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RESEARCH ARTICLE

Evaluation of green lean production in textile industry: a hybrid fuzzy decision-making framework

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Abstract
Textile industry is an old and effective industry in Iran. However, due to its age and high energy consumption, this industry has low profitability and entrepreneurship. One of the most important problems of the weaving industry is the issue of waste regarding manpower, materials, machinery, and especially energy consumption. Another problem is environmental pollution. In this paper, using a multiple decision-making model for ranking and selecting criteria and sub-criteria, which is presented using the step-wise weight assessment ratio analysis (SWARA) and also by examining several industrial plants on weaving, the final ranking was performed using the fuzzy COPRAS method. According to the final result and using the opinions of experts and reviewing the studied cases, the environmental criterion was more important than other criteria, and also according to the existing sub-criteria, the amount of CO2 production and pH in the process of completion and washing and the types of pollution in the effluent and sewage were more important than other sub-criteria. Also, among the alternatives, company 5 is evaluated as the best alternative.

Keywords Green · Lean production · Textile industry · Fuzzy · Decision-making techniques; Evaluation framework

Introduction

The weaving industry is one of the oldest and at the same time the most important industries in the world, which has long been of special interest to the countries and major economies of the world due to its important role in job creation and industrial, economic, and social development. Various benefits of this industry, including currency, production of national wealth, need for less investment than other industries, as well as high added value, have led many industrialized and developed countries in the world today to employ the weaving and garment industries. Industrial weaving products can be divided into a number of categories such as industrial weavings, medical weavings (i.e., implant use), geochemical geo (used to strengthen joints), agro-weaving, construction weavings, protective clothing (clothing for firefighters, molten metal welders, vest welders, bulletproof vests, and gray protective clothing), packaging weavings, sports weavings, and automotive and aerospace fabrics (Yang et al. 2015; Neto et al. 2019). This weaving industry is a polluting industry as well as has low profitability. Today, in addition to economic issues, industries face social and environmental challenges in order to design their products to survive in a competitive world (Fazlzadeh and Marandian 2015; Hasanbeigia et al. 2012). Lean production is one of the solutions that is very useful in reducing economic costs in the economic challenge (Lucato et al. 2017).

Lean manufacturing is a philosophy that Toyota developed in the 1950s to compete with the US auto giants. The goal was to minimize additional or non-value-added methods in the production process. Various tools were used to achieve this goal. For example, comet mapping tools, cell production, Kanban, 5S, and Kaizen were used (Paladugu and Grau 2020; Caldera et al. 2017). The use of lean manufacturing

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Highlights
I. Developing a decision support framework for textile industry
II. Applying hybrid fuzzy decision-making model
III. Strategizing practitioners in textile industry for green lean implementation

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techniques can be effective in identifying and controlling various damages that cause environmental pollution in the industry (Sullivan et al. 2017). Although the concept of lean manufacturing has shown good results in the continuous process industry, it has not been widely used compared to discrete production. The process industry, especially the weaving industry, has highly flexible automatic machines with high volume/low product variety. This complexity of the weaving industry challenges the introduction of lean manufacturing strategies (Prasad et al. 2020).

Lean production has some green production goals, and there are undeniable similarities between lean and green models. The synergy between the two systems has been proven, and the results confirm the efficiency of lean tools in reducing environmental impact. The organizational culture of waste reduction in the lean system is the same as the culture proposed by the Environmental Protection Agency. Because both lean manufacturing and sustainable green production require commitment from management and employee involvement, identifying and reducing organizational waste, and continuous organizational improvement, implementing a lean manufacturing system may facilitate the implementation of a sustainable green production program. Because the production of weavings causes serious damage to the environment in many ways, the identification of conscious structural indicators is vital for the development of environmental-psychological strategies (Roy et al. 2020). Clothing consumes a lot of natural resources and emits polluting effluents, causing serious concerns for the environment and human health. Green design, green procurement, green operations, and green transportation are the main areas of green supply chain management (Giovanni and Cariola 2020). Therefore, using green lean production is an effective method to reduce the amount of damage to the environment and make the product competitive.

In the continuation of the article, its sections are organized as follows: review of the literature on lean production, green production, and weaving; the fuzzy MADM method, including COPRAS and SWARA presenting a case study and results; as well as a comparison with articles in this field and future research paths.

Review of literature

Florentine et al. stated that when lean and green are linked in the so-called green lean, many of these savings also lead to environmental benefits. The main purpose of green lean models is often associated with increasing system efficiency while reducing environmental impact (Florentina et al. 2017).

In a work by Fu et al. (2017), they proposed an operational strategy that can be implemented with a clean and green approach, concepts, ideas, and new tools based on theoretical and practical perspectives. Therefore, companies in developing countries can use this model to reap long-term benefits by creating a sustainable competitive advantage based on clean and green establishment (Fu et al. 2017).

In another work, a method to support developers and professionals in integrating production executive systems with a lean manufacturing approach was defined. A case study in the field of aerospace is presented to validate the method (D'Antonio et al. 2017). Yadegaridehkordi et al. identified and analyzed the relationship between lean and sustainable and its impact on performance from an operational, financial, social, and environmental perspective, examining a set of building blocks to develop a sustainable integration framework aimed at promoting a discussion of how firms can be identified in the sustainability of their operations (Yadegaridehkordi et al. 2020).

In this context, a case study of green productivity and sustainability assessment of the motorcycle tire production process was performed. The main purpose of this study was to achieve a scenario of potential productivity improvement and at the same time evaluate the sustainability of motorcycle tire production using the AHP method. Green productivity analysis showed that the level of productivity is higher than environmental impacts in the production process (Marimin et al. 2018).

Most studies on lean manufacturing have been examined in this way. Masoumi et al. have provided technical solutions for their study on integrated green management to improve the environment in the weaving industry by identifying and prioritizing how to deal with environmental problems (Roy et al. 2020). Using the best and worst methods, a sustainable approach to accepting concepts and using Six Sigma evaluated the organizational readiness to improve the product and green process with the commitment of top management (Kaswan and Rathi 2020).

Prasad et al. as a result of a case study conducted in the weaving industry of South India using lean techniques challenged discrete production in addition to continuous production with a complete analysis of operation, adjustment time, and change time as well as by examining the initial and final diagrams of lean production, they were able to improve the methods of visual control and flexibility of workers (Prasad et al. 2020).

Knowing that the weaving and garment industry is an industry that naturally consumes a great deal of natural resources, Maya et al. found out how to implement an efficient and sustainable approach to this problem through a way to support the implementation of LP (lean production) (Maia et al. 2013).

Given that the garment export sector has the most significant impact on the economy, Annamalai et al. conducted their own research to evaluate the effectiveness of the lean model in the industry. The results of this study showed that in order to prepare a lean model, there are two factors for success to be considered, which are the factors that improve the efficiency of the company and employee satisfaction (Annamalai et al. 2020).

