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RESEARCH ARTICLE

Assessing the lean-green practices in the automotive industry: Perspectives from academia and industry

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ABSTRACT

Since the emergence of rising environmental issues, firms urgently require a supply chain strategy that will allow them to compete effectively in the marketplace. Implementing lean and green supply chain management strategies have been recommended to achieve sustainability and competitiveness. Yet, there is some ambiguity about how these practices must interact with one another. While lean practices have been around for a while and are widely adopted by businesses, the green movement is still evolving in the supply chains for most industries. This paper aims to identify the most important lean-green practices in supply chain management and their relative importance to firms' sustainable performance in automotive industry context using Best Worst Method. The results reveal that green related practices are the most important to achieve environmental, economic, and social performance respectively. Whereas most lean practices remain the least important. As mentioned by the results three green practices, namely Environmental Management System (EMS), Green Purchasing (GP), and Reduce, Reuse and Recycle (3R), are the most important, while Small Lot Sizing (SLZ) is the least important lean practice. These practices contribute to the improvement of environmental, economic, and social performance respectively. The findings of this research offer a theoretical and empirical roadmap for decision makers seeking to identify key practices that are most likely to contribute to improving various aspects of sustainable performance in automotive context.

Keywords: lean-green; supply chain management; sustainable performance; Best Worst Method; automotive industry

1. Introduction

The inefficient use of resources, rising levels of pollution goaded by the global warming over the past few decades resulted in increased concerns of various stakeholders for the environment and sustainability against manufacturing companies as being considered the most polluting entities inciting them to initiate simultaneously or separately lean and green strategies over their operations and supply chains allowing them to maintain competitiveness, efficiency and effectiveness to overcome these issues and enhance sustainability all across the supply chain activities[1–3]. In addition, implementing a lean-green strategy has grown in popularity among researchers over the last decade, by analyzing the literature numerous researchers have recommended the adoption of this strategy regarding sustainable performance enhancement[4,5]. However, evidence from automotive industry is still limited where only few studies such as these references[1,6–9] have

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investigated lean-green strategies for sustainable performance in this industry. Moreover, there is also a lack for applying multi-criteria decision-making methods in evaluating these practices for sustainable performance, also, the impact of green and lean practices on the development of sustainable firms is mostly unexplored and the empirical and theoretical findings have contradictory results, with both positive and negative effects on sustainable performance[10]. Therefore, based on these gaps this study evaluates lean-green supply chain management practices for firms' sustainable performance in the automotive industry through the application of the Best Worst Method. Hence, this study is have developed two main research questions:

(a) What is the relative ranking and importance of lean and green practices for automotive firms' sustainable performance?

(b) What is the relative ranking and importance of lean green practices to achieve sustainable performance in the automotive industry?

To answer these research questions, this study uses a double perspective lens, industry, and academia in the context of automotive industry leading to provide several insights: one the one hand through attempting to identify and rank on the one hand the main lean green practices for automotive firms' sustainable performance and on the other hand the relative ranking of lean green practices to achieve sustainable performance in the automotive industry by using BWM. The findings are summarized in a comprehensive set of recommendations that will help to improve and lead to a successful implementation of lean and green practices toward firms economic, environmental, and social goals.

The paper is organized as follows. In section 2, we review the literature on lean and green paradigms, sustainable performance, and lean green supply chain management practices. Section 3 indicates the criteria and alternatives. Section 4 illustrates the methodology (BWM) and data collection process. The results and discussion are presented in section 5. Finally, the conclusion is presented in the 6th section.

2. Literature review

2.1. Lean and green paradigms

The term lean refers to a set of initiatives and techniques that aim to reduce wastes allowing for a production process that provides real added value to the consumer[11]. Even though the literature presents different definitions of the lean paradigm, they are all based on the same principle: the reduction of costs and the elimination of wasteful activities[12]. Thus, companies can use the tools provided by lean manufacturing to compete in a global market that requires increased quality, quicker delivery, and cheaper prices, all at the volume required to be profitable. Its ultimate purposes are to optimize the organization's production areas in to improve flexibility, as well as to substantially reduce wastage in the supply chain, inventory, and the amount of floor space used for production[13]. In addition to the traditional lean practices that are mainly used within the organization, many other practices must be incorporated in order to have a successful lean supply chain management, among which we cite: supplier development, supplier long term relationship, customer relationship and information spreading through the network[14–18]. Nowadays, the lean concept has been expanded to incorporate the three pillars of sustainability: economic, social, and environmental, in response to the growing understanding of their importance[19,20].

The environmental impacts of industrial production and supply chain activity are no longer merely a regional problem, but a worldwide crisis. Activity in the industrial sector and the supply chain has an impact on a wide range of environmental problems, from regional water pollution and hazardous waste management to global climate change[21]. Thus, implementing green manufacturing practices entails engaging in a variety of actions meant to address environmental concerns, such as conserving energy and minimizing material waste.

Green manufacturing entails procedures that minimize or eliminate damage to the environment as a result of production[20]. In the context of the supply chain, green supply chain management is a strategy for minimizing the negative environmental effects of industrial processes while meeting regulatory requirements and maximizing economic gain. This is accomplished without compromising on quality, productivity and efficient use of energy[12]. Green supply chain management consists also of the integration of many goals, which are derived from both internal and external stakeholder perspectives, with the efficient management of the flow of material, information, capital, and other necessary resources along the nodes and links of the supply chain network to achieve environmental and operational combined performance-related outcomes[22]. The expected benefits from the adoption of green supply chain management are highly significant. The reduction of ecological negative outputs with the efficient use of resources enables all the supply chain partners to generate considerable gains in terms of cost, corporate image and reputation, reliability and sustained competitive advantage, leading to a long-term financial benefit. Thus, the adoption of the green approach allows to perform at the same time environmental and financial results[9,12,15,23–27].

Because of the mutually beneficial relationship between lean and green practices, and especially when both are incorporated by the organization, this results in sustained productivity improvements. As an added benefit, adopting lean and green practices results in increased profitability and therefore less damage to the environment[20,28,29].

