Circular Economy in Automobile Industry: Literature Analysis

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ABSTRACT

With an increasing global focus on sustainability and reducing environmental impact, the concept of Circular Economy (CE) has become necessary for different sectors of the economy. This study targets the automotive industry as it is one of the major contributing sectors in the world. As there is a lack of review studies targeting the broader field of CE in the automobile industry it has become important to review CE concept literature to help

future researchers determine future research directions. The aim of this paper is to present an analysis and better understand the concept of CE within the automotive industry. A systematic view is provided by reviewing, categorizing, and analyzing papers published between 2014 and 2023 on the Web of Science (WOS) database. Analysis of references is done through cataloging. This article investigates the main research directions and trends in terms of CE in the automobile industry and which element of the CE concept is becoming more popular while implementing CE practices. Through literature analysis, gaps are identified, and future research directions are proposed to fill them.

Keywords: Circular economy, automobile industry, sustainability, literature review

INTRODUCTION

With an increasing global focus on sustainability and reducing environmental impact, the concept of circular economy has become important for different sectors of the economy. Linear economy approach results, based on a 'take-make-consume-throw away' pattern, did not allow us to close the loop from production to consumption to secondary resource management and channeling back of these resources back into the economy. The massive waste generation at all stages of a product life cycle right from resource extraction, processing, value addition, consumption and end of life stage needs to be looked at and ways identified to minimize this waste generation and enhance recovery and reuse of resources (Arora et al., 2018). By promoting the adoption of closing-the-loop production patterns within an economic system Circular Economy aims to increase the efficiency of resource use, with targets to

reduce waste to a minimum, re-using, repairing, and recycling used products, with a special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society (Ghiselini et al., 2016). Nathalia Suchek etc, conclude cleaner production, pollution controls, waste management, a product-service logic, and reverse logistics are the main changes observed in the transition to circular business models. Tools such as evaluating the life cycle and ecological design are also high on the agenda. In this perspective, the business models of incumbent firms and startups differ. Incumbents may influence an ecosystem evolving into a CE, but they may also be less flexible than startups in capturing opportunities and developing radical innovations (Suchek et al., 2021).

This study targets the automotive industry for the said purpose as it is one of the major contributing sectors of the global economy. Researchers are working on the economic, environmental, and societal factors in the automobile industry for sustainable development (Sarkar et al., 2018).

The aim of this paper is to present an analysis and better understand the concept of the circular economy within the automotive industry. Accordingly, the main objective of this study is to present the most current research for the given topic, to identify patterns and trends in the literature and to recommend new research areas.

The paper is organized as follows: Section 2 presents the methodology in which the literature review process is explained; in Section 3 literature review results are given and discussions provide both the descriptive statistics and the analysis of the references; Section 4 includes conclusions and future research directions.

METHODOLOGY

Method selection: systematic literature review

The methodology of this research is based on the literature review analysis. This paper contributes to the literature by reviewing and analyzing the engagement of the number of papers. We divide the literature review into three steps (Figure 1), starting with the selection of references from the Web of Science database. A systematic review was conducted with this database using search terms including "Circular economy" and "Automobile industry". At the first step there were found 59 papers, from which after analysis 9 articles were extracted (different from the study area). 50 papers are left for cataloging, descriptive and thematic analysis.

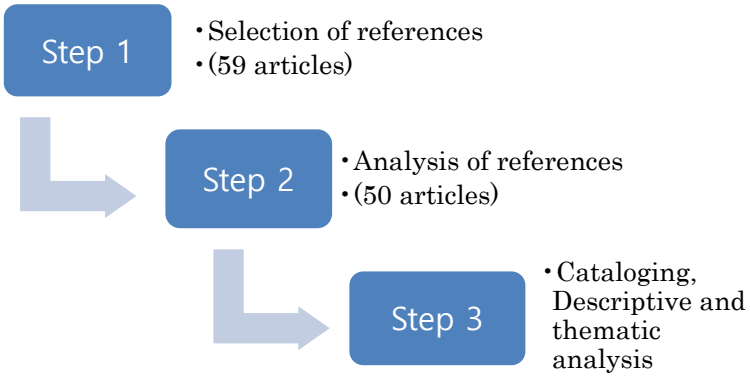

Figure 1. Literature review process

Studied time period

As Brondoni (2020) suggests the number of circular economy-related publications has increased rapidly since 2007, and most of articles were published in the 2014-2016 period, we decided to find all literature related to CE in the Web of Science database and

analyze studies in a car industry. According to our findings, most research has been done during 2015-2021 and it represents the CE is becoming an actual concept that is being introduced and discussed by many researchers and practitioners.

