Green-Lean Operations Evaluation Framework: A case from Iranian Automotive Industry

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Abstract: Companies have been forced to find alternatives to balance productivity and the environment in their operations and products as they move to greener operations and products. The result of this action is the balancing of continuous or simultaneous exploration using pure and green designs. The purpose of this paper is to identify green-lean evaluation model in Automotive Industry. In this study, important criteria of green lean production system were identified from studies conducted in this field. The effects of the proposed criteria and their relationships are examined using a questionnaire. Furthermore, the Best-Worst Method (BWM) has been used for ranking a weight matrix. Also, the causal relationships among each criterion and sub-criteria are obtained by utilizing the Decision making trial and evaluation laboratory (DEMATEL) technique. The results showed that the use of environmental- friendly and recyclable packaging materials and the increase in the useful life of packaged materials ranked as top two in the Green-Lean in this realm. In operational management, the green lean techniques will be implemented to reduce both waste and pollution. Also, this strategy allows the company to enhance its operational and environmental efficiency.

Keywords: Production system, Green-Lean, Best-Worst Method

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1 Introduction

The competition is very intensive in today's domestic and international markets. These conditions have become more complicated because of the growth of manufacturing and distribution technologies. For this reason, manufacturing and service companies are constantly looking for policies and decisions to either attract more and/or to maintain their current customers. Companies and organizations are looking for tools to provide them with a competitive advantage. Lean production can be considered as one of favorable tools (Sreedharan et al., 2018).

Lean production is a continuous-improvement systematic method based on the study of business processes and the removal of wastes from the process. It is waste-free production with the simplest expression (Taj and Morosan 2011; Rahman et al., 2013; Yahya et al., 2019; Gelmez et al., 2020). Lean production is actually the most successful operations management paradigm within production operations, implying high impact on the sustainability of operations (Kurdve and Bellgran, 2021). The focus of this approach is to reduce additional costs, wastes and to make inefficient procedures optimized that influence the production system (Satolo et al., 2017). The term of lean production refers to a set of activities or solutions to minimize operations that are not worthwhile for the organization, or valuable in the production process (Karim et al., 2013). Manufacturers seek to reduce their use of production resources in lean production. In this approach, the workforce used, the purchase capital and machinery installation costs, the space required for production, the warehouses, the materials and the product, and the engineering force and product design, are reduced in half. Thus, the design, construction and distribution time and the sale of a product is halved correspondingly and this is the goal of lean production. Creating a sense of responsibility in the staff is another benefit associated with the lean culture. Responsibility does not mean accountability to superiors, but rather means freedom of action in the work. In this approach, employees have a greater challenge in the production process. Hence, they can nurture their creativity and develop their skills through teamwork in addition to continuous improvement of the system (Karim et al., 2013).

The Green idea emerged in Germany in the late 1980s, where sustainable manufacturing practices began. They have developed a global manufacturing standard for a business that wishes to be globally competent to manufacture goods in compliance with the European Green Market Regulation (Gaikwad and Sunnapwar, 2020). In order to become more eco-efficient, the term green production was coined to represent the modern production paradigm that employs different green strategies (objectives and principles) and techniques (technology and innovations (Deif, 2011). Green production management, in terms of the goods life cycle view, involves all phases of raw material supply, design and production, sale, transportation, operation and recycling of goods. Utilizing green company management can reduce the negative environmental impacts and achieve optimal use of resources and energy in the production process (Xiongyi and wang, 2008). Therefore, in order to reduce the environmental impacts of goods, it is imperative that organizations lead their manufacturing processes towards greening their products (Richey et al., 2005; Hervani et al., 2005; Wei and Lin, 2008; Wooi and Zialani, 2012).

Lean production was firstly introduced in Japan's automotive industry (Toyota) with the goal of reducing waste and increasing customer's value and focus (high quality, low cost, high speed). It has been known to be one of the most prominent paradigms of development (Abualfaraa et al., 2020; Dweiri and Ishaq, 2020). A lean company is an integrated body that effectively creates value for its various shareholders. A green product or process innovation, resulting from environmental regulations or market demand or internal company initiatives, has a significant positive impact on economic, social and environmental performance of the

