, 11, 12	1, 2, 6, 8, 9, 10	8	
9	Increasing landfill (D9)	3, 4, 5, 7, 8, 9, 11, 12	1, 2, 6, 9, 10	9	
10	Environmental conservations (D10)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 6, 10	1, 2, 6, 10	
11	Reverse logistics (D11)	4, 5, 7, 11, 12	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	5, 7, 11	
12	Cost benefits (D12)	4, 12	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12	12	

Table 6 Rank vectors for given EOL tire management drivers

S. no.	Drivers of EOL tire management	Rank vector
1	Extended producer responsibility (D1)	7
2	Codes of conduct (D2)	7
3	Stakeholder pressure (D3)	4
4	Eco design (D4)	1
5	Value recovery (D5)	3
6	Resource scarcity (D6)	7
7	Recycling and remanufacturing options (D7)	3
8	Health issues (D8)	5
9	Increasing landfill (D9)	6
10	Environmental conservations (D10)	7
11	Reverse logistics (D11)	3
12	Cost benefits (D12)	2

of the study are simplified through the MICMAC tool which is shown in Fig. 5. The feedback from the case firm is detailed in Section 6.

6 Results and discussions

This section provides the results obtained by practicing all the steps which were mentioned in the framework and by the discussions made with the case industrial managers.

Duperrin and Godet [53] first developed the MICMAC (cross-impact matrix multiplication applied to classification) analysis, and Warfield [54] argued that it provides a simple way to construct and to analyze complicated problems. There are four clusters in the MICMAC analysis, each cluster has its own characteristics. Cluster I implies the weak driving and weak dependence force, so the elements that belong to cluster I have weak dependence and weak driving power. The elements that belong to cluster I are called autonomous factors. Cluster II implies the weak driving and strong dependence force, so the elements that belong to cluster II have weak driving and strong dependence power. The elements which belong to cluster II are called dependent factors. Cluster III implies the strong driving and strong dependence force, so the elements that belong to cluster III have strong driving and strong dependence power; they are called linkage factors. Finally, cluster IV elements have weak dependence and strong driving power, and these elements are called independent factors.

As per our study, the drivers D3, D5, D7, D11, D12, and D4 belong to cluster II, with strong dependence power and weak driving power, and are known as dependent factors. The drivers D1, D2, D6, D10, D9, and D8 belong to the cluster IV; they are independent factors with strong driving power and weak dependence power.

From the ISM model and MICMAC analysis, it is evident that the most influencing drivers of EOL tire management in Indian scenario are environmental conservation, extended producer responsibility, codes of conduct, and resource scarcity. They are interrelated, but still different within their concepts and implications. These four drivers can influence the other drivers in EOL tire management. The ISM model possesses seven levels of drivers: eco design and cost benefits are captured in last place in the table.

If we compare the results of our study with those from other countries' scenarios, we arrive at some significant insights. In