In the first step, we tried to search for academic papers that obtain all sectors of the economy by using the keyword Circular economy. As a result, more than 16,000 numbers of articles were found (Figure 2). According to this chart, we investigate that the Circular economy started to be studied and researched from 1985. However, this topic was not actual among researchers and practitioners until 2015 and starting in 2015 we can observe a rapid increase in the number of works related Circular economy. The decline in 2023 does not mean this area is becoming less popular, there were given only articles written in the 1st quarter of 2023.

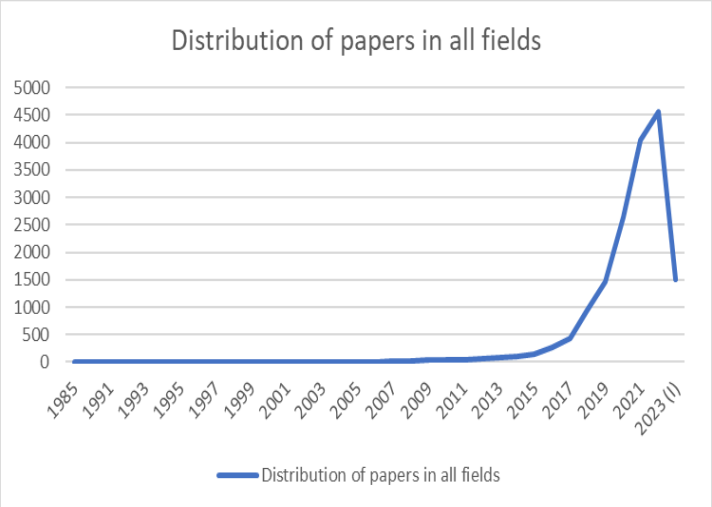

Figure 2. Distribution of papers including all sectors of the economy within CE

Next by using the keywords CE and automobile industry papers related to the automotive industry were extracted from the total quantity of the abovementioned articles, Figure 3.

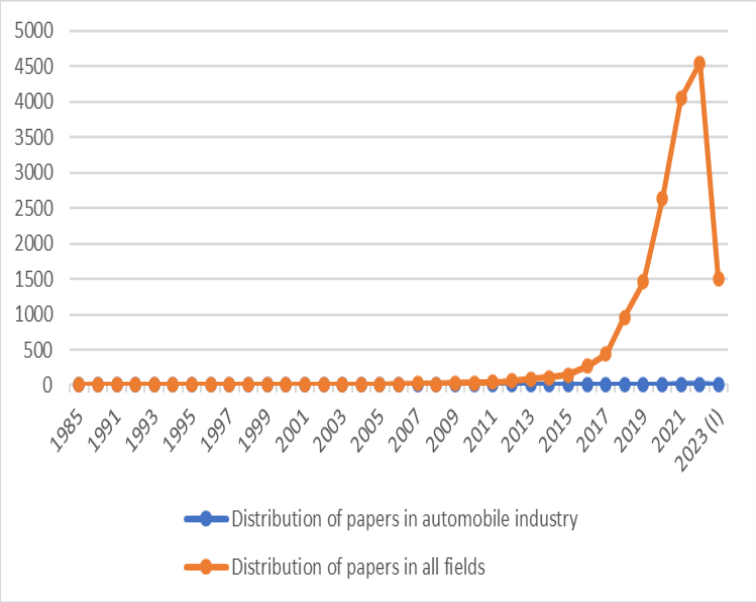

Figure 3. Distribution of papers in all fields and the automobile sector

The total number of articles in the automobile sector assessed was 59, then according to the topic of the research only 50 papers were extracted for future analysis (9 papers were out of research theme), Figure 4.