In order to increase system power time, if workers do not have the necessary experience, changes can be made that increase productivity by planning to set up the system and prepare. The implementation of the green lean initiative for the production of SMEs (small and medium size enterprises) has also been presented and discussed through a comprehensive summary of the state of the art and regular classification. Analysis has shown that lack of managerial support and lost standards are the most important barriers for companies to implement lean and green management (Siegel and Antony 2019).

Baumer-Cardoso et al. (2020) evaluated and supported the integration of lean and green into a Brazilian company using a discrete event simulation model of green analysis in relation to water, energy, and raw materials for each unit operation, including environmental and production variables. Also, the environmental impacts of lean practices such as Kanban are discussed. The results showed that the correlation between lean and green on performance indicators proves a positive impact on trade (Baumer-Cardoso et al. 2020).

The increasing development of the construction industry and the significant contribution of the industry to global energy consumption and CO2 emissions necessitate the use of lean techniques aimed at reducing environmental impacts and waste. The results of research have shown that lean techniques have been used to try to improve production processes and transportation (Heravi et al. 2020).

Lean production is included techniques that not only to reduce business costs but also to improve the sustainability of companies. Saettaa and Caldarellia (2020) analyzed how technological innovations to achieve economic, social, and environmental sustainability affect on the production process. By analyzing different types of them, it can identify the best ones and use them to implement it with changes in the production line (Saettaa and Caldarellia 2020).

Lean production has emerged as one of the most popular models in the market in recent decades. The lean approach is characterized by five principles of value, mapping, value flow, flow, traction, and continuous improvement, that facilitate the reduction of waste and garbage, and because environmental damage is a concern for customers, the demand for clean products with less waste and reduction of environmental damage has been considered, and in parallel, the environmental performance of a company is increasingly considered. In their research, Dieste et al. conducted a literary review to determine whether companies that have been purified have improved their environmental practices using principles and methods and provided new deployment plans and roadmaps for the simultaneous implementation of lean and green strategies or to shift their operations from lean to green and vice versa that are useful for attracting companies and customers in general (Dieste et al. 2019).

Southeast Asian countries are known as the hub of weaving production and clothing supply chain, which consumes a lot of natural resources, emits polluted wastewater, and causes serious health for the environment and humans. In their paper, Majumdar and Kumar Sinha have tried to facilitate the concerns and barriers to the application of green supply chain management by green design, green procurement, green operations, and transportation (Majumdar and Kumar Sinha 2019).

Finally, a table is summarized from the background of reading articles on the study and use of green lean production in various quantitative and qualitative methods. According to the reviewed articles, the gap between the researches can be considered as mathematical modeling for the relationship between the criteria in the integration and composition of green lean production. In this research, according to mathematical modeling, SWARA and COPRAS methods have been used. Among the articles reviewed, the use of this method for modeling has been done for the first time because it has previously examined supply chain management or green or stability between lean and green is mentioned and the combination of lean and green production is not done using the mathematical model Table 1 and 2.

The SWARA method is uncomplicated and specialists can easily work together. The most important advantage of this method in decision-making is that in some problems, priorities are based on the policies of manufacturing plants or countries defined in other methods such as AHP or ANP; our model is based on criteria and expert evaluations affecting the priorities and rankings. Therefore, SWARA can be useful for some cases where the priorities are in line with known conditions; finally, SWARA has been used in some decision environments. COPRAS method is considered as one of the multi-criteria decision-making methods. The advantage of this method is the simplicity of calculation, complete ranking of the options, and considering positive and negative criteria. In fact, it can be said that in order to evaluate several criteria, both minimization and maximization of the value of criteria are considered (Kildienė et al. 2011).

Many articles have been written in the field of textile industry in areas such as green supply chain, sustainability, or green productivity; but this kind of assessment and ranking has not been done for green lean manufacturing. For example, in the articles, lean manufacturing has been done separately in the textile industry or in the case of being green in specialized fields that can change the type of fibers based on their compatibility with the environment. But it has not been conducted to combine green lean manufacturing and use it in large factories to increase efficiency and optimization. Another area of innovation is the application of the SWARA

Table 1 Literature review summary

No.	Article	Industry	Author	Country	Description	Year	Method
1	Find a probabilistic method for lean production analysis	Automobile manufacturing	Hosseini Nasab	Iran	Has compared the benefits of these two methods	2012	AHP and ANP methods
2	Evaluate lean and green strategies for simulating production systems	Machine manufacturing	Diaz-Elsayed	Germany, America	Decreased energy levels in production	2013	Use of visual management and a lean and green integration approach
3	Green lean models for efficient and environmentally friendly production	It is a review article	Florentina Abreu	Portugal	Improve the efficiency of systems while reducing environmental impacts	2017	Analysis of several identified models
4	Investigating the role of lean thinking in sustainable business performance	Different industries	Caldera et al.	Australia	Prioritize lean methods	2017	Conceptual model
5	Investigation of green lean implementation methods in Indian SMEs using AHP	Small and medium enterprises	Shashank Thanki	India	Provide a comprehensive approach	2016	
6	The effect of ergonomics on the production lines of several hybrid models in lean manufacturing	Automobile manufacturing	Lucia Botti	Italy	Risk assessment method	2018	Mathematical modeling
7	Green lean model strategy and model maturity	Toyota automotive company	Brunilde Verrie	France	Eradicate waste in Toyota production	2015	Green lean maturity model and correlation between lean and green
8	Application of green production model in developing countries, case study of China	Chemicals	Xiaoxi Fu	China	Lean adaptive model	2017	Conceptual model
9	A new method for integrating manufacturing executive systems with a lean manufacturing approach	Aerospace	Gianluca D'Antonio	Italy	Creating a sustainable competitive advantage	2017	Conceptual model
10	Sustainable production: Carnac and green business model	Engineering Company	Andrea Brasco Pampanelli	Brazil	Aerospace validation method	2015	Conceptual model
11	Adopt lean and green integrated strategies for modern production systems	Services	Varinder Kumar Mittal	India	Develop an integration approach	2017	VIKOR, MOORA
12	Lean production and integrated facade stability	Casting	Saetta and Caldarelli	Italy	Integrate it with Agile	2020	Conceptual model
13		Review articles	Luana Marques Souza Farias	Brazil		2019	Qualitative model

Table 1 (continued)