2.2. Sustainability paradigm

In the last few decades, the concept of sustainable development has gained widespread attention due to environmental movements and worries about climate change, which are thought to be the result of human meddling in ecosystems that have significant effects on life and society. The United Nations Conference on the Human Environment in Stockholm in 1972 was the first to introduce the concept of sustainable development[19,20]. Then, the Brundtland Commission in 1987 provided the definition of sustainable development as development that provides for the needs of the present without affecting the capacity of future generations to accomplish the same goals[13].

Sustainability in the industrial context refers to thinking about how human activities affect environmental conditions and economic systems. The goal is to create products in a way that improves economic and social well-being, mitigates harmful environmental effects, preserves natural capital and energy, and guarantees the safety of consumers[19,20]. In the context of supply chain, integrating economic, environmental, and social considerations into the design and operations of supply and logistics networks can help all the businesses involved in a complex supply chain network produce value together[22]. Sustainable practices are now widely seen as a source of strategic advantage for companies. Therefore, many previously unusual activities or attitudes have become popular and are now the basis for government laws and regulations that have gradually restricted the market. Organizations that are ready to follow government rules and comply with international commerce and consumer expectations will have an advantage over those competitors who are not[13].

2.3. Literature on the integration of lean and green SCM and sustainable performance

While the term “sustainable business development” has been attached to an individual organization, it is a major issue for the supply chain management as well. In this context, sustainable growth can be achieved by adopting new management paradigms such as lean and green integration[23]. **Table 1**, below, presents the most important contributions of the reviewed articles on the impact of lean and green paradigms on supply chain’s sustainable performance, as well as the different dimensions addressed by each article: economic sustainability (ECO), social sustainability (SOC), and environmental sustainability (ENV). The articles are classified according to the year of their publication, from the oldest to the most recent.

Table 1. Major contributions and sustainability dimensions covered.

Authors	Main contribution	Area of investigation	Performance		
			ECO	SOC	ENV
Sawhney R et al.[30]	A framework called En-Lean was suggested as a tool to improve the assessment of lean principles on the environment for specific processes. According to the findings, several environmental parameters can be improved by the application of lean practices, especially mistake proofing, and employee empowerment and involvement that have been found to be the most powerful lean tools in terms of environmental improvements. The established framework, however, is limited to one specific manufacturing process.	Metal cutting industry			✓
Carvalho H et al.[15]	They have developed a conceptual model that integrates several lean and green practices with their impact on supply chain economic, environmental, and operational performance measurements. According to this model, lean practices have a low contribution to environmental performance, while green practices have a minor impact on the operational and economic performance. However, the conceptual model was developed using empirical data from the literature without an empirical validation.	Theoretical paper	✓		✓
Azevedo SG et al.[23]	They have concluded that managers are implementing green and lean upstream supply chain management practices to increase resource efficiency and material recycling, and also to improve business transparency and ethics, supplier social and environmental oversight, as well as increasing the number of local suppliers. This integration of lean and green practices also allows the reduction of waste, lead times and inventory. Nevertheless, it has been found that green practices impact negatively the economic performance of the supply chain.	Automotive industry	✓	✓	✓
Govindan K et al.[7]	The most important practices for top management to focus on in managing the automotive supply chain are “just-in-time”, “flexible transportation” and “green packaging”. These practices, above all, contribute significantly to the improvement of the various aspects of the supply chain economic and environmental performances in Portugal, through the satisfaction of the consumers’ needs by offering them eco-products, in short time and with high quality levels.	Automotive industry	✓		✓
Martínez-Jurado PJ and Moyano-Fuentes J[25]	They have concluded that the influence of lean methods on environmental performance is unclear, because both positive and negative connections were identified. Otherwise, as a result of the implementation of lean techniques, green practices may be promoted and adopted more easily, enhancing the environmental impact of lean practices. However, there is a lack of literature regarding key measures of the social output of lean management.	Theoretical paper	✓	✓	✓

Table 2. (*Continued*).

Authors	**Main contribution**	**Area of investigation**	**Performance**		
			ECO	**SOC**	**ENV**
Cherrafi A et al.[31]	They have provided a conceptual model combining lean, green, and process innovation practices to the performance of green supply chains, and identified the best lean and green practices that manufacturing businesses may implement to improve their supplier chains' environmental performance. However, it has been claimed that process innovation practices have no direct influence on the development of the green supply chain's efficiency. These techniques can, therefore, be useful in amplifying the effect of lean and green practices.	Different industries	✓	✓	✓
Zhan Y et al.[32]	It was concluded that the application of lean and green practices is beneficial in improving the business and environmental performance of the supply chain. Indicators improved by these strategies include air emissions, wastewater, and consumption of harmful materials. It was also found that the use of guanxi initiatives is critical as a step before adopting lean and green practices in order to achieve positive results related to business and environmental performance.	Different industries			✓
Farias LMS et al.[33]	They have established a conceptual framework for analyzing operational and environmental performance incorporating lean and green techniques. The framework shows how to integrate practices and performance measures for performance evaluation reasons, as well as how lean and green practices may be applied synergistically to improve each of the performance metrics.	Theoretical paper			✓
Singh J et al.[8]	Lean practices were found to have more impact on economic performance when incorporated into green supply chain management, which was considered as a mediating variable. More specifically, JIT is the most important practice, followed by 5S, Total Productive Maintenance and Total Quality Management. There is also a considerable improvement in environmental and competitive performances.	Auto parts, cycle parts, rods and sheet metal components industries	✓		✓
Teixeira P et al.[34]	They have used bibliometric analysis in conjunction with structured literature analysis to investigate the relationship between lean, green, and sustainability. As a result, a conceptual model incorporating lean, green and sustainability practices was suggested in order to achieve better sustainable performance. The findings revealed that lean and green, and particularly their combination, have the potential to improve sustainability outcomes, especially when it comes to economic and environmental dimensions.	Theoretical paper	✓	✓	✓

3. Identification of the criteria and alternatives for lean-green sustainable supply chain's performance

3.1. Lean and green practices in the supply chain (criteria)

After conducting a review of the literature, considering usage frequency, and consulting with experts, the subsequent criteria, presented in **Table 2** below, were selected for application in this study in order to assess the incorporation of lean-green practices in the context of supply chain.

