Review

Sustainable Supply Chain Management in the Automotive Industry: A Process-Oriented Review

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Abstract: The holistic shift from traditional supply chain to sustainable supply chain has been practiced in different industries for many years. The automotive industry, as one of the largest and most influential industries in the world, could have a substantial effect on the movement toward a sustainable society. Despite the growing body of literature in the field of sustainable supply chain management, there is no review article that comprehensively synthesizes the state-of-the-art research in the automotive industry. To cover this gap, this paper reviews the sustainable supply chain management literature in the automotive industry published between 1995 and 2017. A systematic review and content analysis were conducted to collect the studies and analyze their content. The content analysis was structured based upon a set of key business processes following the Integration Definition Function (IDEF0) method, which is a structured approach of analyzing business processes. The study provides a practical guideline for designing a sustainable automotive supply chain and culminates with the outlined research gaps and recommendations for future research.

Keywords: sustainable supply chain management; green supply chain management; automotive industry; supply chain design; review; content analysis; IDEF0 method

1. Introduction

The automotive industry is indubitably one of the largest and most influential industries in the world [1,2]. It involves a wide variety of companies taking part in design, development, manufacturing, selling, and marketing of automobiles and their spare parts [3]. The industry is a major contributor to the world’s economy and is one of the most important economic sectors by revenue, such that its turnover is equivalent to the sixth largest economy in the world [4]. Besides the economic impact, the industry is a huge contributor to the well-being of people and society, through affecting the quality of a human’s life remarkably [5]. With the growth of the industry and the production rate, more vehicles are seen on the roads, bringing their own problem to society. Automobiles affect the environment in various ways during their life cycle. Any automobile, before being ready to roll, consumes a considerable amount of materials like plastics, rubber, glass, steel, and many more, many of which are difficult and expensive to recycle or dispose of. On the other hand, fuel consumption leads to air pollution, which affects air quality and worsens global warming. Considering the substantial effect of the automotive industry on economic, environmental, and social activities all over the globe, effective management of this sector has become vital to assure the well-being of society [6]. Owing to these concerns, automotive companies have started to implement particular practices that enable them to integrate sustainability measures into their operations [7–9].
The necessity of changing industrial activities to attain a more sustainable world started with the report by the World Commission on Environment and Development (WCED) in 1987 [10], with the emphasis that different industries have to incorporate sustainability-conscious initiatives into their business practices. Since then, controversies have risen as to how a better sustainable performance might be achieved for industries, and indeed what practices can be incorporated into conventional supply chain management (SCM) that make supply chain (SC) activities more sustainable. Given the fact that SCs manage the flow of products from their early stage until they are delivered to end users, the focus on SCM is a step toward the wider execution and development of sustainability [11,12]. Consequently, integrating the concept of sustainability into SCM, leading to the definition of the so-called term sustainable supply chain management (SSCM), has provided the opportunity for the broader development of this field. Green supply chain management (GSCM) [13,14], reverse logistics (RL) [15], and closed-loop supply chain management (CLSCM) [16] are terms that have emerged in the literature focusing on the environmental aspect of sustainability.

Recently, the automotive industry, as an industry with huge potential for tackling environmental issues, has felt increasing pressure from authorities and the public. For instance, regulations framed by governments, such as the EU Directive of End-of-Life (EOL) Vehicles, has encouraged car manufacturers in the European region to accelerate greening their SCs. As a result of these pressures and regulations, the concept of SSCM in the automotive industry (from now onward, auto-SSCM) has received growing attention in recent decades and unfolded plenty of opportunities for research in this area. Several studies have been conducted to discuss different aspects of environmentally-conscious practices and the challenges that the automotive sector encounters for the effective implementation of the practices. This had led to the incorporation of sustainable practices and aspects into different stages of automotive SCM, including, but not limited to design, purchasing, supplier collaboration, logistics, warehousing, and packaging [17].

As the field of auto-SSCM grows rapidly, there is a necessity to conduct review studies that structure the literature in a systematic way. Doing so can facilitate identifying primary research streams, analyzing research findings, and highlighting future research directions. Analyzing the studies in the area of SSCM indicates that several review articles have been published so far. However, the published review papers have discussed the SSCM field in general, without drawing specific attention to the automotive industry (see the background of the study in Section 2). As Carter and Easton [18] noted, the existing research on multi-industry samples provides an opportunity for deeper studies on individual industries that aid in discerning specific sustainability issues within those industries. To address this research gap, this paper aims to present a systematic state-of-the-art literature review discussing sustainability-conscious issues in automotive SCs. The paper categorizes and synthesizes the existing studies from a process-oriented perspective, and tries to distinguish prominent research areas that establish an agenda on future research opportunities. In this perspective, the paper will answer the following research questions:

What is the current state-of-the-art research on auto-SSCM from a process’s perspective?

On the basis of the literature review, what steps can be taken for designing a sustainable SC in the automotive industry?

What future research directions can be identified for this field of research?

The rest of the paper is organized as follows. In Section 2, a background to this research is provided. In Section 3, the research process applied in this study is presented. Section 4 provides a classified review of auto-SSCM issues. A conceptual model for designing a sustainable SSCM is presented in Section 5. Finally, the future research directions and the conclusions of this paper are given in Sections 6 and 7.