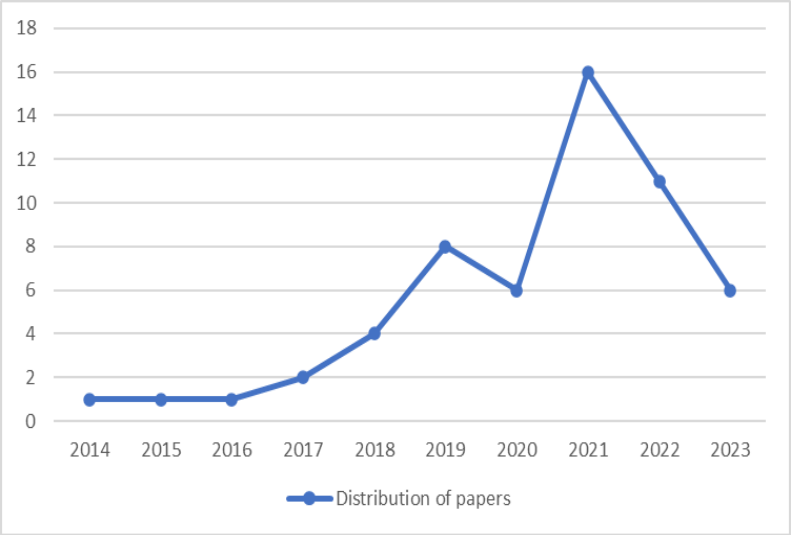

Figure 4. Distribution of papers in the automobile industry within CE

Journal selection

Figure 5 shows that the largest number of articles on CE in the automobile industry were in the Sustainability journal and Journal of Cleaner Production is considered to be the second most popular journal in this direction. Resources conservation and recycling, Science of the total environment, Energies, Waste management, Materials, Business strategy and the environment also contributed a significant number of articles related to our topic. Moreover, the figure presents the range of journals publishing on CE in the automotive industry that the category 'others' includes Procedia CIRP, International Journal of Production Research, Emerging Issues in Management, Journal of Business Research, Journal of Environmental Economics and Management and Journal Strategy and Management.

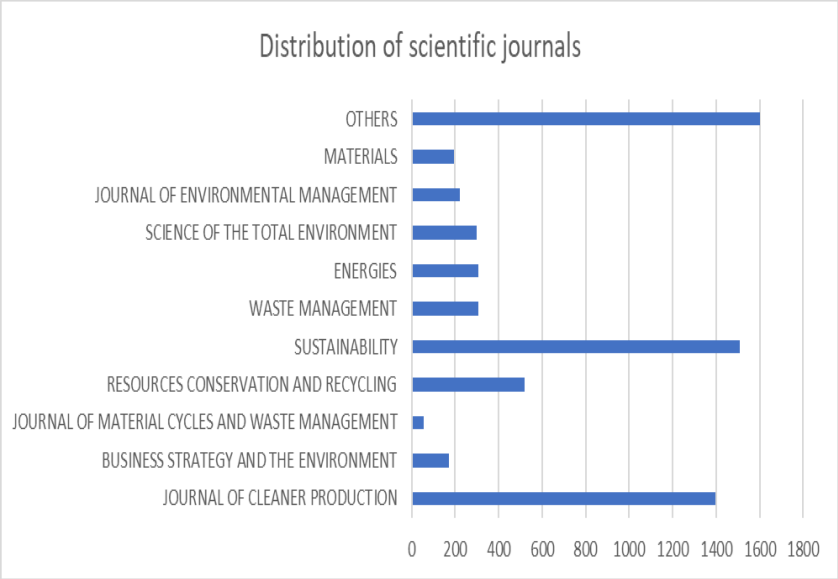

Figure 5. Distribution of scientific journals

Cataloging

After the selection of papers analysis of references started from cataloging. Each paper was analyzed using the following categories:

- Industry: automobile industry.
- Region of the study
- Methodology of the study
- Research question or the "the aim of the paper"
- Findings and results

RESULTS

Region of the study

Most of studies on the Circular economy are focused on the automobile industry of developed countries like the USA, Japan

and some European countries like Germany and Sweden. It is obvious that the Circular economy has replaced the Linear economy with huge economies. For instance, the automotive sector in Europe spends €60.9 billion per annum on innovation, focusing on improving resource efficiency (Kamble et al., 2021). Therefore, the inclusion of CE practices is necessary for manufacturing organizations to compete at a global level. Accordingly, developed countries nowadays concentrate on more CE concepts to support their economies and environment. In our case, the CE practices facilitate the existing automotive companies to keep themselves updated with the recent technological developments and absorb sustainability in their operations (Kamble et al., 2021).

However, China is a leading country in the studies related to the Circular economy in the car industry. China is one of the biggest car producers in the world. According to the report by the China Association of Automobile Manufacturers (CAAM, 2014), in 2014 the number of automobiles produced and sold in China was 23,722,800 and 23,491,900, respectively, increasing 7.3% and 6.9% compared with those numbers in 2013 (Qu et al., 2018).

Moreover, there are some studies that took place in developing countries like Brazil, Turkey and India. According to our findings, the recycling process in Brazil moves at a slow pace, when compared to other European Union countries, Japan, and the United States, where the recycling rate is around 80–95%, while Brazil recycles only 1.5% of its ELV fleet (Soares et al., 2023). Brazil shows a certain delay in terms of strategies to manage their vehicles out of circulation. Despite the great development of the automotive industry in the country, there is not enough attention directed to the management of post-consumption discarded products. The lack of specific legislation generates impertinence that does not support the structure of a waste management program for ELVs. Meanwhile, huge problems are generated, such

as illegal dumping of automotive waste, growth of the illegal market of auto parts, and damage to public health and the environment (Soares et al., 2023).