company (Zailani et al., 2015). The coordination of green and lean must be assessed in term of various organizational areas.
Green-Lean is defined as an integrated strategy aimed at achieving changes that are not only financial or operational, but also environmentally focused. Green and Lean incorporation can be seen as a new opportunity for companies to enhance their efficiency in terms of sustainability (Leong et al., 2019; Siegel et al., 2019).
Considering the limited resources and the inadequacy of research in this field, further research seems inevitable to determine the most appropriate tools for achieving a desirable lean enabler. This important issue can have different levels of priority in companies and organizations with different background. Accordingly, the results obtained from other studies in the field may not be expanded to all industries in general and automotive industries, in particular. Hence, the existing gap in this field shows the necessity to carry out research work using mathematical techniques to achieve the most appropriate lean enablers in order to achieve competitive edge over competition. Therefore, the main question of the present research is: how the model of green-lean can be adopted in the automotive industry and how can it be identified and implemented?

The rest of the paper is organized as follows: The next part is assigned to review the research literature. Then, the research model and data analysis were provided in the third section, and, conclusion and suggestions for the future research were provided in the fourth section.

2 Literature Review

An integrated approach can be adopted of lean and green impacts considering the environmental value alongside economic value (Figge and Hahn, 2012). Such an approach can lead to a reduction in material, product and packaging, defects, rework, waste, energy/water consumption and pollution costs throughout the supply chain (Piercy and Rich, 2015; Kumar and Rodrigues, 2016).
According to previous researches, companies that simultaneously apply the lean and green practices achieve better results than the companies who focus only on one of these approaches. The lean- and green-integrated practices and the interplay between these two approaches can be achieved through innovation in processes and products. Innovation in product, process and supply chain (Li and Ni, 2016; Piercy and Rich, 2015) can help organizations to make a truly green supply chain (Sriparavastu and Gupta., 1997).
Lean production focuses on elimination of wastes in all ways in the workplace (Menon et al., 2020). Lean thought is a paradigm of non-zero-sum (win-win), where the consumer and supplier both win. For a device that is counterbalanced, the theory of flow is applied. To return savings backwards, the content flows forward. The greater Lean's savings, the higher the benefit accrued (Thareja and Kaushik, 2015). Lean is a tool used to speed up and reduce the expense of any operation by reducing waste (Gaikwad and Sunnapwar, 2020).
Lean production system, developed by Taiichi Ohno, is related to sustainability issues that have been raised by various authors (Rolo et al., 2014; Verrier et al., 2014; Dhingra et al., 2014; Fercoq et al., 2016). These writers could integrate the two philosophies of lean and sustainable production which is also known as the green production, or green system. Sustainable development is a major and strategic issue in the present era (Hsu et al., 2013a,

2013b; Sachs, 2015). Lean production is a production technology that, by limiting the use of natural resources, recycling and reusing what was considered waste and reducing emissions, reduces pollution and waste (Gaikwad and Sunnapwar, 2020).

Lean and green could provide a method for companies to create a tool to evaluate both productivity and environmental performance based on qualitative and quantitative analysis (Ramkumar and Satish, 2020). Lean-Green is a concept related to value aggregation and efficiency in operational and environmental terms. This concept emerges as a corollary result of the challenges of businesses to reconsider their priorities and strategies in order to add more value while contributing to social equity and prevent environmental burdens (Abreu et al., 2017; Cherrafi et al., 2017).

Pampanelli et al. (2013) presented a green and lean model using Kaizen approach to improve energy flows and mass production in production environments. Kaizen's deployment is an integral part of the use of lean thinking. This model is designed for cell production. According to the results of their study, the objectives of lean and green model confirmed the reduction of environmental impacts and increase productivity. Also, their findings confirmed the potential of a lean and green model to reduce costs. In the following, Verrier et al. (2014) conducted a study entitled "combining organizational performance with sustainable development issues: Lean and Green project benchmarking repository". Their research results enable companies to measure their lean and green practices in order to target the best related practices. In the same year, Fazl zadeh and Marandiyan Hagh conducted a research in the field of lean production system as a move towards green production. According to their research, lean production brings some of the green production goals and there are undeniable similarities between lean and green models. The synergy between these two systems has been proven, and the results of the utility of lean tools are confirmed to reduce environmental impacts. The organizational culture of waste reduction, posed in the lean system, is similar to one that proposed by the Environmental Protection Agency. Since the lean and sustainable green production systems both require management commitment and employee involvement, identifying and reducing waste, and continuous improvement of the organization, the implementation of lean manufacturing system may actually facilitate conducting the sustainable green production plan (Fazl zadeh and Marandiyan Hagh, 2014).