2. The Background of the Study

Review studies are primary sources in any field of science, as they can critically summarise the body of knowledge of the field [19].
progress in the area under investigation and can identify the strengths and weaknesses of prior studies, which can be beneficial in laying foundations for future studies [20,21]. As the area of SSCM took shape at the beginning of the 2000s, it has gained increasing attention over the years and has been a dominant research domain since 2010 [22]. The growing number of studies has consequently led to the growth in the number of review studies. A recent study by Rajeev et al. [22] comprehensively reviewed studies in the field of SSCM published over a period of 16 years, from 2000 to 2015, where the authors found 59 review papers covering different issues and sub-issues of SSCM. According to Rajeev et al.’s [22] analysis, the first review paper emerged in 2002, and the number of review papers followed a fairly stable trend until 2010, with less than four reviews published per year. From 2011 onward, the trend has changed and the number of review papers showed substantial growth, highlighting the importance that this topic has been gaining in the literature. The content analysis of the papers published during this time frame reveals that only the study of Beske et al. [23] focused on SSCM in a specific industry [22]. Beske et al. [23] investigated SSCM practices in the food industry and analyzed their connection to dynamic capabilities, which refers to the capabilities of companies to gain competitive advantages in a highly dynamic business environment. As a complement to the study of Rajeev et al. [22], Table A1 in the Appendix A provides the review studies that appeared in the literature from 2016 onward. Totally, 23 review papers were found with a focus on SSCM or GSCM. The number of studies within the two recent years also confirms the finding of Rajeev et al. [22], who stated that the number of review studies in SSCM has been growing since 2011. Looking at the fourth column of Table A1, it can be realized that only six papers analyzed a particular industry within the frame of SSCM research. They include mineral [24], textile [25], biorefinery [26], oil and gas [27], food [28], and fashion [29]. This analysis discloses that despite the high number of literature review studies conducted in SSCM, no study can be found that solely focused on the automotive industry. This is surprising given the importance of the automotive industry and its role in building a more sustainable world. This study, therefore, tries to cover this research gap and presents a review of research works published so far with the considerations of auto-SSCM.

3. Research Methodology

In this review study, we used a systematic review and content analysis to search and classify the body of the literature. A systematic literature review is a type of literature review that analyses the literature in a structured way [30,31] and presents the results in a transparent, objective, and reproducible way [32]. In addition, systematic literature reviews are usually performed using defined keywords and through iterative search phases that allow finding sample papers and organizing them for evaluation [33]. Similar to the most recent reviews [30,31,34–36], this paper follows a seven-step methodology for data collection, sample formation, and content analysis in order to investigate and classify research issues in auto-SSCM. The detailed guideline of executing a multi-step methodology for conducting a literature review is discussed by Tranfield et al. [37] and Cooper [38]. In what follows, we explain the methodology that was used to identify and analyze the studies.

3.1. Defining the Relevant Keywords for Searching Databases

Defining the appropriate search terms is an initial step in any systematic literature review. For deriving the necessary keywords, the recent review papers were thoroughly checked. The keywords were in line with the studies of Rajeev et al. [22], Sauer and Seuring [24], Seuring and Müller [39]. Four sets of keywords were defined, aiming at covering different dimensions of the study. Set A sought to retrieve the studies related to sustainability issue, which were chosen in line with three pillars of sustainability (i.e., economic, environmental, and social): “Sustainable”, “Sustainability”, “Sustainable Development”, “Green”, “Environment”, “Ethics/Ethical”, “Social”, “Economic”. The terms “Green” and “Environment” were added to the keywords because of the fact that the term “Sustainable” involves environmentally sustainable development. Set B intended to limit the search to the papers that only discussed SC and its sub-categories: “Supply Chain”, “Logistics/Logistical”, “Supply”,

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“Reverse”, “Closed-loop”. Set C was defined to ensure that different aspects of sustainable operations were covered: “Waste Management”, “Return”, “Reuse”, “Recycle”, “Remanufacture”, “Life cycle assessment”, “EOL”, “Product recovery”. Finally, set D of keywords was defined to limit the search to the papers in the area of the automotive industry: “Automotive”, “Auto”, “Automobile”, “Automaker”, “Car”, “Vehicle”. The final set of keywords was generated by combining the keywords from the four sets defined above. Thus, the search string used in the database search was the combination of keywords from all four sets using Boolean operators: \[\text{“Sustainable” } \lor \text{“Sustainability” } \lor \text{“Sustainable Development” } \lor \text{“Green” } \lor \text{“Environment” } \lor \text{“Ethics/Ethical” } \lor \text{“Social” } \lor \text{“Economic”}\] \[\land \text{“Supply Chain” } \lor \text{“Logistics/Logistical” } \lor \text{“Supply” } \lor \text{“Reverse” } \lor \text{“Closed-loop”}\] \[\land \text{“Waste Management” } \lor \text{“Return” } \lor \text{“Reuse” } \lor \text{“Recycle” } \lor \text{“Remanufacture” } \lor \text{“Life cycle assessment” } \lor \text{“EOL” } \lor \text{“Product recovery”}\] \[\land \text{“Automotive” } \lor \text{“Auto” } \lor \text{“Automobile” } \lor \text{“Automaker” } \lor \text{“Car” } \lor \text{“Vehicle”}\].

3.2. Database Selection and the First Search Phase

To form the initial search sample, Scopus was chosen as the main database to search the relevant papers in the first step. We preferred Scopus over Web of Science (WOS) because Scopus is a more comprehensive database than WOS (Scopus covers over 22,000 peer-reviewed journals, while WOS only comprises 12,000 titles) \cite{30,40}. Furthermore, Scopus was identified as a good source for SC peer-reviewed papers \cite{30,41}. Thus, Scopus was widely searched using the final list of the keywords defined in Section 3.1 to identify the papers that carried the keywords. The title, abstract, and keywords in the two databases were used to search for the defined keywords. Using the aforementioned settings, papers were searched for all years. In this step of our literature search, 957 papers were identified.

3.3. Filtration

In the second phase in Scopus, a number of exclusion criteria were implemented. First, the types of the papers were selected as article, review, and article in press, whereas other sources, the so-called gray literature, such as conference papers, books and book chapters, editorial, notes, short survey, letter, and erratum, were excluded from the search. During the search phase, the language of the papers was set as English. In this step of the search, 389 papers were found. To ensure that no paper was missing from the review, we added Google Scholar as the second scholarly database to our search. Using the same keywords as presented in Section 3.1, the papers were searched through Google Scholar and compared to the list of papers found from Scopus. This step resulted in finding 31 additional papers. Both papers from the databases were integrated and formed a single sample.