The Indian automotive component manufacturing industry is one of the world's largest suppliers, and many developed countries outsource their requirements from India. Even though there is no production of cars in India, however, the manufacturing of car components has a huge contribution to the Indian economy and is considered the major driver of macroeconomic growth. As India's auto component industry has contributed 2.3 % of the Gross Domestic Production (GDP) (India Brand Equity Foundation data, 2023), researchers such as Rajak et al. (2022), Agrawal et al. (2021), Kumar et al. (2023) and Kamble et al. (2021) devoted their work to studying the issues of Indian automotive component industry and opportunities for implementation of CE practices (Kamble et al., 2021).

Finally, we found that many articles did not connect with any specific regions. Most researchers studied the Circular economy concept at a global scale and the majority of these studies were devoted to ELV management, Supply Chain Management, recycling metals and plastics, car components, and so on.

Methods used in the study

The studies reviewed in this paper were classified into 16 categories and 8 subcategories of applied methods. We found many research works are done by using Mathematical modeling (MM) and Multi-criteria decision making (MSDM) methods, where Fuzzy TOPSIS and DEMATEL are the most popular tools among researchers. Table 1 shows the summary of used methods in the reviewed studies.

Table 1. Summary of methods used in the study

Methods	Methods	Methods
Exploratory factor analysis (EFA)	Principal component analysis (PCA)	Multi-criteria decision making (MCDM)
Material flow analysis (MFA)	Theory of planned behavior (TPB)	Analytical hierarchy process (AHP)
Internet of things (IOT)	Cluster analysis (CA)	DEMATEL (DEM)
Life-cycle assessment (LCA)	Linguistic entropy weight method (LEWM)	Fuzzy TOPSIS (FTP)
Best-Worst method (BWM)	Cross-case analysis (CSA)	Fuzzy CRITIC (FCT)
CODAS (assessment method)		TOPSIS (TP)
Strategic Metal Index (SMI)	Mathematical modeling (MM)	Grey-DEMATEL
Large group decision making (LGDM)	Linear programming (LP)	
Comparative analysis (CA)	Structural equation modeling (SEM)	

Research questions

For research questions, we can separate the papers into some categories: first category papers include questions in a formal Research Question format that especially stand out (about 30% from all reviewed papers) like Q1. What are the barriers and enablers to CE implementation for EVBs? Q2. What are the

potential strategies to support successful CE implementation for EVBs? (Sopha et al., 2022).

In the second category of papers, researchers limited to the question form within the introduction part (The numbers of papers are few). Lastly, third category papers stated their research questions with "the aim of the paper" (about 50% of reviewed papers), for instance 'This study aims to highlight the impacts of a rapidly growing automobile industry on the environment and how the implementation of Circular Economy (CE) principles and strategies can help us in improving its sustainability without compromising on our existing economic models.' Or 'The aim of this article is to identify the key opportunities for and challenges to improving the catalyst recycling system in Poland.' (Patel and Singh, 2022, Generowicz et al., 2021).

Finding 1. The most studied CE areas in the automobile industry

The automobile sector generates approximately 5% of the world's industrial waste, either from vehicles or production plants. This sector is one of the largest consumers of raw materials. The demand projections on vehicle sales suggest significant increases worldwide for the next decades. By 2030, up to 1.85 billion vehicles are expected to join the current fleet, requiring massive amounts of raw materials (Valero, 2019). During the research, we highlighted the key areas of CE performance evaluation in the automobile industry. Some of the most important components of CE in the automobile industry within the literature are ELVs (Table 2), policy and strategies, supply chain management and others (plastics, metals, raw materials) (Gunjan et al., 2020).

Area 1: ELV management

The topic of ELVs is at the center of researchers' attention. According to the study by Selman Karagoz, Nezir Aydin and

Vladimir Simic, 232 studies published in the period 2000–2019 are collected, categorized, reviewed, and analyzed in this area (Selman et al., 2020). Accordingly, our review has shown that there is a significant increase in the number of studies over the last few years. In Table 2, we provided the list of papers related to ELV management highlighting names of researchers, titles of works and years of publication.