No.	Article	Industry	Author	Country	Description	Year	Method
	Criteria and methods for evaluating lean and green performance: a systematic review and conceptual framework				Techniques to reduce business costs, but also to improve the sustainability		
14	Application of lean principles in hospital process design in the emergency department	Services	Kyle H. Cichos, BS	Birmingham	Conceptual framework of lean and green performance	2018	Lean methods
15	Green and lean path of sustainable development in China practices and performance	Services	YuanzhuZhan	China	Lean optimization	2018	
16	Six Sigma Green Lean Strategies for Sustainable Development: Integration and Framework	Services	Kaswan and Rathi	India	Unique features of GLS electronic instruments	2020	Six Sigma
17	A model for integration and monitoring of green and green in the coffee sector	Agriculture	Lucas Vinícius Reis	Brazil	Examine 20 criteria	2018	SAW
18	A simulation-based approach to realize the green plant of green unit production processes	Fluid industry	Singh et al.	India	A practical mathematical approach to the relationships of variables	2018	Fuzzy
19	Improve green productivity and assess the sustainability of motorcycle tire production	Motorcycle	Marimin et al.	Indonesia	Increase green productivity index	2018	Qualitative model
20	Sustainable evaluation method to clear the study of manufacturing companies in Brazil	Production companies	Aline Ribeiro Ramos	Brazil	A modeling-based method	2017	Criteria-based method
21	Green lean integration focuses on waste reduction techniques	Production companies	Alain Fercoq	France	Focus on waste reduction techniques	2016	Hierarchical method and use of experimental design
22	Exploration of Prometheus method and MCDM approach to determine the best performance result of dual fuel and biodiesel	Automobile manufacturing	Patrick Taillandier	France	Replacement of fossil fuels and the use of hydrogen and biodiesel fuels	2017	PROMETHEE and AHP method
23		Transportation	Gandhi et al.	India		2017	

Table 1 (continued)

No.	Article	Industry	Author	Country	Description	Year	Method
	Ranking of drivers for integrated production and small companies in India				Reduce waste and improve green lean performance		TOPSIS, in Fuzzy environment and SAW
24	Evaluation of green lean performance in the production of radial tires, dynamic model method	Rubber manufacturing	Vipul Gupta	India	A new method for waste assessment	2018	System dynamics method
25	The relationship between lean performance and the environment: functions and	Services	Marcos Dieste	Italy	Investigating the lean relationship between the environment	2019	Functions and criteria
26	Analysis of green textile supply chain management barriers in	Textile	Abhijit Majumdar	Southeast Asia	Using interpretive structural modeling	2019	Structural modeling
27	Southeast Asia	Review	Luana Marques Souza Farias	Brazil	Systematic review and conceptual framework	2019	Conceptual model
28	Analysis of green weaving supply chain management barriers in	Used in all industries	Singh et al.	India	Key performance parameters of green lean methods	2021	Analysis of the appropriate decision of several criteria
29	An integrated green management model to improve environmental performance of textile industry toward sustainability	Textile	Roy et al.	India	Contribute to the development of a sustainable environment	2020	EPM, DEMATEL, ANP
30	Criteria and methods for evaluating green and lean performance	All industries	Kaswan and Rathi	Germany	Contribute to the optimal use of resources	2020	KPP, MCDA
31	Understand the main parameters of green lean performance	Textile	Prasad et al.	India	The importance of thorough operation analysis, time adjustment, and change time	2020	Use of Kaizen
32	Performance in manufacturing industries	Construction	Yadegari dehkordi	Malaysia	Aiming to identify and rank sustainability	2020	Fuzzy MCDM
33	An integrated green management model to improve the environment	Textile	Annamalai et al.	India	Minimize losses and improve productivity	2020	With ergonomics
34	The performance of the textile industry	Production companies	Usmani et al.	Saudi Arabia	improving Productivity	2020	Use lean tools
35		Textile	Gardas et al.	India	Find the cause and effect relationship	2018	Delphi-DEMATEL

Table 1 (continued)

No.	Article	Industry	Author	Country	Description	Year	Method
	Check the capabilities associated with running green						
36	Six Sigma lean in the production sector using the best and worst methods	Construction	Heravi	Iran	Assess carbon emissions	2020	Lean techniques
37	A framework for implementing lean manufacturing in Indian weavings	Organizational services	Bhattacharya	Australia	Application and effect of lean and green	2019	Qualitative model
38	Lean implementation within manufacturing SMEs in Saudi Arabia: organizational culture aspects	Small and medium enterprises	Abdullah Alkhoraif	Saudi Arabia	Lean implementation in small and medium companies	2018	Qualitative model
This work	**Green lean evaluation framework for textile industry**	**Textile industry**	**Authors**	**Iran**	**Green lean evaluation using decision-making techniques**	**2021**	Quantitative and qualitative methods

and COPRAS methods, for example, Roy et al. (2020) and Gardas et al. (2018) using DEMATEL method and ANP method or different ranking and weighting methods, but in this article, the SWARA method is used for weighting and the COPRAS method is used for ranking, which are more effective methods than other methods, and it gives decision-makers and policymakers the opportunity to select their priority based on the current state of the environment and the economy.

Framework of study

The methodology proposed for this work is according to Figure 1 and inclu, 2012).

Step 2: Many countries have gradually launched a "green" project on environmental protection in their country. Since the launch of the Green Industry Initiative in Japan in 1991, Canada, the United States, and Germany have consistently introduced "green plans," and China has included environmental protection in its sustainable development agenda on the 21 Century Agenda. Definition of green knowledge refers to a set of environmental measures that include the "green plan" and the development and production of "green products" and at the same time create the law of resource use and waste recycling.

Step 3: In this section, based on the literature review and research background and also using the opinions of experts, 36 effective indicators on 5 factories were identified and extracted in 6 main criteria, which are given in Table 3.

Step 4: In this stage, in order to identify the industry, using and surveying 5 factories in Iran and Qazvin province, the desired data has been obtained and studied from them. Also, experts in the weaving industry and related professors in universities as experts have been used to determine some criteria and sub-criteria and to check the validity of the content and select them.

Step 5: Using 54 articles in the field of green lean production and also using the opinions of experts, 54 sub-criteria were defined in 6 main categories of criteria. Then, by examining the content validity using the CCR questionnaire, which was used by experts to determine and complete it, it was reduced to 36 sub-criteria which have been studied as sub-criteria in this research.

Step 6: Among the 6 criteria studied, it can be said that 3 of them were directly related to the green discussion in the weaving industry and also 17 sub-criteria are related to the use of green knowledge in this industry.

Table 2 Fuzzy SWARA language expressions and numbers (Kiani Mavi et al. 2017)

Triangular fuzzy numbers	Linguistic expression
(1,1,1)	Equal importance
(0.67,1,1.5)	Relatively low importance
)0.4,0.5,0.67)	Low importance
(0.286,0.33,0.4)	Very little importance
(0.22,0.25,0.286)	Very little importance

Step 7: At this stage, using a combination of lean and green sub-criteria, green lean production in the weaving industry has been studied.

Step 8: In this step, the method used in this research is the combination of SWARA for weighting and COPRAS method for ranking.

Step 9: The outcome of the study in this field is to identify the cases that have been obtained for the implementation of green lean production in the weaving industry, which is one of the polluting industries.