Pampanelli (2015) conducted a research in the field of lean and green model in term of the value stream. The findings showed that the Lean and Green model can reduce the use of resources at the value stream level from 2 to 40 percent and save 1.5 million dollars. Also, Fercoq et al. (2016) studied a research on the integration of lean/green focused on waste reduction techniques. The results of their study help to implement a plan to reduce waste using a set of tools for monitoring and assessing the achievements of the program, which finally result in improved balanced performance in terms of environmental, social and economic aspects. Mourtzis et al. (2017) also investigated a research on methods for extracting lean rules to design lean Product-service system (PSS) through monitoring key performance indicators. Their research proposes a method to improve the product and services system design by combining the monitoring of the core performance indicators in real time with the idle time principles and methods (Mourtzis et al., 2017). Abreu et al. (2017) studied Lean-Green models for eco-efficient and sustainable production. The key purpose of Lean-Green models has been found to be to increase the efficiency of processes while reducing environmental impacts. Cherrafi et al. (2017) examined the Green Lean implementation barriers and their contextual relationships and effects on the integration and deployment of this approach. The various barriers were classified into 'linkage' and 'dependent' barriers by using Croise's Multiplication Appliqée a UN Classement (MICMAC) analysis.

Gandhi et al. (2018) conducted a research on ranking of lean-green production drivers for Indian medium-sized companies. According to their research, senior management's commitment, upgrading technology, current legislation, green brand image and future law are five of the most important drivers for implementing integrated lean-green production in India. Thanki and Thakkar (2018) identified and analyzed the critical success factors (CSFs) behind the successful implementation of lean-green practices in Indian small- and medium-scale enterprises (SMEs). The results showed "Government support" as the most significant to the successful lean-green implementation in Indian SMEs. Narottam et al. (2019) uncovered existing literature gaps in the field of Lean Six Sigma (LSS). The thorough review of existing literature showed that adoption of LSS plays a vital role in process improvement, variation reduction and defect reduction.

Cherrafi et al. (2019) presented a model for integrating Lean and Green based on the GembaKaizen approach. The model was validated using two cases study in the aerospace and automotive industries. The findings showed that the proposed model helped the case organizations to reduce the consumption of resources and improve their environmental performance. Sony and Mekoth (2019) examined the different dimensions an employee must adapt while implementing LSS. This added value to organizations so that they can better recruit and manage their employees. Farrukh et al. (2020) investigated the various constructs of Green lean six sigma (GLSS). Findings showed that these constructs of GLSS as a holistic approach can facilitate an organization to better achieve environmental goals such as waste minimization, emission reduction, and resource conservation as compared to constructs of only one or any two of these strategies. Singh et al. (2021) analyzed barriers of Green Lean practices in manufacturing industries by DEMATEL approach. Twelve barriers were categorized in terms of cause and effect, and the interrelationships of barriers were also analyzed. Threshold value is calculated as 0.134 and the values lower than a were eliminated to obtain the digraph. "Resistance to change," "lack of top management commitment" and "lack of training to employees" are the most prominent barriers on the basis of their prominent score. Akrami et al. (2020) facilitated the implementation of lean operations in organizations. The result showed that there are three clusters in 20 wastes. Then considering the expense and benefit of the waste, they ranked the clusters.

According to the research done so far, in a direct and independent study, the most appropriate features and enablers of lean production in the Iranian automotive industry have not been studied and prioritized. These priorities vary among organizations, depending on the context and nature of the organization's activities. One of the fundamental constraints of Analytic Hierarchy Process (AHP) is that it does not consider the interdependencies between decision elements, i.e. criteria, sub-criteria, and alternatives, and assumes the relation between decision elements as hierarchical and one-way.

Contribution of this work:

The gap in the literature is that the elements presented in lean and green production are not comprehensive and integrated. Therefore, the present study tries to identify and evaluate all the effective indicators. The automotive is one of the largest key industries in the world. Reducing vehicle emissions, while maintaining the performance and efficiency, are two main objectives to meet. In this context, the proposed research focuses on improving the throughput of automotive industry under a green-lean paradigm. In particular, this works investigates on production efficiency and its greenness via adopting a green-lean decision making. This research contribution can be defined as follows:

(1) adopting the hybrid decision-making tools utilized by BWM in our case study for the first time

(2) determining and simulating green-lean criteria by incorporating expert's opinions into the underlying evaluation techniques

(3) real implementation of the proposed method in automotive industry.