Table 2. The list of papers in the field of ELV management (2014-2023)

Author(s)	Research Titles	Year
Suriyakumar, S; Pattavathi, B; Jojo, A; Shaijumon, MM	Upcycling of Spent LiCoO2 Cathode to Lithium Dual-Ion Battery Anode	2023
Zhang, YF; Liu, SC; Liu, Y; Yang, HD; Li, M; Huisingh, D; Wang, LH	The 'Internet of Things' enabled real-time scheduling for remanufacturing of automobile engines	2018
Generowicz, N	The importance of recovery of PGMS from catalysts - a case study of recycling network in Poland	2022
Jagadeesh, P; Rangappa, SM; Siengchin, S and etc.	Sustainable recycling technologies for thermoplastic polymers and their composites: A review of the state of the art	2022
Deveci, M; Simic, V; Torkayesh, AE	Remanufacturing facility location for automotive Lithium-ion batteries: An integrated	2021

	neutrosophic decision-making model	
Pauliuk, S; Kondo, Y; Nakamura, S; Nakajima, K	Regional distribution and losses of end-of-life steel throughout multiple product life cycles Insights from the global multiregional MaTrace model	2017
Iglesias-Embil, M; Valero, A; Ortego, A; Villacampa, M; Vilaro, J; Villalba, G	Raw material use in a battery electric car - a thermodynamic rarity assessment	2020
Qu, Y; Liu, YK; Guo, LL; Zhu, QH; Tseng, ML	Promoting remanufactured heavy-truck engine purchase in China: Influencing factors and their effects	2018
Ohno, H; Matsubae, K; Nakajima, K; Kondo, Y; Nakamura, S; Fukushima, Y; Nagasaka, T	Optimal Recycling of Steel Scrap and Alloying Elements: Input-Output based Linear Programming Method with Its Application to End-of-Life Vehicles in Japan	2017
Rajak, S; Vimal, KEK; Arumugam, S; Parthiban, J; Sivaraman, SK; Kandasamy, J; Duque, AA	Multi-objective mixed-integer linear optimization model for sustainable closed-loop supply chain network: a case study on remanufacturing steering column	2022
Karagoz, S; Aydin, N; Simic, V	End-of-life vehicle management: a comprehensive review	2019
Tarrar, M; Despeisse, M; Johansson, B	Driving vehicle dismantling forward-A combined literature and empirical study	2021

Ortego, A; Valero, A; Valero, A; Iglesias, M	Downcycling in automobile recycling process: A thermodynamic assessment	2018
Khodier, A; Williams, K; Dallison, N	Challenges around automotive shredder residue production and disposal	2018
Soares, TD; Silva, MM; Santos, SM	A hybrid Grey-DEMATEL approach to identify barriers to the implementation of an end-of-life vehicle management system in Brazil	2023
Ruffino, B; Panepinto, D; Zanetti, M	A Circular Approach for Recovery and Recycling of Automobile Shredder Residues (ASRs): Material and Thermal Valorization	2021

In the meantime, there are several questions regarding this growing issue among researchers: Why is ELV management becoming so an actual problem that much research work is being done? What are researchers studying in their works? What kind of suggestions and conclusions do they offer to solve those issues? Through our findings, we tried to answer these questions.

Jang et al. (2022) stated the annual production of vehicles was around 78 million new cars around the globe in 2020, which indicates a future deluge of ELVs needs to handle. Karagoz et al. (2020) identified that ELVs present a risk and menace from an economic, social, and environmental perspective, as nearly 5% of industrial waste is generated by automobiles. In addition, according to Sakai et al (2014)'s findings, each year, car technology is continuously upgrading, which leads owners to change their vehicles before their expiry; thus, ultimately resulting in an

increased quantity of ELVs. On the other hand, Karagoz et al. (2020) highlighted ELVs are considered one of the largest hazardous waste categories, which involves complicated processing because of their complex structure and composition. ELVs contain precious materials such as platinum, aluminum, lead, zinc, copper, iron and others. ELVs also contain many harmful components such as transmission oils, fuels, refrigerants, brominated flame retardants, and acid batteries. Some other authors confirm that today, ELV management is a well-positioned and emergent research area. However, the available review papers are focused only on a small area of ELV management, such as reverse logistics, recovery infrastructure, disassembly ability, and so on. Moreover, ELV management is considered to be one of the important factors in energy production systems and it should be controlled at a governmental level. For instance, Vuk Petronijevic and others suggest that ELV recycling depends on national pressure related to the implementation of EU directives and national legislation and note that the impact of ELV recycling on the structure of renewable energy sources for the Republic of Serbia can be significant, which means that there is a lot of room for improving the recycling process, the use of resources, and greater efficiency in obtaining energy through recovery and reuse (Petronijevic et al., 2020). Lastly, Zhang et al. (2018) stated ELVs are becoming a serious issue and how to deal with end-of-life vehicles (ELVs) and parts in a more sustainable manner will be an increasingly urgent challenge in the coming years as a result of the growing number of new vehicles.