Table 3. Criteria for lean-green supply chain practices.

Practice	Definition	References
Just-in-Time (JIT)	A production system that encourages the use of low inventories of raw materials, work in progress, and finished items by requiring all raw materials, work in progress, and finished goods to be accessible precisely when needed through a production planning[7].	[2,7–9,14,15,17,23–25,27,30,31,35,39]
Set-up time reduction (STR)	The decrease of the total duration in which the manufacturing equipment was not producing good parts, which is the period between the last good part of the previous lot and the first good part of the following lot[38].	[14,15,17,31,36]
Smaller lot sizes (SLZ)	Lot size describes the amount of the same item ordered for delivery on a specified date or made in one production run. An item with a small lot size refers to the production of a small quantity of this item, which reduces inventory levels, variability, and promotes smooth manufacturing[37].	[9,15,17,30]
Green purchasing (GP)	Purchasing reused and recycled materials, as well as products and services from suppliers providing environmentally friendly products and processes[39].	[2,15,17,23,35,40]
Environmental Management System (EMS)	Having an engagement towards long-term sustainability and incorporating preventive environmental protection tools into a company's activities, such as ISO 14001 certification[41].	[7,14,15,17,24,27,35,36,40,42]
Reverse logistics (RL)	Planification, implementation, and control of raw materials, stock-in-process, finished products and services from the point of consumption all the way back to the source[43].	[2,10,14,15,17,18,35]
Reduce, Reuse and Recycle (3R)	Reduce the quantity of emissions and waste produced, next find ways to reuse the resources, and ultimately, if they cannot be reused, collect them for recycling [44].	[7,9,14,15,17,23,27,42]
Waste minimization (WM)	Reducing lean wastes, resulting from several sources (overproduction, waiting, transportation, defects, inappropriate processing, unnecessary inventory and unnecessary motion) as well as green wastes (excessive water usage, excessive power usage, excessive resource usage, pollution, rubbish, greenhouse effects and eutrophication) [45].	[2,7,9,14–17,23,31,32,35,36,40,42,46]
Cooperation with suppliers (CS)	Cooperation between the organization and its suppliers to improve process performance, quality, costs and delivery while also lowering environmental impacts [47].	[8,14–18,23,27,30,35,36,42]

3.2. Sustainable performance (alternatives)

Presented in **Table 3** is the definition of alternatives sourced from established literature. These alternatives have been used to assess the impact of lean-green practices on sustainable performance through its three aspects: economic, social and environmental.

Table 4. The alternatives of sustainable performance.

Sustainability Elements	Definition	References
Economic performance	Generally, referred as financial gains resulting in an enhancement of profitability sales, market share and productivity.	[48–51]
Social performance	translated to the improvement in overall stakeholder welfare or betterment such as employee's safety and satisfaction, relations with community stakeholders, awareness and protection of the claims and rights of people in community and customer satisfaction.	[52,53]
Environmental performance	Environmental performance referred as the outcomes of firm's activities and their impact on the natural environment.	[48,49]

4. Research methodology

4.1. Data collection

Gathering data for this study shifted from an initial screening for potential candidates based on their background, knowledge, and experience concerning the subject using purposive sampling technics. Moreover, in advance of distribution the questionnaire to determine the importance of lean-green strategies within the supply chain a pilot study was carried out within 3 academician experts in the field to ensure clarity, language and research ethics while omitting their response from the analysis. The survey was divided into three parts using two versions (English and French) based on the second and fourth steps of Best Worst Method (BWM), the first contains questions related to identify the importance of the best lean-green supply chain management practices, as the second consists of identifying the worst practices meanwhile the last part consists of identifying the importance of lean-green supply chain management practices for sustainable performance. The questionnaire was sent to over 100 potential respondents from Moroccan Automotive Manufacturing companies using E-mails (50), LinkedIn (30) and ResearchGate (20). The data was collected during two stages, the first in October and December 2021 while the second during September and December 2022 resulting in the first period of 24 responses, while in the second period 40 responses from which 36 responses were suitable for the analysis. Moreover, to assess reliability and robustness, this study average of δL is $0.131 \leq 0.4747$ which remains under the acceptable threshold for studies using nine criteria[54].

4.2. Best Worst Method

Multicriteria decision making methods has been applied widely in different research areas, as for their ability to deal with qualitative and quantitative criteria, among these methods AHP, TOPSIS and ANP are the highest commonly used methods. However, these tools can be applied to evaluate criteria and alternatives, as any other tools have their constraints as well as benefits. However, one of the most recent innovations in MCDM is the Best Worst Method (BWM) developed by Liang et al.[54]. This research will use the BWM in order to assess lean & green supply and supply chain sustainable performance following these steps:

(1) Problem formulation:

In this step we set the evaluation criteria for decision making about the lean & green sustainable supply chain's performance. As mentioned above in section 2.2 we consider three categories of Alternatives for supply chain sustainable performance such as Economic Performance, Social Performance, Environmental Performance. We considered also 9 practices, as discussed in 2.1, i.e., Just-in-Time (c_1), Set-up time reduction (c_2), Smaller lot sizes (c_3), Green purchasing (c_4), Environmental Management System (c_5), Reverse logistics (c_6), Reduce, Reuse and Recycle (c_7), Waste minimization (c_8), Cooperation with suppliers (c_9).

(2) Determine the best and the worst practice:

In this phase, we cite that the best criterion as the most important as well as for the worst as the least important criterion. We asked the participants, "Which of the following practices is the 'most important' for Sustainable Performance?" and "Which of the following Practices is the 'least important' for Sustainable Performance?".

(3) Determine the preference of the best practice over all other practices:

In this step we asked the participants to rank the importance of the best criterion over all other criteria using Likert scale from 1 to 9[1].

We can express the best to others vector as:

$$A_B = (a_{b1}, a_{b2} \ldots, a_{bn}) \tag{1}$$

where a_{bj} signifies the importance of the best criterion B over the criterion j.