3 The Research Model

In this research, after investigating and compiling the research questions and objectives, the research background and library studies were conducted to identify the lean-green indices. Then, these indicators were evaluated by the experts of Pars Khodro Company through field studies (questionnaires). Pars Khodro is an Iranian automobile manufacturer. It was the first manufacturer of sport utility vehicles in Iran. It is in Tehran province. In this context, 15 managers (experts), considering the age, gender, and other job-related attributes such as work experience (more than 6 years worked in production planning or logistics) and educational level who are familiar with the subject (Master and PhD in Industrial Engineering or Industrial Management) have been involved in answering the questions. In the present study, following the literature review, green standards were identified; then, a questionnaire was prepared and provided to Pars Khodro experts. Afterwards, using the BWM and the DEMATEL technique, data analysis was performed using GAMS software. Finally, the summary and suggestions for future research were provided. The steps of this research are provided in Figure 1.

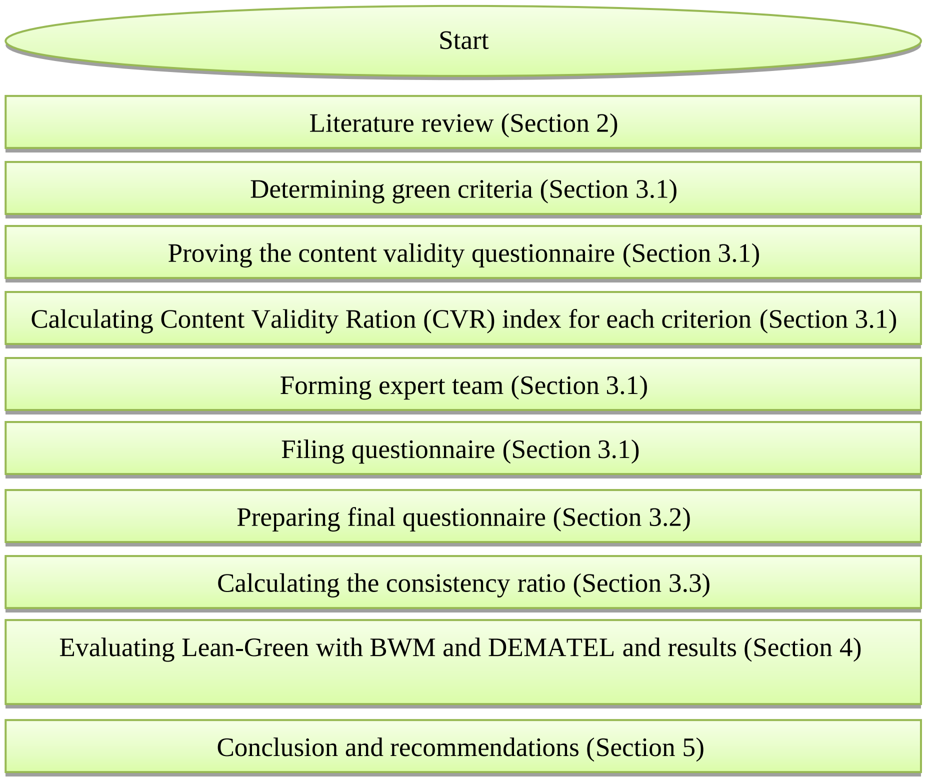

Figure 1 The research process

3.1 Determining Lean-green criteria

Based on the reviewed literature, major criteria and sub-criteria were categorized. At the first, we have taken into account five criteria and 20 sub-criteria. After that, Content Validity Ratio (CVR) was used as a metric. The formula of CVR=(Ne-N/2)/(N/2), in which the Ne is the number of panelists indicating "essential" and N is the total number of experts. The numeric value of CVR is determined by Lawshe (Waltz and Bausell, 1981) and the remained sub-criteria were 15 out of 20. The minimum CVR for 15 experts is determined 0.49. The approved and remained criteria as well as sub-criteria are shown according to Table 1.