As we described papers in Table 2, research works have been done in different scopes. We found the majority of them related to recycling and reusing precious metals, remanufacturing car components, recycling Lithium-Ion batteries, recovery of PGMS from Catalysts, steel recycling and others. Authors offer various

models, frameworks, and methods to solve these issues. For instance, the implementation of the 'Internet of Things' enabled real-time scheduling for remanufacturing of automobile engines (Zhang et al., 2018), Sustainable recycling technologies for thermoplastic polymers and their composites (Jagadeesh et al., 2022), Methods for Optimal Recycling of Steel Scrap and Alloying Elements: Input-Output based Linear Programming Method with Its Application to End-of-Life Vehicles (Ohno et al., 2017), a Circular Approach for Recovery and Recycling of Automobile Shredder Residues (ASRs) (Ruffino et al., 2021) and others.

Area 2: Supply Chain Management

Many papers took 'Supply Chain Management' as a significant research area in the automotive industry (Table 3). To support Sustainable Supply Chain, researchers gave their suggestions varying within the CE concept. Some authors tried to identify the Big Data-Driven Circular Economy (BDDCE) practices that are significant for successfully implementing the CE business models in manufacturing organizations (Kamble et al., 2021). Others pay great attention to suppliers' selection and evaluation methods, as suppliers are one of the main participants in the Supply Chain. For instance, Feng and Gong (2020) suggested that by applying the linguistic entropy weight method (LEWM), the company can select the most suitable suppliers and the suppliers can address underperformance on certain indicators based on the company's evaluation feedback. Generowicz et al. (2021) tried to identify key Challenges and Opportunities for an Effective Supply Chain System. Omair et al. (2022) tried to analyze the role of reverse logistics (RL) which is a contemporary and important study for the CE and critically analyzed blockchain technology and business analytics techniques in the context of supply chain. And they found that advanced technologies have a key role in the implementation

of remanufacturing and recycling practices. Their results also indicate that the remanufacturing and recycling practices substantially improve automobile firm performance (Yu et al., 2022).

Table 3. Studies on Supply Chain Management

Author(s)	Research Titles	Year
Omair, M; Alkahtani, M; Ayaz, K; Hussain, G; Buhl, J	Supply Chain Modelling of the Automobile Multi-Stage Production Considering Circular Economy by Waste Management Using Recycling and Reworking Operations	2022
Haleem, A; Khan, S; Luthra, S; Varshney, H; Alam, M; Khan, MI	Supplier evaluation in the context of circular economy: A forward step for resilient business and environment concern	2021
Chhimwal, M; Agrawal, S; Kumar, G	Measuring Circular Supply Chain Risk: A Bayesian Network Methodology	2021
Generowicz, N; Kulczycka, J; Partyka, M; Saluga, K	Key Challenges and Opportunities for an Effective Supply Chain System in the Catalyst Recycling Market-A Case Study of Poland	2021
Feng, JH; Gong, ZR	Integrated linguistic entropy weight method and multi-objective programming model	2020

	for supplier selection and order allocation in a circular economy: A case study	
Dwivedi, A; Chowdhury, P. and etc	Antecedents of digital supply chains for a circular economy: a sustainability perspective	2023
Zhang, XM; Li, ZZ; Wang, Y	A Review of the Criteria and Methods of Reverse Logistics Supplier Selection	2020
Yu, Z; Umar, M; Rehman, SA.	Adoption of technological innovation and recycling practices in automobile sector: under the Covid-19 pandemic	2022
Zhang, XM; Li, ZZ; Wang, Y; Yan, W	An Integrated Multicriteria Decision-Making Approach for Collection Modes Selection in Remanufacturing Reverse Logistics	2021

Area 3: Policies and Strategies for CE in the automobile industry

The economic incentives and existing legislation have made the CE an integral part of the automotive industry. The automotive industry should adopt design principles that support the idea of CE. Many works have been conducted in this direction. According to the findings from reviewed papers, the US, Japan, European countries, China, and other emerging countries are promoting the development of a CE, and it is becoming an integral part of policymaking. However, some emerging countries still have issues regarding the CE policy implementations. For instance, according to studies in Brazil and Serbia, there is a lack of governmental regulation that can push companies to implement CE practices.

While studying this Area 3, we found that there are some obstacles and effective drivers while implementing the CE concept strategies. Some authors tried to analyze them and give their suggestions in terms of opportunities for CE support.