3.4. Snowball Approach

To ensure that the sample includes all the papers published in the literature, forward and backward snowball approaches were executed via searching through the references of the sample papers. The references were checked to find whether or not they contain the aforementioned keywords. In addition, the papers citing the sample papers were checked in order to find relevant papers. A total of 14 papers were added to the sample papers in this stage.

3.5. Final Filtration

To finalize the sample, the title, abstract, and contents of the papers were analyzed. The papers were examined in terms of their focus on business and operations management aspects of auto-SSCM and, in case they were found irrelevant (i.e., the focus was on other areas such as material design and engineering), they were eliminated from the sample. Moreover, some papers were removed from the sample as they were duplicated. The same size at this state was reduced to 229 papers.
3.6. Descriptive Analysis of the Sample

The results of this search were filtered by keeping the articles that focused on the automotive industry. Finally, a total of 229 articles published between 1995 and 2017 were taken into account for the purpose of content analysis. Table A2 in the Appendix A shows the distribution of articles in the various journal from 1995 to 2017.

3.7. The Content Classification Scheme

In this step, a content analysis framework was developed to classify the sample papers. The framework considers SSCM as a set of key business processes and applies the IDEF0 (Integration Definition Function) method, which is a structured approach for enterprise analysis [42]. IDEF0 is a rigorous and flexible approach that can be successfully applied to model systems with varying objectives, scopes, and complexities [43]. It is an approach that transforms inputs into outputs by using resources and applying the mechanisms under a set of rules and controls [44]. As an SSCM can be viewed as a set of processes, operations, and regulations, IDEF0 is suitable for representing it as a system. Following IDEF0, a content analysis framework was applied in this research, categorizing the SSCM literature in five content categories, which is illustrated in Figure 1. The components displayed in Figure 1 are structured based on the language’s syntax defined for IDEF0 [45]. The boxes represent functions that, in the context of this study, show what must be accomplished to green a supply chain. The input arrows located on the left side of the diagram are the data or objects that are alerted by the functions to produce the outputs, which are displayed as exiting arrows on the right side of the box. In the context of this study, the inputs include the information flows regarding the stakeholders’ requirements that flow into the SSCM processes, and the outputs are the results of greening the supply chain in the form reflecting on the performance measures. The control arrows flowing into the top of the function box are the standards and regulations; the SSCM processes are performed under the constraints imposed by them. According to IDEF0’s syntax, if an input arrow serves as both input and control, it is shown as control only. The mechanism arrows flowing into the bottom of the function box are defined as the enablers in accomplishing the SSCM processes.

![Figure 1. The framework for content analysis based on Integration Definition Function (IDEF0).](image)

SSCM—sustainable supply chain management.

4. Classification and Review of Studies in Auto-SSCM

In this section, the results of the content analysis of the auto-SSCM literature are presented. First, a descriptive analysis of the reviewed articles is presented, which is followed by a discussion highlighting some key research issues from the literature within each category and its sub-categories.
4.1. Descriptive Analysis of the Literature Based on Their Content

To descriptively analyze the literature, the frequency of appearance of each five content category and their sub-categories (for categories and their sub-categories, see Figure 2) was counted in the sample articles. Table 1 illustrates the result of the analysis. It is necessary to note that some articles only investigated one category, while the others discussed more than one category. Hence, the frequency of the categories is more than the number of papers.

<table>
<thead>
<tr>
<th>Content Category</th>
<th>Fre.</th>
<th>Perc. **</th>
<th>Content Category</th>
<th>Fre.</th>
<th>Perc.</th>
<th>Content Category</th>
<th>Fre.</th>
<th>Perc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>12</td>
<td>3.87%</td>
<td>Delivery</td>
<td>3</td>
<td>2.27%</td>
<td>Management Capabilities</td>
<td>7</td>
<td>17.07%</td>
</tr>
<tr>
<td>Legislation and Standards</td>
<td>18</td>
<td>5.81%</td>
<td>Supply</td>
<td>26</td>
<td>19.70%</td>
<td>Network Structure</td>
<td>16</td>
<td>39.03%</td>
</tr>
<tr>
<td>Processes</td>
<td>130</td>
<td>41.93%</td>
<td>Production</td>
<td>15</td>
<td>11.36%</td>
<td>Technology</td>
<td>18</td>
<td>43.90%</td>
</tr>
<tr>
<td>Resources/Mechanisms</td>
<td>36</td>
<td>11.62%</td>
<td>Use</td>
<td>8</td>
<td>6.06%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>102</td>
<td>32.9%</td>
<td>Post-use</td>
<td>80</td>
<td>60.61%</td>
<td>Total</td>
<td>41</td>
<td>100%</td>
</tr>
<tr>
<td>Overall Review</td>
<td>12</td>
<td>3.87%</td>
<td>Total</td>
<td>132</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>310</td>
<td>100%</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

* Frequency of appearance in the literature, ** Percentage.

As can be seen from Table 1, “process” is the most highly studied area in auto-SSCM (almost 42%). The “output”-related studies, with about 32% of the total frequencies, constitutes the second considerable portion of the reviewed literature. “Resource”-related research placed third with about 12% of total publications. The less published areas are “inputs” and “legislations and standards”, accounting for approximately 4% and 6% of the total studies, respectively. Among “process” sub-categories, the heavily investigated area is “post-use” process, with a percentage of roughly 61%. This is far more
than “supply”, with almost 20% of the publications of this category. In this sub-process, “delivery” and “use” are less explored areas, which just account for almost 2% and 6% of studies, respectively. Concerning the sub-category of “resources and mechanisms”, while the “technology”-centered studies have been favored more by researchers, “management capabilities” is a research area that is faced with a significant shortfall. Some examined articles discussed the concept of sustainability in the automotive industry, investigating how the sustainability-conscious issues can be integrated into the business strategy. They provided a comprehensive insight into the challenges that the companies encounter while developing a sustainable SC. The category of overall review represents this kind of study. As illustrated in Table 1, the articles falling into this category account for a small proportion of the total reviewed articles. Table A3 in Appendix A provides more detailed information and categorizes all the reviewed articles under the five main categories.