SWARA method

The SWARA method is one of the multi-criteria decision-making methods that aims to calculate the weight of criteria and sub-criteria. The purpose of this method is to weigh the criteria. The SWARA method was introduced by Kersuliene, Zavadskas, and Turskis in 2010. This word is one of the first letters of the phrase step-wise weight assessment ratio analysis, meaning the analysis of the gradual weighting evaluation ratio. In this method, the criteria are ranked based on value. In this method, the most important criterion is ranked first, and the least important criterion is ranked last. Finally, the criteria are prioritized based on the average values of relative importance. This technique is based on the opinions of experts and is a completely judgmental method. In this method, experts (respondents) have an important role in determining the weight of the criteria.

Fuzzy SWARA method

The algorithm of this technique is the same as the SWARA method, but it is used in a fuzzy environment. As previously stated, the purpose of the SWARA method is to calculate the weight of the factors, so it is of particular importance, so by implementing this method in a fuzzy environment, the ambiguities in the words of the respondents are removed and the results will be more accurate. The steps of the fuzzy SWARA method are as follows (Kiani Mavi et al. 2017):

Step 1: Arrange the research factors in descending order according to their importance.

Step 2: Based on the spectrum of Table 3, the relative importance of factor *j* is compared to factor j-1 which is more important to reach the last factor. After determining all the scores of relative importance of all specialists, in order to integrate their judgments, we obtain the geometric mean of the relevant scores. The output of this step is to calculate S_j.

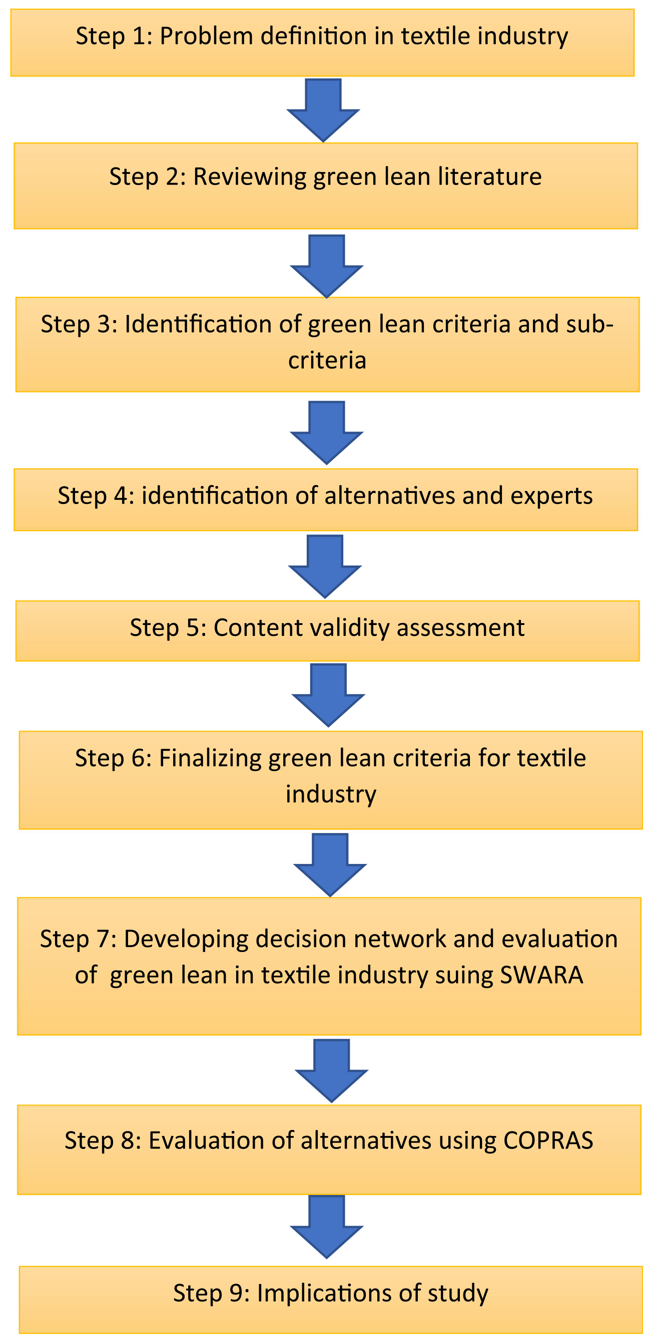


Fig. 1 Framework of the study

Step 3: Calculate the coefficient K_j.

This coefficient is calculated from Eq. 6:

$$\widetilde{K}_j = \begin{cases} \widetilde{1} & j = 1 \\ \widetilde{S}_j + \widetilde{1} & j > 1 \end{cases} \quad (1)$$

Step 4: Calculate the fuzzy weights (q_j).

Fuzzy weights are obtained from Eq. 7:

$$\widetilde{q}_j = \begin{cases} \widetilde{1} & j = 1 \\ \dfrac{\widetilde{x}_{j-1}}{\widetilde{k}_j} & j > 1 \end{cases} \quad (2)$$

Step 5: Calculate the relative weights.

$$\widetilde{w}_j = \frac{\widetilde{q}_j}{\sum_{k=1}^{n} \widetilde{q}_k} \quad (3)$$

The output of this step is the relative fuzzy weights (w_j^l, w_j^m, w_j^u). Equation 9 is used to convert these weights to definite numbers.

$$W_{crisp} = \frac{\left(w_j^m - w_j^l\right) + \left(w_j^u - w_j^l\right)}{3} + w_j^l \quad (4)$$

Fuzzy COPRAS method

In this section, research alternatives are ranked using the fuzzy COPRAS method.

Step 1: Form a decision matrix.

The decision matrix of this method is a criterion option, that is, a matrix in which the criteria are placed in a column and the alternatives in a row and each cell is the score of each option relative to each criterion.

Step 2: Defuzzification of the decision matrix.

In this section, we make the fuzzy decision non-fuzzy using the following equation matrix.

$$\text{defuzzy} = \frac{((u-l) + (m-l))}{3} + l \quad (5)$$

Table 3 Verbal expressions and corresponding fuzzy numbers for evaluating options (Patil and Kant 2014)

Fuzzy triangular numbers	Linguistic expression
(1,1,3)	Very little
(1,3,5)	Low
(3,5,7)	Medium
(5,7,9)	Much
(7,9,11)	Very much

Step 3: Normalize the decision matrix based on the following equation:

$$d_{ij} = \frac{q_i}{\sum_{j=1}^{n} x_{ij}} x_{ij} \quad (6)$$

where q_i is the weight of the i-th criterion and x_{ij} is the value of each option per criterion.

Step 4: Calculating the total weight of the benchmark.