(4) Determine the preferences of all other practices over the worst criterion:

In this step we asked the participants to rank the importance of all other criteria over the worst criterion using Likert scale from 1 to 9,

$$A_w = (a_{1w}, a_{2w} \ldots, a_{nw}) \tag{2}$$

where a_{jw} signifies the importance of the criterion j over the worst criterion W.

(5) Estimate & find the optimal weights:

In this phase, we need to find the optimal weights by minimizing the maximum absolute differences $\left(\left|w_b - a_{bj}\, w_j\right|, \left|w_j - a_{jw} w_w\right|\right)$ for all j. According to the study of Liang et al.[54], the problem minimization can be expressed as follow:

$$\begin{gathered}
\mathrm{Min}\left[max_j\left(\left|w_b - a_{bj} w_j\right|, \left|w_j - a_{jw} w_w\right|\right)\right] \\
\text{s.t.} \sum_j w_j = 1 \\
w_j \geq 0, \text{ for all } j
\end{gathered} \tag{3}$$

Also, to solve Equation (3) a linear optimization model is needed and it can be expressed as follow:

$$\begin{gathered}
min^{\delta^L} \\
s.t. \\
\left|w_b - a_{bj} w_j\right| \leq \delta^L, \text{ for all } j \\
\left|w_j - a_{jw} w_w\right| \leq \delta^L, \text{ for all } j \\
\sum_j w_j = 1 \\
w_j \geq 0, \text{ for all } j
\end{gathered}$$

[1] 1 = equal importance; 3 = Moderately more important; 5 = Strongly more important; 7 = Very strongly more important; 9 = Extremely more important; 2, 4, 6, 8 = Intermediate values.

Nevertheless, the optimal weights $(w_1 *, w_2 * \dots, w_n *)$ and the optimal value of the consistency ration δ^L are solved using Linear version of BWM Excel solver[13].

(6) Scores of the Alternatives:

Right after finding the optimal weights there is a need to calculate the final priority of the alternatives, in our case the supply chain's sustainable performance. Thus, for doing so, we asked the respondent to rate the lean and green practices (criterion) under the three alternatives (Economic, Social, Environmental Performance) using 1–9 Likert scale indicating the level of importance (1 refers to not important and 9 refers to absolutely very important). The values were normalized using linear normalization approach that consists of dividing each value by its column maximum value and it could be expressed as follow:

$$\left(x_{ij}^{norm} = \frac{x_{ij}}{x_j^{max}}\right)$$

The priority of the three alternatives was calculated by multiplying respectively the optimal weights by each normalized value.

$$Z_i = \sum_{j=1}^{n} w_j \, x_{ij}^{norm}$$

5. Results and discussion

The results of this study are presented in **Tables 4** and **5** below. **Table 4** shows the ranking order for each of the lean and green practices used in this study, while **Table 5** presents the priority of the three alternatives under each practice/criterion.

Table 4. Optimal Weights of lean-green supply chain management practices.

Resp	JIT	STR	SLZ	GP	EMS	RL	3R	WM	CS	δ
1	0.017	0.020	0.026	0.145	0.158	0.158	0.158	0.158	0.158	0.013
2	0.023	0.052	0.052	0.225	0.155	0.104	0.155	0.155	0.078	0.085
3	0.067	0.067	0.025	0.067	0.207	0.089	0.133	0.089	0.257	0.059
4	0.019	0.094	0.047	0.057	0.094	0.142	0.226	0.226	0.094	0.057
5	0.242	0.046	0.024	0.206	0.206	0.082	0.103	0.046	0.046	0.170
6	0.061	0.078	0.031	0.110	0.336	0.092	0.092	0.092	0.110	0.214
7	0.091	0.071	0.036	0.071	0.091	0.071	0.071	0.408	0.091	0.230
8	0.070	0.032	0.079	0.070	0.079	0.079	0.090	0.090	0.411	0.219
9	0.144	0.064	0.082	0.064	0.377	0.030	0.072	0.072	0.096	0.198
10	0.069	0.088	0.077	0.077	0.428	0.077	0.077	0.077	0.030	0.190
11	0.044	0.050	0.050	0.200	0.253	0.133	0.133	0.100	0.035	0.148
12	0.040	0.051	0.022	0.257	0.120	0.120	0.090	0.180	0.120	0.103
13	0.065	0.076	0.076	0.114	0.330	0.034	0.076	0.114	0.114	0.127
14	0.057	0.057	0.057	0.092	0.153	0.327	0.115	0.028	0.115	0.131
15	0.091	0.078	0.136	0.374	0.068	0.060	0.026	0.091	0.078	0.170
16	0.051	0.065	0.091	0.152	0.024	0.325	0.114	0.065	0.114	0.130
17	0.326	0.056	0.064	0.112	0.150	0.112	0.064	0.090	0.026	0.122
18	0.098	0.027	0.098	0.074	0.074	0.074	0.065	0.417	0.074	0.172
19	0.082	0.070	0.070	0.123	0.247	0.062	0.123	0.099	0.123	0.247

Table 4. (*Continued*).

Resp	JIT	STR	SLZ	GP	EMS	RL	3R	WM	CS	δ
20	0.024	0.031	0.028	0.185	0.209	0.125	0.251	0.084	0.063	0.066
21	0.180	0.200	0.080	0.080	0.120	0.020	0.120	0.080	0.120	0.060
22	0.050	0.070	0.062	0.079	0.062	0.070	0.427	0.111	0.070	0.129
23	0.088	0.088	0.076	0.088	0.379	0.088	0.028	0.076	0.088	0.151
24	0.027	0.054	0.048	0.214	0.310	0.107	0.107	0.071	0.061	0.119
25	0.118	0.157	0.236	0.094	0.079	0.079	0.118	0.067	0.052	0.236
26	0.088	0.132	0.132	0.088	0.132	0.223	0.088	0.088	0.026	0.042
27	0.054	0.040	0.020	0.161	0.242	0.161	0.161	0.081	0.081	0.081
28	0.060	0.033	0.060	0.371	0.095	0.095	0.095	0.095	0.095	0.105
29	0.082	0.082	0.069	0.137	0.137	0.103	0.297	0.069	0.023	0.114
30	0.018	0.053	0.053	0.160	0.234	0.160	0.160	0.080	0.080	0.086
31	0.030	0.050	0.050	0.113	0.151	0.151	0.272	0.091	0.091	0.181
32	0.380	0.076	0.032	0.106	0.089	0.076	0.089	0.076	0.076	0.153
33	0.053	0.026	0.053	0.123	0.185	0.123	0.288	0.074	0.074	0.082
34	0.338	0.141	0.141	0.085	0.071	0.071	0.031	0.061	0.061	0.086
35	0.056	0.056	0.071	0.357	0.167	0.027	0.125	0.071	0.071	0.143
36	0.317	0.106	0.141	0.071	0.085	0.085	0.085	0.026	0.085	0.106
Mean	0.101	0.071	0.069	0.142	0.175	0.109	0.131	0.108	0.094	0.131
Rank	6	8	9	2	1	4	3	5	7	-