4.2. Key Findings from the Previous Research on Auto-SSCM

In this section, the results of the content analysis of the auto-SSCM literature are presented. Figure 2 depicts a comprehensive framework of the processes and sub-processes of an auto-SSCM.

4.2.1. Legislation and Standards

Environmental management standards and legal directives on environmental issues have played a key role in extending environmentally-conscious initiatives in the automotive industry. The European Union (EU) directive on ELV Commission [46] is one of the most influential legislative policies. It forces auto manufacturers to reuse, recycle, and adopt other forms of recovery for end-of-life vehicles (ELVs) and their components, aiming at preventing waste generation from vehicles and a reduction in disposal of waste. Considering the requirements of this directive, Zorpas and Inglezakis [47] tried to investigate the challenges that the automotive industry is experiencing to meet the quantified targets for reuse and recovery per vehicle and year specified by the EU directive. Other studies such as Ferrão and Amaral [48], Johnson and Wang [48,49], and Coates and Rahimifard [50], discussed the circumstances in which EOL activities could be economical, while meeting the requirements of the EU directive on ELVs. Apart from the EU rules, some studies investigated standards in China as the largest automobile manufacturer and the biggest market in the world. For instance, Zhang and Chen [51] discussed the rules and regulations of ELVs’ plastic recovery in China and criticized that the regulations of plastic recovery in China are not as perfect as in other developed countries. Zhang and Chen [52] investigated the effect of vehicles’ emission standards set up in China (China 2, China 3, and China 4) on diesel engine remanufacturing.

ISO 14001 is the environmental management system (EMS) standard that is widely established among original equipment manufacturers (OEMs) and their suppliers [53]. Some researchers like Nawrocka et al. [53] and Gonzalez et al. [54] investigated the role of this standard on extending SSCM practices within the automotive industry. “Recycling regulation” [51], “economic instrument including free take back” [54], “landfill tax” [54], “recycling credit-fee” [54], “tax on virgin materials subsidies on recycled material” [54], “imposing tax on used car export” [55], and “extended producer responsibility” [56] are the other policy-related issues investigated in the literature.

4.2.2. Inputs (Stakeholder Requirements)

Stakeholders are a group or single entity who may influence a firm or are influenced by the firm’s goals and behaviors [57,58]. According to the literature, stakeholders are classified into internal and external types, and typically include customers, suppliers, competitors, government, community, consumers, consumer defenders, environmentalists, and collaborators [57,58]. Increasing pressure from various stakeholders has driven the automotive industry to adopt SSCM practices. However, the types of pressures and stakeholders that enforce them are variable. In this respect, Sarkis et al. [59] and Zhu et al. [60] tried to explore different stakeholders’ requirements and evaluate the impact of their pressure on the adoption of SSCM practices in the automotive industry. They also investigated
the link between stakeholders’ pressure and the ultimate outcomes of implementing SSCM initiatives. Stakeholders’ pressure was examined in different automotive sectors as well as geographical areas. Lin and Lan [61] studied external pressure on Taiwanese auto component firms and investigated its possible link to the performance of the firms. Roh et al. [57] analyzed how stakeholders’ pressures affect the decision of developing hybrid cars in seven reputable automotive companies. Vanalle et al. [62] investigated stakeholders’ pressures on a Brazilian automotive SC and further explored its effect on the performance of GSCM. They found out that internal environmental management, green purchasing, and customer cooperation are the main practices adopted by suppliers in Brazil’s automotive industry, which are thanks to the high pressure from assemblers and regulations such as ISO 14000. Finally, Seles et al. [58] tried to find a relation between stakeholders’ pressures and the green bullwhip effect in a Brazilian automotive company.

4.2.3. SSCM Processes

To classify processes-related studies in auto-SSCM (as given in Figure 2), this paper adopted the classification developed by Sutherland et al. [63], which is one of the most comprehensive studies concerning the practical issues of environmental challenges in the automotive industry. Their classification is appreciated and applied by other studies, which discussed SSCM processes, such as the works published by Dyckhoff et al. [64] and Olugu et al. [65].

The first category in SSCM processes is the sustainable supply management process. There are two major directions in this research field: (1) sustainable supplier selection (SSS), and (2) sustainable supplier development (SSD). Supplier selection and evaluation (SSE) refers to the process in which a company tries to select an individual or a group of suppliers as a source of procurement. However, supplier development (SD) is a post-supplier selection process and can be defined as any effort taken on to enhance the performance of the existing supplier [66]. The majority of papers in SSS came up with grouping models or evaluation techniques that aid in selecting relevant suppliers or/and allocating orders among the suppliers (e.g., [67–76]). A few other studies developed decision support models for SSE in different sectors of the automotive industry, for instance, in logistics service providers ([77–79]) and spare part suppliers [80]. A different study of this area was that of Govindan et al. [81], who combined supply chain network design (SCND) with the order allocation problem in order to minimize procurement costs and environmental impacts of an automobile manufacturer in Iran. Even though SSE has been found to be a very well-discussed topic, the supplier–buyer relationship for improving the performance of suppliers has been infrequently addressed in the automotive industry. Koplin et al. [82], however, were the only authors who made an attempt to develop a sustainability concept for supply management in a focal company of the automobile industry. Their solutions for greening the supply process focused on managing the relationships with suppliers in terms of determining the relevant requirements of social and environmental aspects, evaluating and monitoring suppliers’ sustainability-related performance, and providing support for the suppliers in order to solve their social and environmental problems. Similar to the supplier–buyer relationship, SD in the automotive industry has not been a well-liked topic among researchers. The only work was conducted by Akman [83], who developed a decision support model that enables managers to evaluate suppliers and decide which supplier should be undertaken in green development program.