Table 1 Finalized Criteria and sub-criteria of Lean-Green

Criteria	Criteria symbol	Sub-criteria	Sub-criteria symbol	Reference
Speed	M1	Delivery speed by observing environmental regulations	C1	Carvalho et al. (2017)
		Sensitivity and responsiveness to the market by observing environmental regulations	C2	Carvalho et al. (2017)
		Flexibility by observing environmental regulations	C3	Carvalho et al. (2017)
Quality	M2	Appropriate planning to reduce energy consumption	C4	Fazl zadeh, and Marandiyan Hagh (2014)
		Use of equipment and machinery with required technical and environmental standards	C5	Fercoq et al. (2016)
		Designed to reduce environmental and noise pollution	C6	Fercoq et al. (2016)
		Having environmental management certificates	C7	Fazl zadeh, and Marandiyan Hagh (2014)
Cost	M3	Value and quality of green materials versus cost	C8	Atlas and Florida (1998)
Pollution	M4	Use of recycled or environmental materials	C9	Fercoq et al. (2016)
		Use of green fuels and reducing the use of hazardous fuels	C10	Zailani et al. (2015)
		Use of IT tools	C11	Shen et al. (2013)
		Use of environmentally friendly and recyclable materials in packaging	C12	Xiongyi and Wang , 2008
		Fair and reasonable price of the product in compliance with environmental regulations	C13	Atlas and Florida (1998)
Waste	M5	Increase the useful life of packaging materials	C14	Carvalho et al., 2017
		Use of proper method for disposal of sewage	C15	Bergmiller and McCright, (2009)

3.2 DEMATEL Technique

DEMATEL is one of the decision-making methods based on paired comparisons and expert judgments, which was developed by Fontela and Gabos during the years 1971 to 1976.

The procedural Steps in DEMATEL

Step 1: Creating a Direct Contact Matrix (M): the simple mean of the views is used when contributing several experts and the matrix M is formed as the matrix (1).

$$M = \begin{bmatrix} 0 & a_{12} \cdots & a_{1n} \\ a_{21} & 0 \quad \cdots & a_{2n} \\ \vdots & \vdots \quad \ddots & \vdots \\ a_{n1} & a_{n2} \quad \cdots & 0 \end{bmatrix} \qquad (1\ )$$

Step 2: Normalizing the Direct Relationship Matrix (DRM): Calculate the sum of the rows of the M and multiply the largest inverse value in the matrix M.

$$N = a * M \qquad (2)$$

$$a = \frac{1}{Max_i \sum_{j=1}^{n} aij} \qquad (3)$$

Step 3: Calculating the complete relationship Matrix: At this step, the matrix of complete existing relationship of direct and indirect relations (s) is formed according to Equation (4):

$$\lim N^{T}_{t\to\infty}=0 \qquad S= N+ N2+N3+ \ldots+Nt= \frac{N(1-N^{t})}{1-N} = N(1-N)^{-1} \qquad (4)$$

Step 4: Creating the causal diagram and calculating the criteria weight:

- The sum of the elements of each row (D) for each element indicates its effect on other system elements (the effectiveness of the variables)
- The sum of column elements (R) for each element indicates the extent of its impact on other system elements (the extent of being affected for variables)
- So, the horizontal vector (D + R) is the effect of the given element in the system. In other words, the greater amount of (D+R), the more the two elements interact with other system agents.
- Vertical vector (D-R) shows the effectiveness of each element. In general, the variable is a causal variable if (D-R) is positive, and is considered an effect, if (D-R) is negative.

If D> R D-R> 0, then the element is absolutely deterministic and an effective variable.

If D <R → D-R <0, then the element is absolutely deterministic and a variable that being affected.

Then, the causal diagram can be obtained based on the ordered pair (D+R, D-R), which provides a valuable introspection for decision making. For this purpose, a Cartesian coordinate system with the longitudinal axis (D+R) and a transverse axis (D-R) is drawn in which the position of each factor is determined by the point with the coordinates (D+R, D-R).

Finally, a Cartesian coordinate system is drawn. The longitudinal axis in this system is the D+ R values and the transverse axis is based on the D-R. Each point's position is determined by the point with the coordinates (D+R, D-R) in the system. In this way, a graphical diagram is obtained.

According to Chang and Cheng (2011), the elements importance weight is simply obtained by normalizing the absolute impact scores according to (5):

$$W_i = \frac{|D_{i-R_i}|}{\sum_i |D_{i-R_i}|} \quad (5)$$

where, D i -R_I is considered as the impact score of i.

Step 5: Calculating the relationships threshold: A Network Relationship Map (NRM) can also be drawn between elements. For this purpose, the threshold value of the relationship must be calculated using the average of the matrix s. Thereby, it is possible to ignore the partial relations (all relations with the value smaller than the threshold value in the matrix s) and consider them zero. That is not considered causal relation and the network of significance relationships (relations with values greater than the threshold value in the matrix s) are drawn (Habibi et al., 2014).