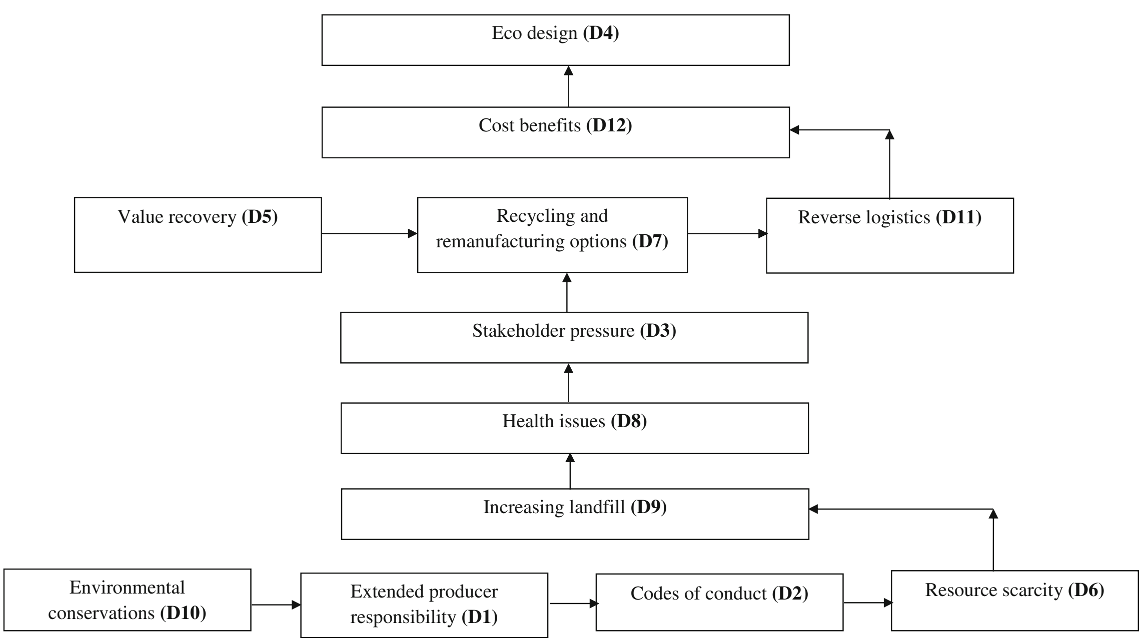
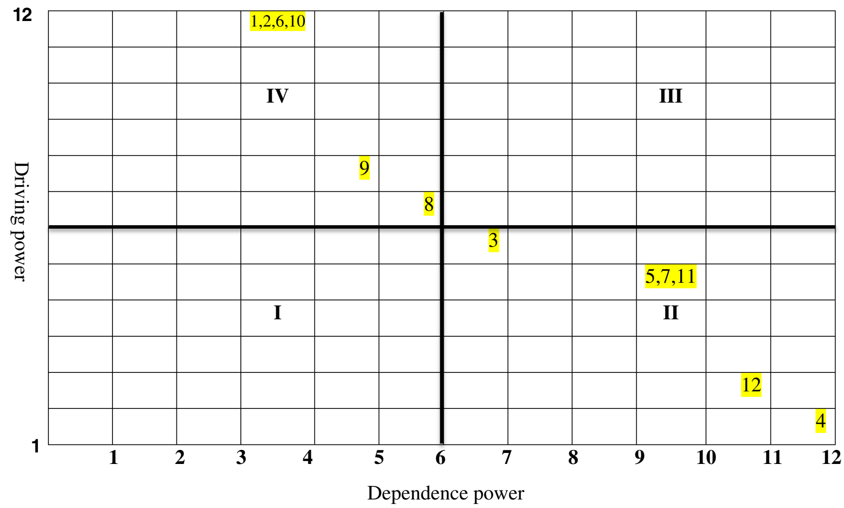


Fig. 4 ISM model for the drivers affecting the implementation of EOL tire management

Fig. 5 Driving and dependence power diagram (MICMAC analysis)



a developed context like the EU, legislation is an influential factor of EOL tire management—especially EPR—as confirmed by Sienkiewicz et al. [26] in their review on used tires management. Our results both contradict and share similarities with some existing studies made in developing scenarios. Specifically, our results conflict with an existing study made in the emerging market of Brazil. In that study [28], the author argued that the most effective driver of EOL tire management is extended producer responsibility, a conclusion drawn from their institutional case study. In our case, however, the most influential driver is environmental conservation. If we further explore this contradiction, a key point is clearly revealed. Even though firms follow EOL tire management with the regulation of EPR, EPR is a function of the environmental conservation needs; hence, the actual "hidden" influential driver is environmental conservation. At any cost, the volunteer driver (environmental conservation) is better than the mandatory driver (EPR) because, whereas a firm may appear to engage in EOL management, they may practice such strategies only upon an occasion of auditing. If they voluntarily and regularly practice these management strategies, then such moves will lead to sound implementation of EOL tire management. de Souza and D'Agosto [27] argued that growing environmental conservation leads to waste tire management strategies with the consideration of Chinese scrap tire reverse logistics. This statement is similar to our study, and the study by Siddique and Naik [55] on waste tire management further supports our results.