A portion of the studies addressed sustainability in the production process and studied the problem from different angles. Some studies pursue a sustainable production process in terms of product design for ELVs. Meeting the targets for recycling determined in the EU directive is a great challenge for the automotive industry. In this respect, studies concerning product design issues tried to provide design solutions for improving vehicle recyclability while considering economic issues. The studies conducted by [84–87] are examples of the works revolving around this topic. As a different study in this area, Pechancová [88] investigated utilizing renewable energy in the production processes of a supplier chosen from a region in the Czech Republic.
Fuel efficiency in the utilization stage of the vehicle is another issue that has been given attention in the literature. For instance, Granovskii et al. [89] compared four types of vehicles—conventional, hybrid, electric, and hydrogen fuel cell—in terms of economic and environmental aspects. Other contributions to this topic are the works of Jones [90] and Sivak and Tsimhoni [91].

Green delivery is another research topic in auto-SSCM. The primary role of delivery in SCM is highlighted in the literature [92]. Particularly, delivery is a part of SC that generates environmental waste and releases pollutant gases into the air, thus affecting the performance of an SSCM ([92]). In this line of thought, White et al. [93] addressed the issue of complexity in green packaging design in a case company, and tried to understand how the company made a tradeoff between the operational requirements and sustainability objectives. Staš et al. [94] focused on green transportation and developed a model to assess the green transportation performance. However, despite the emphasis on the importance of environmentally-friendly packaging for materials and components [95], little effort has been made to discuss this issue comprehensively.

A significant body of literature brought up the issues of the post-use stage and investigated different processes that ELVs would undergo. Figure 2 illustrates different treatments that ELVs receive in the post-use stage, and it further shows the flow of ELVs after they are entered into this phase. In the following, the papers are discussed according to the steps of ELVs depicted in Figure 2. The post-use phase starts with the collection of the used products from customers, where the reverse flow starts. In relation to this step, Krikke et al. [96] conducted a study to optimize the collection process of used products or dismantled components from EOL vehicles. Sundin and Dunbäck [97] studied the obstacles of the reverse fellow for collecting automotive mechatronic devices among a number of European automotive companies. In a similar study, [98] explored the challenges that Chinese manufacturers are facing in executing RL. In an exploratory study, Abdulrahman et al. [99] investigated the inputs and outputs of product returns management in five case studies from various industries in Malaysia, one of which was automotive. Concerning the disassembly process, Colledani and Battaïa [100] conducted the only study that addressed this problem by developing a decision support model that integrates disassembly and line balancing problems. When a vehicle undergoes the recycling process, the recyclable components are first segregated, and the remainder that are not recyclable are sent for shredding. These components are known as Automotive shredder residue (ASR); a few papers concentrated on this topic. Hwang et al. [101] and Vermeulen et al. [102] are among these studies that discussed the techniques and solutions to either increase ASR’s recyclability or improve its quality for fuel utilization. Through analyzing a shredder plant in the United Kingdom, Khodier et al. [103] pointed out that shredder plants in the United Kingdom should have better technologies and recovery techniques in shredding processes that would enable them to enhance recovery of material and energy from ASR. Among the post-use options, remanufacturing and recycling were among the favorite topics of research. Saavedra et al. [104] analyzed the attributes of the automotive’s remanufacturing industry in Brazil through an exploratory study, where the researchers highlighted the roles of the government and associations in motivating the remanufacturing companies to expand their business. Similarly, Yusop et al. [105] conducted research within the Malaysian automotive industry to realize the know-how level of remanufacturers. Chaowanapong et al. [106] derived primary factors that affect the remanufacturing decision in the Thailand automotive industry. Ramoni and Zhang [107] debated the issues of recycling as the common method for ELV treatment of electric vehicle batteries, and suggested remanufacturing as a viable option that would be more environmentally friendly. In line with this type of study, some research works were performed to aid in ELV recovery systems and management. In this context, Đorđević and Kokić [108], Ahmed et al. [109], Keivanpour et al. [110], and Kuik et al. [111] developed decision-making models for selecting recovery options including reuse, remanufacturing, recycling, and energy recovery. Subramoniam et al. [112] and Ahmed et al. [109] addressed strategic issues concerning the remanufacturing of auto parts. Yang et al. [86] and Anthony and Cheung [113] discussed the issue of design for remanufacturing, which involves integrating remanufacturing factors into different perspectives of product design. Recycling is another reprocessing option studied in the
literature. Li et al. [114] evaluated the environmental impact of ELVs’ recycling in China by examining Corolla taxis as a subject of analysis. Chavez and Sharma [115] studied the chemical recycling of polyethylene terephthalate seats in the Mexican automotive sector from economic and environmental perspectives. There are also some different studies [116] that focused on recycling specific materials (i.e., car plastic, aluminum) with the intention of coming up with the processes and techniques to increase the recyclability rate, while taking economic issues into consideration.

4.2.4. Resources/Mechanisms

A variety of resources and mechanisms are required to carry out SSCM processes effectively. From the literature review, it can be seen that three main categories of resources have attracted the attention of researchers, which are shown in Figure 2. Therefore, in the following paragraphs, the papers of this group will be discussed according to the subcategories presented in Figure 2.

In most cases, the literature concerning SSCM processes is intertwined with the literature of SCND. In other words, SCND is considered as a key element for implementing SSCM processes. With respect to this matter, the topic of “CLSC/RL network design” has been deeply studied by several researchers [117–125]. The main objectives of these studies are determining optimal locations and material flows, while satisfying the capacities and demand as constraints. According to the description provided by Sutherland et al. [63], a typical structure for auto-SSCM is drawn in Figure 3.