3.3 BWM method

A new method called BWM is introduced in this research for solving a multi-criteria decision problem to evaluate and rank the components of the green integrated system. According to the BWM method, the best (the most desirable and the most important) and the worst (the most undesirable) criterion is determined by the decision maker. The pair comparisons between each of these two best and the worst criteria and the other criteria is conducted (Rezaei, 2015).

The Steps of BWM Method

BWM applied five steps to determine the weights of criteria (Rezaei, 2015; Mi et al., 2019).

Step 1: Determining the set of criteria. The criteria used in decision making are considered in this step. The alternatives are determined based on these criteria.

Step 2: Determining the best (in other words, the most desirable and the most important) and the worst (the most unfavorable and the least important) criteria. The decision maker generally defines the best and worst criteria. No comparison is conducted in this section.

Step 3: Determining the performance of the best criterion than the other criteria using numbers between 1 to 9. The best criterion results for the rest of the criteria can be as follows:

$$A_B = (a_{B1}, a_{B1}, \ldots, a_{Bn}) \quad (6)$$

where, a_{Bj} is the best B performance criterion than j criterion. Obviously $a_{BB} = 1$.

Step 4: Determining the performance of all criteria than the worst criterion using numbers 1 to 9. The vector of comparison results than the worst-case scenario can be as follows:

$$A_w = (a_{w1}, a_{w1}, \ldots, a_{wn})^T \quad (7)$$

Where a_{wj} is the performance of the worst W criterion than the j criterion. Obviously $a_{WW} = 1$

Step 5: Determining the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$

The optimal values are unique for criteria that can be defined for each pair of $\frac{w_j}{w_W}$ and $\frac{w_B}{w_j}$. $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_W} = a_{wj}$. In order to satisfy these conditions for all js, it is needed to find a solution that minimizes the absolute value of the maximum difference $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_B} - a_{Wj}\right|$. Given that the weights are non-negative and summable, the following problem can be defined and the optimal value is obtained under the name ε.

$$Min\ \varepsilon \tag{8}$$

$$\left|\frac{w_j}{w_B} - a_{Wj}\right| \leq \varepsilon \quad for\ all\ j \tag{9}$$

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \varepsilon \quad for\ all\ j \tag{10}$$

$$\sum_j W_j = 1 \tag{11}$$

$$W_j \geq 0 \quad for\ all\ j \tag{12}$$

Inconsistency Ratio

A comparison is quite inconsistent when $a_{Bj} * a_{jW} = a_{BW}$ for all js that a_{Bj} and a_{jW}, a_{BW} are respectively include the superiority of the best criterion than criterion j, the superiority of the criterion j than the worst criterion, and the superiority of the best criterion than the worst criterion. However, it is possible that this relation is not true for some of js, in which case the Consistency Ratio is computed using Equation 13.
Table 2 is used to determine the consistency index according to the a_{BW} superiority score:

Table 2 Consistency Index in Best-Worst Method

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency ratios	0	0.44	1	1.63	2.30	3	3.73	4.47	**5.23**

$$\text{Consistency ratio} = \frac{\varepsilon^*}{\text{consistency index}} \tag{13}$$

4 Results and Discussion

4.1 Optimal weight based on the response of each respondent

The weight of each criterion is determined by the responsiveness of each respondent after analyzing the data which is indicated in Table (3).