These results were shared with the industrial managers to get their feedback. At first, they were surprised at the results because cost benefits emerged as the least option among other drivers. This ranking is difficult for top level management officials to comprehend. On the other hand, the industrial manager accepted environmental conservation and legislation as influential drivers. In fact, this manager said that they engaged EOL tire management due to the pressures of extended producer responsibility which, directed by the government, are ultimately concerns of environmental conservation. Another industrial manager stated that this kind of study can improve their organizational standards, and that it will allow them to evaluate the importance of their perspectives in terms of EOL tire management. These results will be shared with their trading partners and customers to improve the sustainable development which will also increase their partnership collaboration beyond the boundaries, he added. After 3 months, our research team approached the case firm to learn the impact of our study results. In this connection, they explained that they promoted the study to their trading partners, customers, and top level management, and they got positive feedback from their surroundings. In terms of these results, now, they tighten the rules with their trading partners with the EOL tire management, and also, they said that this study creates some awareness among their customers which helps to motivate their willingness to increase more effective EOL tire management.

7 Managerial implications

This study provides some useful managerial implications for the companies which really want to integrate EOL tire management activities in their operations. This study helps the industrial manager to utilize EOL tire management strategies by pointing out their importance to the environment and to society. Industrial managers can stimulate the most influential driver to achieve EOL tire management because the most influential driver impacts all other drivers. It also allows the company to compare their status with our results, and they can improve their weak areas through this important identification. This study also serves some societal implications. Because EOL tire issues cause major threats to human health and safety, in this regard, this study helps to avoid these destructive societal concerns in India. This work sheds light on the path of EOL tire management which serves to improve further in the future.

8 Conclusion

Due to the urgent concerns of environmental and societal considerations, EOL product management became a highly important research topic, along with studies of waste from energy, waste used as alternative material, and so forth. In this scenario, EOL tire management is currently considered a primary issue due to the dangerous impacts we have identified. In this connections, this study attempts to analyze the drivers of EOL tire management with a proposed model where ISM serves as a solution methodology, a MCDM approach. The common drivers of EOL tire management were collected from the combined assistance of literature resources and from field and industrial experts. The proposed model is then validated with the third party case company situated in southern India, a sister concern of a rubber tire manufacturer. The study provides some valuable results: the most influential driver of EOL tire management is environmental conservation, followed by three other important influential drivers, extended producer responsibility, codes of conduct, and resource scarcity. These results were communicated with the case managers to validate the study and to obtain some positive feedback and other relevant discussions. Many studies accept that after the integration of extended producer responsibility, EOL tire management became efficient in the developed countries. Our study provides environmental considerations as the most influential driver because due to the concern of the environment, the government passes many regulations, including the extended producer responsibility. Hence, our study coincides with the existing literatures and provides some useful managerial and societal implications. This study provides the interaction between each and every driver of EOL tire management; it is one of the initial steps in EOL tire management in an Indian context. There is a need to dig out more opportunities and options to explore the optimal management techniques, so further explorative study is needed in the scenarios of developing countries.

Every study has its own limitations, as does this one. This study is purely dependent upon the industrial managers' opinions. If they harbor biases, those views may affect the originality of the results. This study considers a third party company in the southern region of India. In a different area or locality, or with a different firm size or a different region, results may change. To satisfy these potential drawbacks in the ISM and to fill these limitation gaps, one could extend this study with statistical analysis like structural equation modeling (SEM), an approach that could include many different samples in different regions in the future. Another area for future researchers to focus on might include a consideration of sub-drivers and other new drivers according to their current situation. Finally, some inter-organizational and benchmarking studies with developed countries might improve EOL tire management strategies in India.

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