Figure 3. A typical structure of an auto-SSCM. ELV—end-of-life vehicles.
Technology is another major resource that lays the foundation for the accomplishment of SSCM practices. As noted by Sutherland et al. [64], the automotive recovery system is heavily dependent on the capabilities provided by the recycling technologies. To emphasize the key role of technology in driving recycling and remanufacturing initiatives in Auto-SSCM, some articles addressed this topic in detail. The works by Boks and Tempelman [126] and Pickering [127] represent the direction of these types of studies. In this line of research, some scholars reviewed specific technologies and brought up their specifications, applications, implementation challenges, and future research needs. For instance, Zhang and Chen [51] studied recycling technology and equipment that are utilized for treating the plastic components of ELVs in China’s automotive industry. The authors expressed the reasons why ELVs’ plastic recycling system in China is not as perfect as those of other developed countries. Günther et al. [128] underlined the impact of electric vehicles on deriving an SSCM, and further anticipated future development of the automotive industry in applying this type of vehicle. The examples of other technologies presented in the literature are as follows: ASR treatment technology [102,129], ELV recovery technology [130], fuel-propulsion system technologies [131], integrated management system (IMS) for EOL tires [132], recycling technology [51,133], reverse engineering technologies for remanufacturing [134], battery electric vehicles (BEV) [135], and automotive components remanufacturing [136]. The study of Förster [137] is relatively different from those reviewed above. The authors studied the future technologies that would facilitate sustainable production within the scope of German automotive manufacturers. They further tried to designate the time when the technology will be commonly used in the German industry.

It goes without saying that management skills are an imperative part of the successful implementation of SSCM practices. Management skills include all the management capabilities, systems, and strategies that are utilized, intending to improve the sustainability of SC. Reviewing the content of the works in this area reveals that the topic of management skills has diversely been discussed in the relevant literature. For example, the work done by Ferguson and Browne [138] and Rahimifard et al. [139] argued for designing information systems to support ELV recovery activities. The studies conducted by Vachon and Klassen [140] and Samson Simpson, et al. [141] were about relationship and collaboration management, covering issues related to collaboration with suppliers and customers in environmentally-related initiatives. Another topic seen in the literature is SC capabilities (SCCs), which refers to the combination of people skills and knowledge, physical assets, and organizational routines. In this respect, Liu et al. [142] and Liu et al. [143] analyzed the role of SCCs in the implementation of sustainable strategies and practices. Finally, Xie [144] investigated the impact of cooperative strategies on sustainability in the automotive industry and concluded that the industry can benefit from a cooperative strategy, as it can positively affect the sustainability of SC.

4.2.5. Outputs (Performance)

An SC may not achieve its sustainable objectives without having an appropriate system that measures the performance of the SC’s practices. When it comes to the automotive industry, measuring performance is very demanding as the industry is very unusual and complex [65]. Given the importance of the output phase in the automotive industry, many existing studies discussed this important issue by taking up two major directions: 1—defining performance measures and/or 2—designing measurement systems. The first type of research (e.g., [60,93,106,145–148]) tried to develop key performance indicators (measures) and measurement procedure for evaluating particular practices for SSCM and/or investigating the impact of the green practices on economic and environmental performance. The measures appeared with different terminology in the literature, typically termed as drivers, barriers, enablers, and success factors. The studies did not confine their investigation merely to the identification of the measures, but some rather investigated the interactions among measures as well (e.g., [149–151]). The second group of studies (e.g., [62,65,152–155]) were dedicated to measuring the ultimate outcomes of SSCM in terms of social, environmental, and economic performance. In this group, apart from some studies that investigated only sustainable performance of automotive SC, some
others were developed in combination with other SCs’ characteristics to assess the performance more comprehensively; for example, with resilient [156]; lean and resilient [157]; lean, agile, and resilient [155]; customer-centric and customer pressure [158]; and green human resource management [159]. Talking about the output phase generally, the problem was investigated across the industry of emerging markets (e.g., [106,145,160–171]). However, few studies investigated the problem within European industries [159,172]. Furthermore, developing models to measure the performance for automotive components was observed to be under-researched in this category (e.g., [169,172,173]).

5. Implications for Designing an Auto-SSCM

The comprehensive review of all issues in the research area of auto-SSCM provides useful insights into the aspects required to be considered while designing an automotive SSC. On the basis of the findings of the review, this section presents a practical guideline for designing a sustainable SC (SSC) in the automotive industry, which could be a useful resource for practitioners, managers, and policymakers who aim to plan for designing their sustainable SSC.

Figure 4 illustrates five stages in which an automotive SSC can be designed and implemented. The main goal of this procedure is to help designing an automotive SSC that would generate values for stakeholders and that, at the same time, is aligned with the policy requirements enforced by legislation and standards. According to the key findings of the literature review presented in this paper, stakeholders’ requirements are the main inputs for designing an automotive SSC. In addition, an automotive SSC is designed under the controls of legislation and environmental management standards. In this respect, as shown in Figure 4, the automotive SSC designers should initially analyze the stakeholders’ requirements related to the environmental, social, and economic performance that are expected to be achieved. Meanwhile, they would examine the requirements of environmental regulations and standards.

Stakeholders may include a wide variety of sources in the automotive industry. Customers are one of the main external stakeholders of any firm, who impose normative isomorphic pressure on them to adopt environmental strategies [174]. Firms have been increasingly influenced by consumers’ ethical values and ecological thinking, pushing them to address environmental management practices [175]. Firms’ successful competitors are the second important stakeholders who motivate them to improve their environmental management systems [176]. Previous studies showed that the pressure from competitors in the form of mimicking isomorphic is one of the major drivers of implementing environmental management practices [177,178]. Non-governmental organizations (NGOs), media, local communities, and environmental interest groups are external stakeholders who do not participate in a firm’s transactions, but are affected by the organization [179,180]. These stakeholders are a source of coercive pressure that can influence companies’ decisions to adopt environmental strategies [176]. Thus, the requirements of all these stakeholders should be taken in designing an automotive SSC.

Concerning the legislation, governmental bodies with environmental management legislation, such as waste reduction, cleaner production, resource savings, and conservation regulations, are forcing companies to implement environmental practices across their value chain [7]. In this respect, an automotive SSC should follow the requirements of legislation and environmental management standards while designing the SSC. At the end of the first stage of design, a formal document can be provided by decision makers, representing the results of the requirement analysis.