Table 3 Criteria weight based on respondents' responses

Criterion / Respondent	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	ξ
Expert 1 weigh	0.118	0.042	0.072	0.028	0.093	0.031	0.062	0.086	0.110	0.118	0.068	0.017	0.018	0.032	0.104	**0.107**
Expert 2 weigh	0.033	0.106	0.032	0.121	0.046	0.026	0.033	0.081	0.062	0.046	0.109	0.077	0.072	0.120	0.037	**0.101**
Expert 3 weigh	0.116	0.116	0.058	0.087	0.012	0.008	0.082	0.120	0.143	0.020	0.087	0.072	0.002	0.052	0.025	**0.055**
Expert 4 weigh	0.107	0.042	0.071	0.022	0.081	0.035	0.088	0.093	0.101	0.061	0.011	0.031	0.123	0.021	0.111	**0.036**
Expert 5 weigh	0.071	0.132	0.010	0.059	0.014	0.127	0.001	0.102	0.108	0.115	0.011	0.053	0.034	0.106	0.057	**0.105**
Expert 6 weigh	0.036	0.019	0.028	0.036	0.063	0.008	0.137	0.144	0.075	0.074	0.051	0.137	0.056	0.017	0.119	**0.124**
Expert 7 weigh	0.072	0.044	0.074	0.018	0.024	0.173	0.176	0.106	0.011	0.043	0.065	0.151	0.003	0.008	0.031	**0.049**
Expert 8 weigh	0.082	0.092	0.082	0.057	0.069	0.037	0.094	0.024	0.087	0.023	0.047	0.079	0.099	0.010	0.117	**0.091**
Expert 9 weigh	0.089	0.056	0.050	0.051	0.035	0.058	0.058	0.094	0.091	0.074	0.043	0.093	0.061	0.040	0.107	**0.063**
Expert 10 weigh	0.140	0.088	0.099	0.094	0.033	0.048	0.075	0.037	0.135	0.031	0.036	0.027	0.036	0.070	0.050	**0.110**
Expert 11 weigh	0.129	0.060	0.026	0.127	0.137	0.061	0.016	0.036	0.057	0.083	0.037	0.084	0.099	0.031	0.016	**0.103**
Expert 12 weigh	0.042	0.045	0.060	0.071	0.012	0.037	0.113	0.004	0.131	0.103	0.069	0.081	0.033	0.065	0.135	**0.030**
Expert 13 weigh	0.070	0.067	0.030	0.062	0.080	0.087	0.050	0.047	0.126	0.005	0.113	0.117	0.102	0.013	0.033	**0.114**
Expert 14 weigh	0.044	0.089	0.018	0.094	0.014	0.085	0.064	0.101	0.093	0.118	0.116	0.044	0.091	0.026	0.004	**0.129**
Expert 15 weigh	0.092	0.062	0.059	0.112	0.075	0.076	0.106	0.100	0.071	0.023	0.030	0.110	0.004	0.061	0.021	**0.072**

4.2 Criteria Weight

To calculate the weight of each criterion in this step, the average of the different weights obtained by 15 experts for each criterion is calculated, and the final weight of each criterion is shown in Table (4).

Table 4 Final optimal weight of criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
Weight	0.082	0.062	0.058	0.062	0.046	0.048	0.075	0.093	0.093	0.061	0.051	0.079	0.056	0.0032	**0.050**
Inconsistency ratio								**0.016**							

Also, the average of the inconsistency ratios obtained by each expert is used to calculate the overall inconsistency ratio. Since the calculated consistency ratio is 0.016, it can be concluded that paired comparisons have been performed correctly which indicates a good fit.

4.3 Criteria Ranking

The criteria of lean-green production system can be ranked based on the obtained weights. The order of the criteria is as Table (5):

Table 5 Final ranking of criteria

Index	Criteria	Rank
C8	Use of environmentally friendly and recyclable materials in packaging	**1**
C9	Increase the useful life of packaging materials	**2**
C1	Appropriate planning to reduce energy consumption	**3**
C12	Flexibility by observing environmental regulations	**4**
C7	Designed to reduce environmental and noise pollution	**5**
C4	Use of equipment and machinery with required technical and environmental standards	**6**
C2	Use of recycled or environmental materials	**7**
C10	Fair and reasonable price of the product in compliance with environmental regulations	**8**

C3	Use of green fuels and reducing the use of hazardous fuels	**9**
C13	Use of IT tools	**10**
C11	Value and quality of green materials versus cost	**11**
C15	Sensitivity and responsiveness to the market by observing environmental regulations	**12**
C6	Use of proper method for disposal of sewage	**13**
C5	Having environmental management certificates	**14**
C14	Delivery speed by observing environmental regulations	**15**

The ranking of criteria is performed based on the average weight of each criterion provided in Table (4) and final ranking of criteria is given in Table (5). Accordingly, a higher rank is assigned to a criterion with a higher average weight than the other. As shown, the use of environmentally friendly and recyclable materials in packing is the most important. The delivery speed by observing environmental regulations is the least important criterion in terms of the expert.

4.4 Comparisons between criteria and sub-criteria

Table (6) provides the results of row and column matrices for comparing different criteria.