Table 5. Priority of alternatives under each criterion.

Alternatives/Criteria	JIT	STR	SLZ	GP	EMS	RL	3R	WM	CS	Overall	Mean	Rank
ECOP	0.072	0.054	0.057	0.112	0.134	0.086	0.105	0.089	0.073	0.781	0.087	2
SOCP	0.054	0.037	0.039	0.099	0.116	0.075	0.091	0.082	0.081	0.674	0.075	3
ENVP	0.046	0.042	0.045	0.138	0.171	0.100	0.125	0.097	0.079	0.844	0.094	1

As mentioned in **Tables 4** and **5**, environmental performance (ENVP) is the most improved dimension through the adoption of lean and green practices studied, with a mean of (0.094). The second rank was obtained by the economic performance (ECOP) (mean 0.087), then the social performance (SOCP) (mean 0.075). This ranking shows that a large number of respondents agree that these practices have a positive impact on improving environmental aspects, which is in line with the results of several previous studies[28,33,55–57]. Cherrafi et al.[28] have presented two case studies that aimed at testing the efficacy of their proposed model. The findings clearly indicate that organizations can attain significant environmental advantages by integrating lean and green practices, primarily through the reduction of resource consumption. Farias et al.[33] have argued that lean and green practices share similar objectives and should be considered as a unified and integrated system. They have established a matrix to connect lean and green practices with performance criteria. Waste reduction is an area where the impacts of lean and green practices have been extensively studied, highlighting its significance. However, when it comes to lean practices, it has been found that some practices such as JIT have a negative impact on environmental performance. Zhu and Sarkis findings indicate that JIT have negative effects when combined with internal environmental management. Consequently, JIT implementation may hinder the environmental performance associated with internal management practices. One possible explanation for this is the existence of formalized systems required within internal management programs. JIT, on the other hand, typically relies on streamlined processes and techniques, some of which may be informally executed[27]. Thus, the results concerning the impact of lean practices on environmental performance are still not conclusive, as both positive and negative relationships have been found in the literature[25]. This is consistent with our results, because based on the ranking of practices we obtained, all the green practices studied are placed first, then followed by the other practices: EMS > GP > 3R > RL > WM > JIT > CS > STR > SLZ. The three most important are Environmental Management Systems (EMS) (mean 0.175), followed by Green Purchasing (GP) (mean 0.142), then Reduce, Reuse and Recycle (3R) (mean 0.131). This is aligned with the finding of previous studies. One of the most important elements of the EMS is the environmental certifications such as ISO 14001. According to the study of Carvalho et al.[15], higher levels of quality are a direct outcome of implementing such certifications, thus improving economic performance for all participants in the supply chain. The improved quality levels might be interpreted as a source of competitive advantage for the supply chain, since it provides a potential means of maintaining and expanding market share through increased competition. In addition, by adopting those green initiatives all over its supply chain, the company's reputation improves, resulting in increased market-share and financial profits. In addition, the certification is a point of differentiation especially for small companies, giving them an advantage over their rivals in the market. However, for large companies, certification become a necessity in order to maintain a significant presence in their markets[58]. Concerning the impact of EMS adoption on the supply chain's environmental performance, Darnall et al.[59] have confirmed through their study that companies implementing EMS are generally able to have a positive impact on their supply chains. Those companies are including their supply chain networks in efforts to reduce their environmental impact by measuring waste produced by their operations, informing consumers about how they can reduce their environment impact, and assessing suppliers' contributions to environmental damage. Through the elimination of harmful pollutants and chemicals use, employees' health will be protected as a result[60]. Concerning Green Purchasing, companies that adopting this practice often use collaborative strategies including training, environmental information exchange, and cooperative research to ensure that their suppliers are also committed to preserving the environment. For instance, cooperating with ISO 14001 certified suppliers is considered as an insurance that the materials and resources used are not harmful to the environment and are created using environmentally friendly methods, which is a prerequisite for green purchasing. Therefore, this leads to sustainable performance across the entire supply chain[50]. Malaysian companies practice green purchasing to ensure the efficiency of their suppliers. For example, several large companies from electronics industry have formed the Electronics Industry Code of Conduct, which establishes mandatory guidelines for suppliers to follow in terms of workplace safety, environmental protection, management practices and ethical conduct. These findings suggest that large companies often establish strict environmental requirements for their suppliers to follow when sourcing materials. These requirements extend all through the upstream supply chain level. Therefore, in response to these demands from their clients, suppliers also require the same standards for the materials they purchase[61]. Moreover, Khan et al.[62] demonstrate that implementing green purchasing practices has a positive influence on both economic and environmental performance, while its impact on social performance is found to be insignificant. However, the study conducted by Yildiz Çankaya and Sezen[60] have not found any meaningful relationship between the different facets of green purchasing and the three dimensions of corporate sustainability. The authors explained this result as green purchasing practice focuses mainly on improving suppliers' environmental performance, driven by the company's own environmental performance. The third best practice in our results is the 3R. According to the study of Pariatamby and Fauziah[63], environmental managers around the world have chosen the 3Rs, an acronym for "reduce", "reuse" and "recycle", as the best approach to achieving sustainability. This method has long been the fundamental pillar of waste management. Consistent with the waste management focus, it emphasizes recycling and composting and seeks to reduce waste as a primary goal. Based on the same research paper, waste reduction and reuse are beneficial to the companies because they allow the improvement of resource efficiency, saves money and protects the environment by reducing resource use and waste creation. However, there are also disadvantages to the reuse of resources. There may be additional expenses to clean up or modify certain types of waste before it can be reused. These mandatory steps also require an additional investment of time and money. The last position was assigned to small lot sizing (SLZ) (mean 0.069) as being the worst practice. This can be justified on the basis that some activities such as frequent deliveries, handling, and restarts contribute to air pollution, while more intensive cleaning increases wastewater levels. In addition, the increased residual products from frequent cutting operations increases waste creation, the frequent restarts and turnoffs increases energy consumption, and the frequent cleaning negatively impacts employee health by exposing them to toxic chemicals in cleaning products[30].