To satisfy stakeholders’ and regulatory requirements, at the second stage, the processes of the whole SC are required to be designed with eco-design provisions. As has been previously stated in Section 5.2.3, this involves designing SSCM processes, such as supply, production, delivery, use, and post-use. Including eco-design aspects into SSC design can ensure that SSCM processes are planned to maximize environmental performances or mitigate the environmental impact of SCM operations (i.e., reducing waste and emissions; increasing rate of reuse, recycling, and recovery).
The processes coupled with sustainable supply remarkably affect the environmental impacts of products through resource reduction and waste elimination [181]. The sustainable supply process can be classified into two major sub-processes: (1) sustainable purchasing that entails using environmentally friendly materials to reduce resource usage in production, and (2) SSS/SSD that includes integrating environmental initiatives into selection and management of suppliers in sourcing. The production phase might involve a wide range of manufacturing processes, accounting for a large amount of potential pollution and waste generation. In this respect, taking environmental-related actions to design and optimize the production process would critically contribute to the efficient resource usage, pollution prevention, and waste management [182,183]. On the downstream side of the SC, there are processes associated with delivery and consumption that might affect the environment [182,183]. In the green delivery process, the entire process of delivery to customers will be set up to reduce the environmental impact. The green consumption process, on the other hand, entails integrating the customer’s voice into the firm’s environmental activities and collaboration with customers to reduce the environmental impact of products in the usage stage.

To transfer from the traditional SC towards the SSC, an extension of the SC including product and material recovery operations has been suggested in the literature. Recovery management is an important process in the transition to SSCM, which takes place in the post-use stage. Recovery management involves product recovery options, such as repair, refurbishing, remanufacturing, cannibalization, and material recycling from packages or EOL products [184]. Investment recovery in terms of product and material reuse or selling the scrap or used materials and components is another process in the post-use stage that has been introduced in previous studies. Investment recovery seeks to find alternative uses for products, components, or materials that no longer create direct value for the firm [185].
In order to implement the designed SSCM processes, the proper infrastructures are supposed to be acquired at stage 3. This includes the appropriate forward and reverse logistics networks, clean technologies, and management capabilities.

After finalizing the design stages and acquiring the related resources, the designed automotive SSC can be implemented in stage 4. The ultimate outcome of such an implemented auto-SSCM is expected to be the realization of sustainable values by all the SC’s stakeholders. In this respect, within stage 5, the expected sustainable values generated as a result of implementing the designed SSC would be measured, and the corrective actions will be done according to the results of the performance measurement system.

6. Research Gaps and Recommendations for Future Research

Despite the growing body of the extant literature on SSCM in the automotive industry, there are yet a couple of areas that are not studied to an adequate degree. According to the comprehensive literature review conducted in this research, the main research implications are provided in the following as the basis for future research. These suggestions might be suitable for researchers who wish to work further on advancing this research field.

- The automotive industry is an industry that is highly influenced and shaped by its stakeholders’ (e.g., investors, governments, employees, consumers, competitors) demands. As our study shows, investigating the stakeholders’ requirements is one of the less studied areas in the literature. Specially, we discovered that a few studies available in this literature have mainly focused on the effect of stakeholders’ pressure on performance or adoption of environmental policies of a single firm. The automotive industry has a complex supply chain network with many tiers, where environmental degradation happens mostly within the supply chain network. Future studies should be directed toward how stakeholders’ requirements may affect the collaboration of supply chain tiers in the automotive industry in responding to the pressure.

- Discussing the stakeholders’ pressure further, future research needs to catch up with the fast growth of the industry and changing stakeholders’ expectations. Given the globalization of the industry and the universal growth of car manufacturing, the stakeholders’ demands are constantly changing, putting more pressure on the industry to ensure that the sustainable requirements of the stakeholders are met. For instance, the industry is moving toward zero emissions and clean cities through renewable energies for electricity and alternative fuels by 2050 [186]. In this regard, it is crucial for the automotive industry to respond effectively to the complex and evolving needs of its stakeholders. To help the industry in tackling this issue, more academic research is required. For example, identifying the most influential stakeholders and investigating the change in their needs and expectations with growth of technology can be a promising research area. Furthermore, the growth in technology also increases the challenges of making the balance between environmental expectations of stakeholders and the economic benefit of the industry. These are some of the main challenges that leave a substantial room for future studies.

- Concerning the aforementioned matter, it is further observed that the effect of stakeholders’ requirements on the relationship between different tiers in SC is largely unexplored. For instance, it is still not clear how different tiers in the automotive supply chain work collaboratively to address the environmental concern or regulations in the industry. Furthermore, the relationship between the tiers can additionally be joined to performance indicators of an SSC to explore how stakeholders’ requirements and the relationship between different tiers may affect the performance of an SSC.

- Legislation and standards is another area that is not deeply studied. The studies have thus far investigated the problem across only one emerging economy (i.e., China) and in a few automobile sectors (i.e., plastic industry). There is not much knowledge about the effect of legislation and standards on the automobile sectors of several countries, particularly on the world’s major
automobile manufacturers (i.e., India, Brazil). In addition, further research is required to study the impact of legislation and standards on reprocessing activities of various components in the automotive industry.

- As to the sub-categories of SSCM processes, far more studies have been done on the post-use process compared with other sub-categories. Thus, more researches are needed to be conducted in the sub-categories of delivery, supply, production, and use to make a balance between the number of research in all sub-groups. Future studies in these sub-classes of SSCM processes would also lead to the development of the field.

- In spite of the strategic importance of management capabilities for developing an SSCM, this topic is observed to be an under-researched area. Although the importance role of management capabilities including information management, relationship and collaboration management, risk and knowledge management, and human resource management in the supply chain has been already very well researched in the literature of traditional SCM, it is certainly less investigated in the auto SSCM literature.

- Despite the growing body of literature in the field of performance analysis, little effort has been made to discuss the intangible values that could be created by sustainability-conscious practices in the automotive industry. Studying the latent cost or intangible values of SSCM practices would provide a better understanding of the link between SSCM implementation and organizational performance, which could encourage proactive adoption of SSCM practices beyond the legislation.