Table 6 Relations of the Relationship Matrix of the Main Criteria

	R	**J**	**R+J**	**R-J**
M3	4.5315	3.8451	8.3767	0.6864
M5	3.8971	3.223	7.1202	0.6741
M4	3.5329	3.8008	7.3337	-0.2678
M2	3.4192	3.6571	7.0763	-0.2379
M1	3.3496	4.2044	7.554	-0.8548

4.5 The causal relationships of criteria

The diagram, provided in Figure 2, schematically shows the mutual influence between criteria. The relationship and the impact of each element on others is depicted as follows: the relationship is showed with one-sided arrow if only one element affects the other, and is showed by a two-way arrow if both criteria are mutually effective.

Main criteria	**Attribute**
M1	**Speed**
M2	**Quality**
M3	**Cost**
M4	**pollution**
M5	**waste**

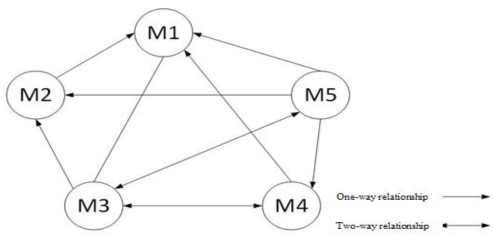

Figure 2 Diagram of the relationship of the main criteria (causal relationships)

Using the conducted research in this area, the important criteria that should be observed in the field of lean-green production system were identified in the present study, and the criteria effects and relationships were investigated using the questionnaire. Then, the BWM multi-criteria decision making technique was used to obtain the importance weight of the measurement criteria. The causal relationships of each criterion were also examined using the DEMATEL method.

In this study, at first, questionnaires were distributed among the experts and they were asked to select the best and the worst criterion and compare them with other criteria and allocate the relevant scores according to these two criteria. Also, the DEMATEL technique was used to investigate the effect and relationship of the main criteria with each other which results were presented schematically. After solving the model of the Best-Worst Method for each expert and calculating the average of the weights of each criterion, the criterion of the use of environmentally-friendly and recyclable material in packaging and the delivery speed by observing environmental regulations were chosen as the most important and the least important criteria, respectively according to the experts.

5 Conclusion and Recommendations

More specifically, in this study, we use field and library studies to present and rank the components of green-lean production system tailored for Pars Khodro. Two main criteria, namely the use of environmentally-friendly and recyclable packaging materials and also the increase in the useful life of packaged materials, that ranked as first and second in the criteria ranking procedure, were adopted as two dominant criteria to investigate about this research. These two criteria were further divide into more detailed sub-criteria, so that the obtained results make the role of each of the two main criterion more credible in a lean-green production system. It is therefore suggested that government projects and awareness programs have significant progress in their operational and commercial performance through the implementation of green-lean production. Companies need to create a positive outlook for green-lean initiatives to be used as a major local and global resource in a competitive environment. Also, it was concluded that the speed criterion had the most effectiveness based on the study of the interaction effects among the main criteria. Hence, its role should be studied in further depth within a lean-green production system.

Literature pertinent to this subject matter is vast. A short review is provided below. Fercoq et al. (2016) studied the role of waste reduction in lean/green production system, in which a reduction in waste would have a significant environmental impact. Accordingly, our study is in good agreement with Fercoq's study. It shows that the design criteria aimed at: (1) reduction in environmental and noise pollutions, (2) efficient use of the equipment and machinery by reducing their carbon footprints, and (3) effective use of the recycled or environmental-friendly material will play very important role in making the production at Pars Khodro more green-lean. In the research of Carvalho et al. (2017), eco-friendly packaging criteria, delivery speed and environmental standards play a significant role in the efficiency and effectiveness of the lean/green production system. Also, the results of our study showed that these factors were crucial, based on experts' opinion. Farrukh et al. (2020) found that a comprehensive GLSS strategy meets the necessities of environmental performance together with operational objectives. Their research results are also in line with our research results.

This study helps the company's executives to better plan future investments. This can lead to a bench-mark study problem that can be learned and adopted by other industries interested in green-lean. Due to the lack of availability of appropriate and adequate literature on the topic, this research may have some limitations. Limited information is, however, available on the linkage between green-lean method in the automotive industry. Also, the key drawbacks of the proposed analysis are sample size and study time. Therefore, to overcome these limitations, it is proposed to increase the number of statistical sample size in the geographical area. The Future researches can perform annually study to assess the progress of lean manufacturing and determine how it endures. It is noteworthy that even though this study was targeted for Pars Khodro, however, the research results can be extended to other companies and/or industries.

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