6. Conclusion

Based on the double perspective provided by academicians and automotive industry experts, this study evaluated nine of lean and green supply chain management practices for automotive firms' sustainable performance. This research provides new insights, by Best Worst Method, concerning the importance level of lean and green practices and the most important dimension of automotive firms' sustainable performance influenced by the use of these practices. The results of the analyzed data from 36 respondents yielded that there are three important practices related to the green paradigm, namely, Environmental Management System (EMS), Green Purchasing (GP), and Reduce, Reuse and Recycle (3R) and the least important practice is related to lean paradigm, namely, Small Lot Sizing (SLZ). Moreover, it was indicated that these practices contribute to the improvement of Environmental, Economic and Social performance respectively in the context of automotive supply chain industry. However, despite the fact that adopting research-based knowledge as a substitute for industry specialists is a legitimate option for the data gathered using academicians to determine the importance of the lean green supply chain management practices and their importance to firms' sustainable performance might be considered as one of the limitations of the study. Moreover, the single use of BWM might not be sufficient in gaining a deep understanding of such complex issues. Thus, a qualitative method is needed to gain more in-depth information on the investigated issue. Yet, there are multiple research directions for this study. First, as aforementioned, besides the assessment through the BWM a qualitative investigation is needed. Second, a comparative study between different industries and countries might also be conducted to attain generalizability.

Our study provides a classification of lean and green practices, enabling organizations to better understand and categorize the different practices within their supply chain. This classification facilitates the identification of specific practices that can contribute to sustainability objectives. Moreover, the study emphasizes the need for continuous improvement in lean and green practices. Managers can use the classification to identify gaps in their current practices and explore opportunities for further enhancements. Continuous improvement efforts help organizations stay responsive to evolving sustainability challenges and maintain a competitive edge. The study's findings offer insights into the impact of lean and green practices on sustainability. Automotive companies can use these insights to develop performance metrics and measurement systems that assess the effectiveness of their lean and green initiatives. This enables managers to track progress, identify areas for improvement, and align their sustainability goals with actual performance. In summary, the study's classification of lean and green practices and their impact on sustainability provides practical insights and managerial implications for automotive companies seeking to integrate and optimize their supply chain practices.

Author contributions

Conceptualization, IAH and AH; methodology and software, AH; validation, SO; formal analysis, IAH; investigation, IAH; resources, SO; writing—review and editing, IAH and AH; visualization, SO; supervision, SO and ASE; project administration, SO and ASE. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

1. Duarte S, Cruz Machado V. Green and lean implementation: An assessment in the automotive industry. *International Journal of Lean Six Sigma* 2017; 8(1): 65–88. doi: 10.1108/IJLSS-11-2015-0041
2. Dües CM, Tan KH, Lim M. Green as the new Lean: How to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production* 2013; 40: 93–100. doi: 10.1016/j.jclepro.2011.12.023
3. Eslamipoor R. A two-stage stochastic planning model for locating product collection centers in green logistics networks. *Cleaner Logistics and Supply Chain* 2023; 6: 100091; doi: 10.1016/j.clscn.2022.100091
4. Abualfaraa W, Salonitis K, Al-Ashaab A, Ala'raj M. Lean-green manufacturing practices and their link with sustainability: A critical review. *Sustainability* 2020; 12(3): 981. doi: 10.3390/su12030981
5. Huo B, Gu M, Wang Z. Green or lean? A supply chain approach to sustainable performance. *Journal of Cleaner Production* 2019; 216: 152–166. doi: 10.1016/j.jclepro.2019.01.141
6. Agarwal V. Analysis of lean, green, and resilient practices for Indian automotive supply chain performance using best-worst method. *Advances in Interdisciplinary Research in Engineering and Business Management*. Springer; 2021.
7. Govindan K, Azevedo SG, Carvalho H, Cruz-Machado V. Lean, green and resilient practices influence on supply chain performance: Interpretive structural modeling approach. *International Journal of Environmental Science and Technology* 2015; 12(1): 15–34. doi: 10.1007/s13762-013-0409-7
8. Singh J, Singh H, Kumar A. Impact of lean practices on organizational sustainability through green supply chain management—An empirical investigation. *International Journal of Lean Six Sigma* 2020; 11(6): 1035–1068. doi: 10.1108/IJLSS-06-2017-0068
9. Wu L, Subramanian N, Abdulrahman MD, et al. The impact of integrated practices of lean, green, and social management systems on firm sustainability performance-evidence from Chinese fashion auto-parts suppliers. *Sustainability (Switzerland)* 2015; 7(4): 3838–3858. doi: 10.3390/su7043838
10. Hebaz A, Oulfarsi S, Hammou IA, Eddine AS. Assessing lean, green and supply chain's sustainable performance: Perspectives from academia and industry. *IFAC-PapersOnLine* 2022; 55(10): 2445–2450. doi: 10.1016/j.ifacol.2022.10.075
11. Kamble S, Gunasekaran A, Dhone NC. Industry 4.0 and lean manufacturing practices for sustainable organizational performance in Indian manufacturing companies. *International Journal of Production Research* 2019; 58(5): 1319–1337. doi: 10.1080/00207543.2019.1630772
12. Cabral I, Grilo A, Cruz-Machado V. A decision-making model for Lean, agile, resilient and green supply chain management. *International Journal of Production Research* 2012; 50(17): 4830–4845. doi: 10.1080/00207543.2012.657970
13. Alves JRX, Alves JM. Production management model integrating the principles of lean manufacturing and sustainability supported by the cultural transformation of a company. *International Journal of Production Research* 2015; 53(17): 5320–5333. doi: 10.1080/00207543.2015.1033032
14. Campos LM, Vazquez-Brust D. Lean and green synergies in supply chain management. *Supply Chain Management: An International Journal* 2016; 21(5): 627–641. doi: 10.1108/SCM-03-2016-0101
15. Carvalho H, Azevedo SG, Cruz-Machado V. Supply chain performance management: Lean and green paradigms. *International Journal of Business Performance and Supply Chain Modelling* 2010; 2(3–4): 304–333. doi: 10.1504/IJBPSCM.2010.036204
16. Duarte S, Cruz-Machado V. Investigating lean and green supply chain linkages through a balanced scorecard framework. *International Journal of Management Science and Engineering Management* 2014; 10(1): 20–29. doi: 10.1080/17509653.2014.962111
17. Engin B, Martens M, Paksoy T. *Lean and Green Supply Chain Management: A comprehensive review: Optimization Models and Algorithms*. Springer; 2019. pp. 1–38
18. Espadinha-Cruz P, Grilo A, Puga-Leal R, Cruz-Machado V. A model for evaluating Lean, agile, resilient and green