Normalized benchmark weight describes the alternative; alternatives that are calculated with positive criteria are denoted by s_j^+ , and alternatives that are calculated with negative criteria are denoted by s_j^-. The sum of s_j^+ and s_j^- is calculated based on the following formula.

$$s_j^+ = \sum d_{ij}^+ \quad (7)$$

$$s_j^- = \sum d_{ij}^- \quad (8)$$

Step 5: Comparing the alternatives.

Comparative ranking of alternatives are calculated based on positive and negative criteria. The relative importance of Q_j from each Aj alternative is calculated according to the following formula:

$$Q_j = S_j^+ + \frac{\sum_{j=1}^{n} S_j^-}{S_j^- \sum_{j=1}^{n} \frac{1}{S_j^-}} \quad (9)$$

Step 6: Prioritizing alternatives based on Q_j.

The higher the value of Q_j, the higher the ranking of the alternative in the prioritization. The alternative that has the best possible state or, in other words, the ideal alternative always has the highest value.

Step 7: The final step is to determine the alternative that has the best status among the criteria, which increases or decreases with the increase or decrease of the ranking of each alternative. The alternatives that have the best status in terms of criteria are identified with the highest degree of N_j importance, which is equal to 100%. The total value of the degree of importance of each criterion that is calculated is from 0 to 100%. Among these domains, the best and worst alternatives are determined. The degree of importance of each of the A_j alternatives is calculated based on the following formula:

$$N_j = \frac{Q_j}{Q_{max}} \times 100 \quad (10)$$

In this equation, Q_j is the degree of importance of each alternative, and Q_{max} is the highest value that the ideal alternative has.

Analysis

To begin with analysis, decision network is developed according to Figure 2. The relationships between criteria, sub-criteria, as well as alternative are illustrated.

The decision tree is a concept that you can use if you are planning to make a complex decision or if you want to break things down into smaller parts so that you can better solve them and organize your mind. It is a tool to support the decision. They use trees to model. A decision tree usually starts with an initial part. In this research, the evaluation of green lean production in the weaving industry, after which other sectors are branched out into branches, and each of those consequences leads to another part. This branch structure eventually turns into a tree-like diagram. They have been used to study the factories that are the alternatives of this research and have been identified from Iran and the industrial town of Qazvin province. Some of these sub-criteria have been identified by experts.

Processes, machines, and products of textile industry

Yarn and fabric are famous weaving products in which yarn is made of filament and then fabric is made of yarn. Yarn and fabric production processes, i.e., filament spinning, production of various fibers, yarn spinning and yarn production, and then double-layer weaving, finishing, dyeing, and then printing, which is fabric production, are used with the machines used. Polyester filament is generally made by spinning speeds of 1000 to 1500 meters per minute, single harvesting, and four-stage or five-stage stretching to reach acceptable stresses (Figure 3).

Lighting devices are generally divided into two categories, flat filament yarn and spun yarn, used for spinning filament yarns – turning and re-screwing machines according to a general procedure (Figure 4).

Most of the printed fabrics in the garment industry for the production of women's and children's clothing are in the field of rumble fabrics, curtains, sheets, pillowcases, bedspreads, and some towels (Figure 5).

And finally, the product is a variety of yarns with various natural and artificial colors and materials, as well as a variety of fabrics with different colors, materials, and prints (Figure 6).

Experts qualification

The number of experts in question was 10, which are divided into two groups of 5 people, experts from the academic perspective and experts from the weaving industry. Required characteristics in the field of industry are having a managerial or supervisory position for 4 years and also familiar with the subject of green lean, and the required characteristics in the academic part are having at least the rank of assistant professor with 4 years of experience and familiar with the subject of green lean and decision models Table 4

Calculating the weight of the indicators

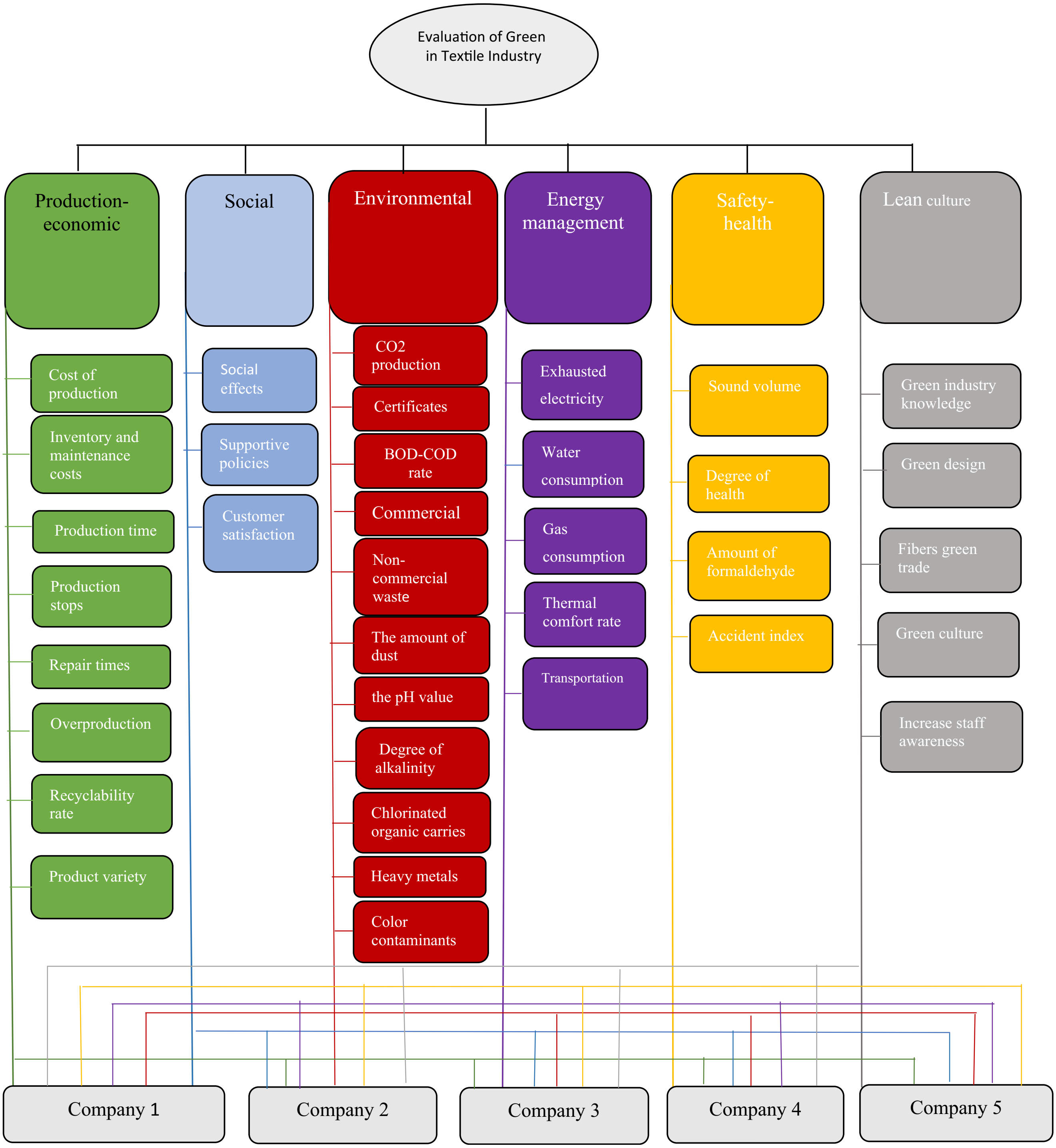
In this section, the weight of the criteria was calculated using the fuzzy SWARA method. First, the criteria were arranged in descending order according to the importance of the expert team Table 5 and 6