Drivers. According to our findings, there are many drivers of CE implementation like government regulation and policy, company value, environmental protection, consumer perception, consumer awareness, technology, region, cost savings, resource scarcity and others. For instance, in Japan based on the realization that all resources are limited, Toyota promotes effective use of resources such as measures to improve yield ratios and reduce the volume of packaging materials, supports activities to reduce water consumption at the production stage, continues implementing waste reduction measures such as reducing industrial dust and sludge volume. Ohno and others in their work evaluated the potential benefits of parts scrap utilization as a secondary source of AEs on the reduction of embodied greenhouse gas (GHG) emissions and costs (Ohno et al., 2017).

As there are a number of manufacturing enterprises in China, air pollution is becoming one of the biggest issues. As a result, people are suffered and must move to cleaner areas. To support and develop low carbon cities and provide sustainable cities, China's government takes measures and implements policies moving towards CE. Researchers such as Li (2021), Qu et al. (2018), Shao et al. (2020), Wang et al. (2023), Zhang and Chen (2015), Zhang et al. (2021) devoted their works to solving various problems in this direction. In that case, even one rising problem in the country can be the driver of the development of CE concept strategies.

Moreover, the geographical placement of countries can play a role in supporting CE practices. European countries like Germany, Great Britain, France, Sweden, Italy and Poland push each other

to implement CE and try to be a good example in some directions (technology and legislation). Besides, in European countries, consumer perception is widely studied in terms of CE.

Obstacles. However, there are some obstacles to the implementation of CE strategies, for instance, such as lack of policy, technology, cost, and lack of data (consumer awareness). Emerging countries still have no concrete policies toward CE. The implementation of the CE concept is at the infancy level. As researchers mentioned in their works in many emerging economies including Pakistan, the exploration of CE concept and its potential benefits has been rare. Limited attempts have been made to identify the barriers and drivers in implementing the CE in emerging economies. For example, in Pakistan, the automobile manufacturing sector makes a significant contribution to the GDP. The sector mainly consists of automobile assemblers (Toyota, Honda, Suzuki, and Hino) and automotive parts manufacturers.

Area 4: Plastics, metals and raw materials

In the last few years, a growing trend in the automotive industry has been observed, in which metals are replaced by plastic components for a reduction in weight, thus leading to low fuel consumption. Plastics, in general, present a wide category, and their decomposition is also one of the major concerns faced globally. For these purposes, the research work on plastics recovery through CE in the automotive industry holds substantial significance. In the automotive industry particularly, the disassembly of used parts and the cleaning, remodeling, assembling, storage, and packaging, for example, are only a few of the phases of sequences involved in the process of remanufacturing items, which is regarded as a fundamental process in the scientific literature (Omair et al., 2022). Plastic recycling is gaining much importance in EVs offering lightweight features to offset bulky batteries'

weight. Our findings imply that automotive companies should invest in advanced material sorting and recycling technology enabling waste reuse with a long-term objective of lowering the cost of recycled material without compromising the quality.

Valero (2019) studied the recycling processes of metals in a common vehicle (A segment, 103 kW) to identify valuable vehicle metals and components that are not functionally recovered. We also identified which current vehicle recycling process should be improved.

Finding 2: Distribution of R(s) in CE

In this subsection, we investigated the main directions regarding CE approach. As we know, companies try to implement step by step all the key elements of CE like Recycling, Reusing, Reducing, Remanufacturing, Refurbishment, and Recovery. We found there is a big difference in terms of their implementation to the processes of companies. According to our research results, Remanufacturing and Recycling processes are well extended elements of the CE concept in the automobile sector. We tried to make an analysis of this trend considering the benefits, obstacles, and opportunities for the implementation of CE elements and tried to study the levels of progressing CE components.

(1) Recycling

We found the majority of researchers and practitioners pay great attention to the recycling process and 15 papers are done only studying this process. For instance, Generowicz et al. (2022) think the development of recycling is becoming more and more popular. In their work, they suggest the subject of recycling catalysts from secondary sources perfectly fits the model of Circular Economy which is being developed nowadays. Such a policy of catalyst management from spend vehicles is something that will be

required in the near future. Jagadeesh and others discuss that Recycling is one of the most important measures available to mitigate these effects and is one of the most dynamic segments of the plastics industry at present and identify recycled plastics are recovered from the waste stream, which is considered as a renewable source of material, while virgin plastics are mainly made from fossil fuels which is non-renewable (Jagadeesh et al., 2022). Using recycled plastics in manufacturing industry fits the popular idea of circular economy and become a common practice towards the full scope of socio-ecological sustainability (Gu et al, 2016).