practices interoperability in supply chains. In: Proceedings of the 2011 IEEE International Conference on Industrial Engineering and Engineering Management; 6–9 December 2011; Singapore. pp. 1209–1213.
19. Cherrafi A, Elfezazi S, Chiarini A, et al. The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model. *Journal of Cleaner Production* 2016; 139: 828–846. doi: 10.1016/j.jclepro.2016.08.101
20. Zekhnini K, Cherrafi A, Bouhaddou I, et al. A model integrating lean and green practices for viable, sustainable, and digital supply chain performance. *International Journal of Production Research* 2021; 60(21): 6529–6555. doi: 10.1080/00207543.2021.1994164
21. Sarkis J, Zhu Q. Environmental sustainability and production: Taking the road less travelled. *International Journal of Production Research* 2018; 56(1–2): 743–759. doi: 10.1080/00207543.2017.1365182
22. Bhattacharya A, Dey PK, Ho W. Green manufacturing supply chain design and operations decision support. *International Journal of Production Research* 2015; 53(21): 6339–6343. doi: 10.1080/00207543.2015.1065021
23. Azevedo SG, Carvalho H, Duarte S, Cruz-Machado V. Influence of green and lean upstream supply chain management practices on business sustainability. *IEEE Transactions on Engineering Management* 2012; 59(4): 753–765. doi: 10.1109/TEM.2012.2189108
24. Carvalho H, Govindan K, Azevedo SG, Cruz-Machado V. Modelling green and lean supply chains: An eco-efficiency perspective. *Resources, Conservation and Recycling* 2017; 120: 75–87. doi: 10.1016/j.resconrec.2016.09.025
25. Martínez-Jurado PJ, Moyano-Fuentes J. Lean management, supply chain management and sustainability: A literature review. *Journal of Cleaner Production* 2014; 85: 134–150. doi: 10.1016/j.jclepro.2013.09.042
26. Sharma G, Singhi R, Mittal A. Lean and green supply chains—Key Practices, inter linkages and effects on sustainability—A case study with reference to automobile industry. *International Journal of Mechanical Engineering and Technology* 2019; 10(3): 317–330.
27. Zhu Q, Sarkis J. Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management* 2004; 22(3): 265–289. doi: 10.1016/j.jom.2004.01.005
28. Cherrafi A, Elfezazi S, Hurley B, et al. Green and lean: A Gemba–Kaizen model for sustainability enhancement. *Production Planning and Control* 2019; 30(5–6): 385–399. doi: 10.1080/09537287.2018.1501808
29. Oubrahim I, Sefiani N, Happonen A. The influence of digital transformation and supply chain integration on overall sustainable supply chain performance: An empirical analysis from manufacturing companies in Morocco. *Energies* 2023; 16(2): 1004. doi: 10.3390/en16021004
30. Sawhney R, Teparakul P, Bagchi A, Li X. En-Lean: A framework to align lean and green manufacturing in the metal cutting supply chain. *International Journal of Enterprise Network Management* 2007; 1(3): 238–260. doi: 10.1504/IJENM.2007.012757
31. Cherrafi A, Garza-Reyes JA, Kumar V, et al. Lean, green practices and process innovation: A model for green supply chain performance. *International Journal of Production Economics* 2018; 206: 79–92. doi: 10.1016/j.ijpe.2018.09.031
32. Zhan Y, Tan KH, Ji G, et al. Green and lean sustainable development path in China: Guanxi, practices and performance. *Resources, Conservation and Recycling* 2018; 128: 240–249. doi: 10.1016/j.resconrec.2016.02.006
33. Farias LMS, Santos LC, Gohr CF, et al. Criteria and practices for lean and green performance assessment: Systematic review and conceptual framework. *Journal of Cleaner Production* 2019; 218: 746–762. doi: 10.1016/j.jclepro.2019.02.042
34. Teixeira P, Sá JC, Silva FJG, et al. Connecting lean and green with sustainability towards a conceptual model. *Journal of Cleaner Production* 2021; 322: 129047. doi: 10.1016/j.jclepro.2021.129047
35. Azevedo SG, Carvalho H, Machado VC. The influence of green practices on supply chain performance: A case study approach. *Transportation Research Part E: Logistics and Transportation Review* 2011; 47(6): 850–871. doi: 10.1016/j.tre.2011.05.017
36. Hajmohammad S, Vachon S, Klassen RD, Gavronski I. Reprint of Lean management and supply management: Their role in green practices and performance. *Journal of Cleaner Production* 2013; 56: 86–93. doi: 10.1016/j.jclepro.2013.06.038
37. Fritsche R. Reducing set-up times for improved flexibility in high-mix low-volume electric drives production. In: Proceedings of the 2011 1st International Electric Drives Production Conference; 28–29 September 2011; Nuremberg, Germany. pp. 74–77.
38. Kovilage MP. Influence of lean–green practices on organizational sustainable performance. *Journal of Asian Business and Economic Studies* 2020; 28(2): 121–142. doi: 10.1108/jabes-11-2019-0115
39. Yang W, Zhang Y. Research on factors of green purchasing practices of Chinese. *Journal of Business Management and Economics* 2012; 3(5): 222–231.
40. Hussain M, Al-Aomar R, Melhem H. Assessment of lean-green practices on the sustainable performance of hotel supply chains. *International Journal of Contemporary Hospitality Management* 2019; 31(6): 2448–2467. doi:

10.1108/IJCHM-05-2018-0380

41. Massoud MA, Fayad R, El-Fadel M, Kamleh R. Drivers, barriers and incentives to implementing environmental management systems in the food industry: A case of Lebanon. *Journal of Cleaner Production* 2010; 18(3): 200–209. doi: 10.1016/j.jclepro.2009.09.022
42. Duarte S, Cruz-Machado V. Green and lean supply-chain transformation: A roadmap. *Production Planning and Control* 2019; 30(14): 1170–1183. doi: 10.1080/09537287.2019.1595207
43. Rogers DS, Tibben-lembke R. An examination of reverse logistics practices. *Journal of Buisness Logistics* 2001; 22(2): 129–148. doi: 10.1002/j.2158-1592.2001.tb00007.x
44. Kabirifar K, Mojtahedi M, Wang C, Tam VWY. Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: A review. *Journal of Cleaner Production* 2020; 263: 121265. doi: 10.1016/j.jclepro.2020.121265
45. Verrier B, Rose B, Caillaud E, Remita H. Combining organizational performance with sustainable development issues: The lean and green project benchmarking repository. *Journal of Cleaner Production* 2014; 85: 83–93. doi: 10.1016/j.jclepro.2013.12.023
46. Verrier B, Rose B, Caillaud E. Lean and green strategy: The lean and green house and maturity deployment model. *Journal of Cleaner Production* 2016; 116: 150–156. doi: 10.1016/j.jclepro.2015.12.022
47. Simpson DF, Power DJ. Use the supply relationship to develop lean and green suppliers. *Supply Chain Management* 2005; 10(1): 60–68. doi: 10.1108/13598540510578388
48. Abdallah AB, Al-Ghwayeen WS. Green supply chain management and business performance. *Business Process Management Journal* 2020; 26(2): 489–512. doi: 10.1108/BPMJ-03-2018-0091
49. Eltayeb TK, Zailani S, Ramayah T. Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. *Resources, Conservation and Recycling* 2011; 55(5): 495–506. doi: 10.1016/j.resconrec.2010.09.003
50. Laosirihongthong T, Adebanjo D, Choon Tan K. Green supply chain management practices and performance. *Industrial Management & Data Systems* 2013; 113(8): 1088–1109. doi: 10.1108/IMDS-04-2013-0164
51. Samad S, Nilashi M, Almulihi A, et al. Green supply chain management practices and impact on firm performance: The moderating effect of collaborative capability. *Technology in Society* 2021; 67: 101766. doi: 10.1016/j.techsoc.2021.101766
52. Lee SM, Kim ST, Choi D. Green supply chain management and organizational performance. *Industrial Management & Data Systems* 2012; 112(8): 1148–1180. doi: 10.1108/02635571211264609
53. Younis H, Sundarakani B, Vel P. The impact of implementing green supply chain management practices on corporate performance. *Competitiveness Review* 2016; 26(3): 216–245. doi: 10.1108/CR-04-2015-0024
54. Liang F, Brunelli M, Rezaei J. Consistency issues in the Best Worst Method: Measurements and thresholds. *Omega* 2020; 96: 102175. doi: 10.1016/j.omega.2019.102175
55. Galeazzo A, Furlan A, Vinelli A. Lean and green in action: Interdependencies and performance of pollution prevention projects. *Journal of Cleaner Production* 2013; 85: 191–200. doi: 10.1016/j.jclepro.2013.10.015
56. Leong WD, Lam HL, Ng WPQ, et al. Lean and green manufacturing—A review on its applications and impacts. *Process Integration and Optimization for Sustainability* 2019; 3: 5–23. doi: 10.1007/s41660-019-00082-x
57. Rodrigues HS, Alves W, Silva Â. The impact of lean and green practices on logistics performance: A structural equation modelling. *Production* 2020; 30: 1–14. doi: 10.1590/0103-6513.20190072
58. Bravi L, Santos G, Pagano A, Murmura F. Environmental management system according to ISO 14001:2015 as a driver to sustainable development. *Corporate Social Responsibility and Environmental Management* 2020; 27(6): 2599–2614. doi: 10.1002/csr.1985
59. Darnall N, Jolley GJ, Handfield R. Environmental management systems and green supply chain management: Complements for sustainability? *Business Strategy and the Environment* 2008; 17(1): 30–45. doi: 10.1002/bse.557
60. Yildiz Çankaya S, Sezen B. Effects of green supply chain management practices on sustainability performance. *Journal of Manufacturing Technology Management* 2019; 30(1): 98–121. doi: 10.1108/JMTM-03-2018-0099
61. Eltayeb TK, Zailani S. Investigation on the drivers of green purchasing towards environmental sustainability in the Malaysian manufacturing sector. *International Journal of Procurement Management* 2010; 3(3): 316–337. doi: 10.1504/IJPM.2010.033448
62. Khan SAR, Yu Z, Umar M, Tanveer M. Green capabilities and green purchasing practices: A strategy striving towards sustainable operations. *Business Strategy and the Environment* 2022; 31(4): 1719–1729.
63. Pariatamby A, Fauziah SH. Sustainable 3R practice in the Asia and Pacific regions: The challenges and issues. *Municipal Solid Waste Management in Asia and the Pacific Islands*. Springer; 2014. pp. 15–40.