Then, the relative importance of each criterion j with the criterion j-1 based on the spectrum 1 to 5, Table 3 (fuzzy rider spectrum), was expressed. Then, using weights 1 to 4, the weight of the criteria was calculated. The w_j column is the weight of the criteria. For example, criterion "D" is calculated as follows:

$$K_D = (1, 1, 1) + S_D = (1.742, 1.952, 2.241)$$

$$q_D = \frac{q_{j-1}}{K_j} = \frac{q_C}{K_D} = \frac{(1, 1, 1)}{(1.742, 1.952, 2.241)}$$

$$= (0.446, 0.513, 0.574)$$



Figu. 2 Decision network

$$W_D = \frac{q_j}{\sum q_j} = \frac{q_D}{\sum q_j} = \frac{(0.446, 0.513, 0.574)}{(2.090, 2.354, 2.593)} = (0.172, 0.218, 0.275)$$

$$W_{Non-fuzzy} = \frac{\left(w_j^m - w_j^l\right) + \left(w_j^u - w_j^l\right)}{3} + w_j^l = \frac{(0.218-0.172) + (0.275-0.172)}{3} + 0.172 = 0.43$$

Fig. 3 Production of staple fibers (short, cut)

Calculations are performed in a similar way for the sub-criteria, the final results of which are given in Table 7.

In this section, the ranking of criteria and sub-criteria is illustrated in Fig. 7, according to the decision and using the final weights obtained. As can be seen, the environmental criterion has gained more weight than the other criteria, and also in each criterion, the highest sub-criterion has been determined according to the same color scheme in the decision tree. The amount of CO2 has more weight than all sub-criteria and as the most important case for the implementation of lean green production has been evaluated and investigated.

As shown in Fig. 7, the environmental criterion has the most weight. In the weaving industry, due to pollution and the production of carbon dioxide regarding the existence of various processes, machinery, materials as well as effluents that include different types of dyes, carriers, and chemicals and also the presence of noise pollution in the factory environment were closely monitored in order to help reduce environmental pollution by providing appropriate solutions. After that, energy and economic criteria have gained more weight. Due to the use of old machines, they consume a lot of electricity, and also the water consumption in this industry is very high due to the processes of completing the washing, dyeing, salting, etc., which also affects the economic criteria. In addition, the amount of fuel consumption for transportation also has an effect on increasing energy consumption. In economic cases, due to not using a proper supply chain or the cost of storing raw materials, as well as the use of unprincipled production and inventory costs or not using the recyclability of materials, an increase in the weight of this criterion is also observed.

Fig. 4 Filament spinning

Fig. 5 Printing equipment

Figure 8 shows the amount of CO2 due to the lack of proper filtration and also the use of old machines. Pigment contaminants in the dyeing process and the pH value in the finishing and washing process have the highest weight, respectively, because they have a significant share in factory effluents.

According to Fig. 9, the amount of water and electricity consumed as well as transportation have the highest weight, respectively. Due to the processes of finishing, washing, and dyeing, as well as the type of loading and high consumption of fossil fuels to transport products.

As shown in Fig. 10, the cost of production and the cost of inventory and maintenance, as well as production time due to not using the lean production method, have the highest weight.

According to Fig. 11 in the safety and health criteria, degree of employees health and also the accident index have the highest weight.

As shown in Fig. 12, green industry knowledge, green design, and green culture have the most weight, because by paying attention and establishing and raising the level of

Fig. 6 Textile products, cloth, thread

awareness in these cases can help green production and environmental protection.

According to Fig. 13, social sub-criteria customer satisfaction has the highest weight. This shows the high importance of obtaining satisfaction with high-quality production and cost-effectiveness, which is achieved by using green lean production.

Results of the fuzzy COPRAS method

In this section, using the fuzzy COPRAS method, five companies were ranked. These companies are indicated by the symbol CO1 to CO5. The first step in this method is to form a decision matrix, which was completed by 10 experts based on the spectrum of Table 4, and then integrate with the arithmetic mean method, which is summarized in Table 8. Then the fuzzy COPRAS steps were performed and the final result is given in Table 9. Based on this, company 5 (CO5) has gained the first rank.

In Figure 14, the factories were ranked based on the determined weights, and according to the observance and importance of the criteria and sub-criteria studied, factory no. 5 performed better than the others and obtained the first rank in this evaluation.

Management consequences

According to the study, recommendations can be made to the managers of this industry to improve production. Based on data and graphs in the criteria section, environment, energy, and economy have the most weight. To improve the environment, green production can be reduced by problems. For example, the use of environmentally friendly raw materials such as plant fibers or the use of green fiber production methods and a variety of methods in the production of refractory fabrics or the production of fabrics with low transfer coefficient of gases emitted from synthetic fibers is suggested. Furthermore, the method of treatment of wastewater and effluents and separation of water used to return to the production cycle or the use of modern machinery to reduce noise pollution is a topic of discussion. In the case of energy, the arrangement of machines for better loading with lower fuel consumption losses can also be important. Economically, using high-standard machinery, using a proper supply chain, as well as reducing inventory and maintenance costs by using lean manufacturing, as well as using recyclability in downstream industries can be improved. Using green lean production will be a suitable and cost-effective production strategy.

Results and benchmarking with other works

Because the weaving industry is one of the industries that cause environmental damage, therefore, by using and implementing green lean production, it both reduces environmental pollution and helps increase productivity. In this regard, recognizing the important criteria, which include several sub-criteria, is very important to examine and determine the importance of each in this industry. An example is an article that explores the Indian weaving industry to discover an integrated model through the decision path and evaluation laboratory (DEMATEL) and analytic network process (ANP). Using the DEMATEL method, the causal relationship was determined, and the weight method was used to determine the indicators. As a result, indicators such as waste generation, volatile organic emission (VOC), and energy consumption in this study seem to be very important for the weaving industry (Roy et al. 2020). Or, in another article, again by examining the criteria and sub-criteria for studying the construction industry in Malaysia and the implementation of green lean production in this industry, using the fuzzy DEMATEL method and also the BWM method, they were able to increase productivity among 6 main criteria and 17 sub-criteria by determining the most important sub-criteria in addition to the implementation of green lean production in the construction industry. In this study, the sub-criteria energy efficiency and indoor quality were the most important, while water efficiency and innovation were the least important criteria for evaluating the construction of green buildings in Malaysia (Yadegaridehkordi et al. 2020).