However, there is a opposite ideas about the importance of recycling. As Valero (2019) stated recycling, the most common industrial approach is to compare the price of the raw material against the cost of extracting it from a recycle at the product's EoL. In many cases, the recycling process is discarded for being uneconomic. The same comparison can be made in exergy terms with similar results. Using exergy allows us to delve deeper into the physical process. In fact, a highly mixed/alloyed object requires substantial amounts of exergy for its dismantling and metal recovery. Therefore, the industry has been in search of a "paying metal" regardless of the recoverability of additional components in the produced waste. Regularly, it becomes even more challenging to recover additional materials from such waste. Usually, the first recycled material no longer meets the quality standards of the virgin raw material.

(2) Remanufacture

Another important component of CE is Remanufacturing and 10 papers explain its effectiveness in automobile manufacturing companies. Zhang et al. (2018) gave a good definition of Remanufacturing process: 'The remanufacturing process begins

with the collection of the used parts. It includes the following steps: complete or partial disassembly of products, parts cleaning, inspection and storage of parts, reconditioning and replacement of parts, and reassembly of products, further producing "like-new" products even better than new products in quality and performance. Elgowainy et al. (2018) consider automotive remanufacturing is seen as a significant contributor to sustainable development, accounting for almost two-thirds of all remanufacturing activities globally. Deveci et al. (2021) stated Remanufacturing is the most environmentally friendly since remanufacturing of ALiBs can mitigate the raw material problem for the EV industry, decline import dependency, counteract price volatility, reduce the carbon footprint, and ensure sustainable e-mobility. Wang et al. (2023) in their studies highlighted that remanufacturing is a circular economy model with higher comprehensive benefits, compared with the recycling of scrapped automobile materials, The production of an automobile emits an average of 690 kg of greenhouse gases, and it is conservatively estimated that the production of an automobile by remanufacturing can reduce 550 kg of greenhouse gas emissions.

Other strategies of CE like Reuse, Reduce, Refurbishment and etc are studied by mixing ways. For example, Patel and Singh tried to highlight the impacts of a rapidly growing automobile industry on the environment and how the implementation of Circular Economy (CE) principles and strategies (Recycle, Reuse, Reduce) can help us in improving its sustainability without compromising on our existing economic models. They investigate carbon footprint or environmental emissions during different stages of an automobile life cycle that can be minimized using CE principles and strategies without compromising on the existing economic models (Patel and Singh, 2022). Rajak et al. (2022) tried to propose a model where an industry can optimize the number of parts to be

repaired, dismantled, and recycled, determine the supplier's optimum quantity of parts purchase, help the organization to maximize profit, and minimize the environmental impact by attaining sustainability.

CONCLUSION AND IMPLICATIONS

This work presents a systematic literature review of CE in the automobile industry. It is a preliminary literature analysis to give an idea about the current situation happening in the automobile industry within CE and what factors and CE areas researchers pay attention to more. 50 papers were analyzed from the WOS database and results show research on CE in the automobile industry is still in its infancy and knowledge is needed to better understand what is going on in terms of CE and what actions are either necessary or sufficient for a CE to go ahead.

It is found that the Sustainability Journal and then Journal of Cleaner Production are leading journals in the studied area. Furthermore, the main important studied directions of CE in the automobile industry were identified and analyzed. As a result, ELV management and Supply Chain Management are at the center of researchers' attention. Besides, we found that while implementing CE practices, all participants of the automobile industry are focusing more on Recycling and Remanufacturing than other ways (Reuse, Reduce, Refurbishment), in addition, there were studied obstacles and enablers while implementing CE strategies.

While conducting this literature analysis, we found there are still some gaps that need to be researched in the future:

- even though there are many works done related to ELVs and SCH, there is a lack of studies targeting the broader field of ELV management and Supply Chain Management.

- some authors highlighted a greater number of studies have acknowledged the need for investigations into the micro-level CE implementation to provide managers with insights for addressing barriers that challenge implementation and drivers in the transition of enterprises to CE. From our findings, many studies focused on the macro-level at the example of a specific country, while the half of reviewed studies have no specific region, and they are studied globally.

- most of these studies are centered on the general manufacturing sector with none focusing on the automobile industrial sector.

Moreover, as our research obtains just one database search, the literature is limited in terms of CE in the automobile industry, and it is complicated to give a clear whole picture of the study area. Future research should be done by reviewing a wider set of published articles including other databases, because future studies can include more papers to obtain a broader picture and provide more insights targeting specific automobile companies or specific regional areas.

Our aim is to continue the investigation of the deeper context of the circular economy in the automotive industry. Additionally, as there are limited studies with a case study-based approach, future research directions will be focused on advanced cases of CE practices in the automobile industry.

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