- The sustainability reports of the top-ranking car manufacturers are valuable secondary resources presenting the best sustainability-conscious practices in addition to the performance outcomes of the practices. These valuable sources have rarely been investigated in the reviewed literature. Future studies can develop further practical studies in this area relying on the useful information provided in these reports. Designing expert systems for measuring the environmental performance of automotive SCs and benchmarking with the best practices in this industry is an example.

- Reviewing the available studies discloses that they have only discussed the selected stages of auto-SSCM. However, more studies should be conducted to develop an integrated perspective that resembles several processes of SSCM (or ideally even the whole processes). Doing so not only can boost the potential of designing a more sustainable SCM, but also would allow researchers to analyze the interaction between the processes and stages to make a transition toward a more sustainable SC.

Other than the aforementioned recommendation for future research adopted from the processes analysis, we observed a couple of other research gaps that are worth further investigation in the future:

- The focus of studies in the automotive industry has only been on single countries so far. The practices and lessons learned from every country are different and comparing countries may shed more light on the establishment of a more sustainable automotive industry.

- There is a growing concern on the social aspects of supply chains in the literature. We found only nine papers in our sample addressed a social issue. The social aspects of an automotive supply chain such as safety, health, training, education of the employees and their satisfaction, community development, and public policy of companies are understudied to a great extent.

- The concentration of the studies in the literature has mostly been on large to medium size companies. The supply chain of automotive companies may include many small-sized companies’ employees and the level of adaptation of sustainability may be different for these companies compared with the large to medium sized ones. So, future studies should investigate the adaptation of sustainability by small companies.

7. Conclusions

The study at hand presented a process-oriented review of the studies in the area of auto-SSCM. A broad range of publications was collected, applying a structured and systematic approach, where the
core themes addressed in the literature of auto-SSCM were classified and discussed. To categorize the
papers, a content analysis framework was developed based on IDEF0, which divided the studies into a
number of major processes in the industry, namely (1) inputs/stakeholder requirements; (2) legislation
and standards; (3) SSCM process, (4) resources/mechanisms; and (5) outputs/performance. Relying
on the results of the investigation into the different aspects of auto-SSCM literature, a five-stage
procedure was presented that can be used as a guideline to design an automotive SSC. The content
analysis resulted in the identification of several promising research opportunities that will require
further investigation.

Even though this review paper applied a rigorous and systematic research methodology, it carries
some limitations like any other review study. The first limitation is affiliated with the search phase,
where we limited our search to the papers published in journals, and skipped other scientific resources
(i.e., theses, conference papers, and book chapters). Adding these overlooked resources to the sample
papers could have led to additional studies that may derive further insights. As another limitation,
this review is structured on the basis of the processes in the automotive industry, and not based on
other characteristics of the studies (e.g., model’s characteristics). Obviously, conducting a different
content analysis approach on the same sample will lead to a different study that may provide beneficial
insights. This limitation will be left for future studies.

**Author Contributions:** S.M.M. prepared the original draft and reviewed and edited the final draft. N.K. updated
the original draft by including the recent literature, and reviewed and edited the final draft. S.H.A.-R. supervised
the research, and reviewed the final draft.

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### Appendix A

**Table A1.** Review studies in the area of sustainable supply chain management (SSCM) published from
2016 onward. GSCM—green SCM.

<table>
<thead>
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<th>No.</th>
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<th>Area of Study</th>
<th>Objective</th>
<th>Industry-Oriented</th>
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<td>1</td>
<td>[187]</td>
<td>SSCM</td>
<td>Reviewing the studies applied system dynamic approach in renewable energy in SSCM</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Reviewing and classifying the whole area in order to find research gaps, and building a theoretical framework to define world-class SSCM</td>
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<tr>
<td>2</td>
<td>[188]</td>
<td>SSCM</td>
<td>Reviewing the themes and challenges of social sustainability in the context of SCs</td>
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<td>3</td>
<td>[189]</td>
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<td>Tracking the integration of sustainable dimensions of automated guided vehicles into SCs</td>
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<td>4</td>
<td>[190]</td>
<td>SSCM</td>
<td>Analyzing the advancement of sustainability issue for mineral SC</td>
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<td>5</td>
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<td>Presenting an overview of the studies addressed social issues in SSCM in the textile industry</td>
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<td>Review of the studies related to sustainable management and optimization of biorefinery SC</td>
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<td>7</td>
<td>[26]</td>
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<td>A systematic literature review of the role of information systems in supporting SSCM</td>
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<td>Building a conceptual framework on GSCM and proposing future research opportunities</td>
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<td>Tracking the emergence of SSCM topic in the literature</td>
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<td>Deriving the key elements of SSCM implementation in the oil and gas industry and their relationship</td>
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<td>[17]</td>
<td>GSCM</td>
<td>Drivers and barriers of adopting GSCM practices in Asian emerging economies</td>
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Table A1. Cont.

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<td>GSCM</td>
<td>Identifying the factors affecting GSCM in small and medium enterprises (SMEs)</td>
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<td>Review of the models in SC dealing with optimizing CO₂ emission</td>
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<td>[201]</td>
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<td>Reviewing and classification of GSCM models and concepts</td>
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Table A2. Distribution of studies over different journals and years.

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<td>6</td>
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<td>36</td>
<td>70</td>
<td>94</td>
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* This category includes articles from several journals only published one paper.
Table A3. Classification of auto-sustainable supply chain management (SSCM) papers.

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<td>Inputs</td>
<td>[56–58,60–62,202–208]</td>
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<tr>
<td>Legislation and Standards</td>
<td>[47,50–54,56,132,133,203,204,209–213]</td>
</tr>
<tr>
<td>Resources/Mechanisms</td>
<td>[51,81,102,118,120,122–126,128,129,131,134,136,137,139,142–144,147,202,204,206,210,211,237,266–271]</td>
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<td>Overall Review</td>
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</table>

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