We can also refer to an article that, using the SWARA method, was able to evaluate 3 cities in Turkey and determine the most important of them according to 12 sub-criteria. In addition, they have selected the best of them to establish a

Table 4 Criteria and sub-criteria table

N	Indicator/sub-criteria		Reference	Definition
1	Production-economic	Cost of production	Abreu et al. 2017	The amount of cost to produce a unit of product
2		Inventory and maintenance costs	Gardas et al. 2018	The cost of creating and maintaining a defined level of inventory
3		Production time	Abreu et al. 2017	The amount of time required to produce a unit of product
4		Production stops	Experts	Average rate of production stop due to safety, health, and environmental problems
5		Repair times	Abreu et al. 2017	Average amount of machine repair and service time
6		Overproduction	Gardas et al. 2018	The amount of production that remains as inventory and is costly
7		Recyclability rate	Experts	Recyclability of fabric or yarn for use in relevant downstream industries
8		Product variety	Abreu et al. 2017; Bhattacharya et al. 2019	Production rate due to complexity in different forms
9	Social	Social effects	Experts	The negative impact of the weaving industry on the social issues of the surrounding cities
10		Supportive policies	Gardas et al. 2018	Existence of government support policies for the weaving industry
11		Customer satisfaction	Siegel and Antony 2019	Having timely delivery and high-quality product
12	Environmental	CO2 production	Abreu et al. 2017	The amount of CO2 production per unit of product
13		Certificates	Gardas et al. 2018	Have ISO-14001 and HSE-ms certifications
14		BOD-COD rate	Farias et al. 2019; Bareera and Büyükgüngör 2019; Mathewa et al. 2019	Oxidation load of oxidants in industrial wastewater
15		Commercial waste	Gardas et al. 2018; Silva et al. 2021	The amount of waste produced that can be sold and recycled from each unit of product
16		Non-commercial waste	Experts	The amount of waste produced that cannot be sold / recycled per unit of product
17		The amount of dust	Experts	Average concentration of dust in the air of production halls
18		Measuring the pH value in the finishing and washing process	Abreu et al. 2017	Measurement of pH in wastewater from completion and initial rinsing processes
19		The scarcity of effluent from the use of different dyes	Siegel and Antony 2019	The degree of alkalinity of the effluent in the use of azoic dyes, alkalis, and dispersions
20		Measuring the amount of chlorinated organic carriers	Farias et al. 2019	Measuring the amount of chlorinated organic carriers used for anti-electricity and fire suppressants
21		Investigation of heavy metals	Siegel and Antony 2019	Investigate the amount of heavy metals in natural fibers such as cotton
22		Measurement of color contaminants in the dyeing and dyeing process	Farias et al. 2019	The concentration of pigments in the wastewater of the production unit
23	Energy management	Exhausted electricity	Gardas et al. 2018	The amount of electricity consumed per unit of product
24		Water consumption	Abreu et al. 2017	The amount of water consumed per unit of product
25		Gas consumption	Farias et al. 2019	Gas consumption per unit of product
26		Thermal comfort rate	Experts	Average PPP-PMV thermal comfort index in production halls
27		Transportation	Siegel and Antony 2019	The rate at which fossils or other forms of energy are used
28	Safety/health	Sound volume	Farias et al. 2019	The amount of noise pollution in production units

Table 4 (continued)

N	Indicator/sub-criteria		Reference	Definition
29		Degree of health	Gardas et al. 2018	The number of staff visits to the clinic unit per day
30		Measure the amount of formaldehyde release	Experts	Measure the amount of formaldehyde release in clothing in a hidden state and in the form of a resin
31		Accident index	Gardas et al. 2018	Number of accidents per year for every 200,000 working hours
32	The culture of purification	Green industry knowledge	Experts	The amount of knowledge and attitude of green production among collection managers
33		Green design	Abreu et al. 2017	Extent of considering green attitude in designing and expanding processes
34		Use of fibers compatible with green trade	Gardas et al. 2018	Increasing the culture of using fibers compatible with green trade
35		Green culture	Siegel and Antony 2019	Existence of rules and instructions of purification in the studied collection
36		Increase staff awareness	Gardas et al. 2018	Increase staff awareness of environmental protection

biogas power plant using the COPRAS method. The distance criterion for the preparation of raw materials is one of the most important criteria, and city A2 has been selected as the desired city (Ycenur et al. 2020), which, according to the review of 3 previous articles, in this research 5 weaving factories in Iran were examined. After determining 6 criteria and 36 sub-criteria among several articles and also using the comments of experts, the weights were given using the SWARA method. The amount of CO_2 production as well as the amount of production cost and inventory was selected as 3 of the most important sub-criteria, and then using the COPRAS method, the factories were ranked

Conclusion

In this paper, using multiple decision models for ranking and selecting criteria and sub-criteria, which are presented using fuzzy weight measurement analysis (SWARA) method and also by examining several industrial factories in the field of weavings, the final ranking was performed using the fuzzy COPRAS method. According to the final result and using the opinions of experts and reviewing the studied cases, the environmental criterion had higher importance than other criteria.

Also, according to the existing sub-criteria, the amount of CO_2 production as well as the amount of pH in the process of completion and washing and the types of contaminants in the effluent and wastewater was of great importance compared to other sub-criteria. Among the alternatives, factory number 5 ranked first in the rankings.

As mentioned, the criteria and sub-criteria were weighed using the SWARA method in that the environmental criteria had the highest value in this study and each of the criteria of energy, economy, safety and health, green, and social purification culture has gained more weight, respectively. In the case of the environmental sub-criteria, the content of carbon dioxide and the use of old machinery and dye pollutants in the dyeing process, respectively, had the highest weight that, considering that out of 5 factories, factory no. 5 was ranked as a better factory according to the importance of sub-criteria with higher weight. Since this factory produces less carbon dioxide and uses new devices and machines and less dye pollutants in its effluent than other factories based on the values studied, it has better performance in terms of other sub-criteria, for example, in Figure 9, the sub-criteria belonging to the criteria of energy management, the water and electricity consumption rate, as well as transportation, have the highest weight, respectively, in which case factory no. 5 has had better performance. In Figure 10, which is related to production-economy, production costs, inventory and maintenance costs, and production time had higher weights in that factory no. 5 has paid more attention to these items than others.

Table 5 Research factors

Code	Sub-criteria	Criterion
A1	Cost of production	Production-economic (A)
A2	Inventory and maintenance costs	
A3	Production time	
A4	Production stops	
A5	Repair times	
A6	Overproduction	
A7	Recyclability rate	
A8	Product variety	
B1	Social effects	Social (B)
B2	Supportive policies	
B3	Customer satisfaction	
C1	CO2 production	Environmental (C)
C2	Certificates	
C3	BOD-COD rate	
C4	Commercial waste	
C5	Non-commercial waste	
C6	The amount of dust	
C7	Measuring the pH value in the finishing and washing process	
C8	The scarcity of effluent from the use of different dyes	
C9	Measuring the amount of chlorinated organic carriers	
C10	Investigation of heavy metals	
C11	Measurement of color contaminants in the dyeing and dyeing process	
D1	Exhausted electricity	Energy management (D)
D2	Water consumption	
D3	Gas consumption	
D4	Thermal comfort rate	
D5	Transportation	
E1	Sound volume	Safety/health (E)
E2	Degree of health	
E3	Measure the amount of formaldehyde release	
E4	Accident index	
F1	Green industry knowledge	The culture of purification (F)
F2	Green design	
F3	Use of fibers compatible with green trade	
F4	Green culture	
F5	Increase staff awareness	

Table 6 Weight of the main criteria

Criterion	S_j	K_j	q_j	Fuzzy w_j	Non-fuzzy w_j
C	-	(1,1,1)	(1,1,1)	(0.386.0.425,0.479)	0.430
D	(0.742,0.95,1.241)	(1.742,1.95,2.241)	(0.446,0.513,0.574)	(0.172,0.218,0.275)	0.222
A	(0.367,0.415,0.501)	(1.367,1.415,1.501)	(0.279,0.362,0.420)	(0.115,0.154,0.201)	0.157
E	0.361,0.425,0.543)	(1.361,1.425,1.543)	0.193,0.254,0.309)	(0.074,0.108,0.148)	0.110
F	(0.901,1,1.167)	(1.901,2,2.167)	(0.089,0.127,0.162)	(0.034,0.054,0.078)	0.055
D	(0.266.0.306,0.375)	(1.266,1.306,1.375)	(0.065,0.097,0.128)	0.025,0.041,0.061)	0.043

According to the diagram of the following sub-criteria, which belong to the safety and health criteria, the importance of the employee health degree criterion as well as the accident index has the highest weight, in which case factory no. 5 had better performances than other factories in terms of the above items. Regarding the sub-criteria of green leaning culture, green industry knowledge, green design, and green culture have the most weight that factory no. 5 has paid more attention to and applied these cases. Regarding the sub-criteria of the last criterion, which is social, customer satisfaction has the most weight. In these cases, factory no. 5 has had the best performance in this field compared to other factories, which

Table 7 Final weights of factors

Criterion	Weight of criterion	Sub-criteria	Code	Relative weight under the criteria	Final weight of sub-criteria
Production-economic (A)	0.201	Cost of production	A1	0.321	0.0646
		Inventory and maintenance costs	A2	0.248	0.0499
		production time	A3	0.149	0.03
		Repair times	A5	0.106	0.0212
		Production stops	A4	0.074	0.0149
		Overproduction	A6	0.049	0.0098
		Recyclability rate	A7	0.038	0.0076
		Product variety	A8	0.024	0.0048
Social (B)	0.061	Customer satisfaction	B3	0.466	0.0286
		Supportive policies	B2	0.319	0.0196
		Social effects	B1	0.217	0.0133
Environmental (C)	0.479	CO2 production	C1	0.308	0.1475
		Measurement of color contaminants in the dyeing process	C11	0.238	0.1141
		Measuring the pH value in the finishing and washing process	C7	0.143	0.0686
		The scarcity of effluent from the use of different dyes	C8	0.104	0.0497
		BOD-COD rate	C3	0.073	0.0349
		Measuring the amount of chlorinated organic carrier	C9	0.048	0.0229
		Investigation of heavy metals	C10	0.037	0.0177
		The amount of dust	C6	0.026	0.0125
		Commercial waste	C4	0.016	0.0078
		Non-commercial waste	C5	0.01	0.0047
		Certificates	C2	0.007	0.0036
Energy management (D)	0.275	Water consumption	D2	0.362	0.0995
		Exhausted electricity	D1	0.273	0.0749
		Transportation	D5	0.175	0.048
		Gas consumption	D3	0.115	0.0316
		Thermal comfort rate	D4	0.08	0.0219
Safety/health (E)	0.148	Degree of health	E2	0.406	0.06
		Accident index	E4	0.269	0.0397
		Sound volume	E1	0.2	0.0295
		Measure the amount of formaldehyde release	E3	0.13	0.0193
The culture of purification (F)	0.078	Green industry knowledge	F1	0.385	0.0299
		Green design	F2	0.247	0.0192
		Green culture	F4	0.187	0.0145
		Use of fibers compatible with green trade	F3	0.117	0.0091
		Increase staff awareness	F5	0.071	0.0055

Fig. 7 Ranking of criteria

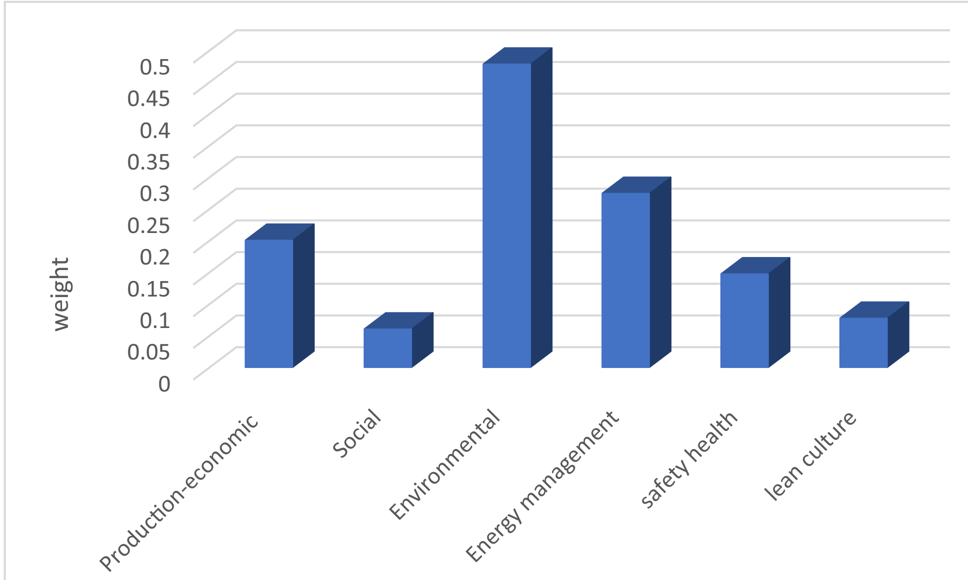


Fig. 8 Comparison of the weight of environmental criteria

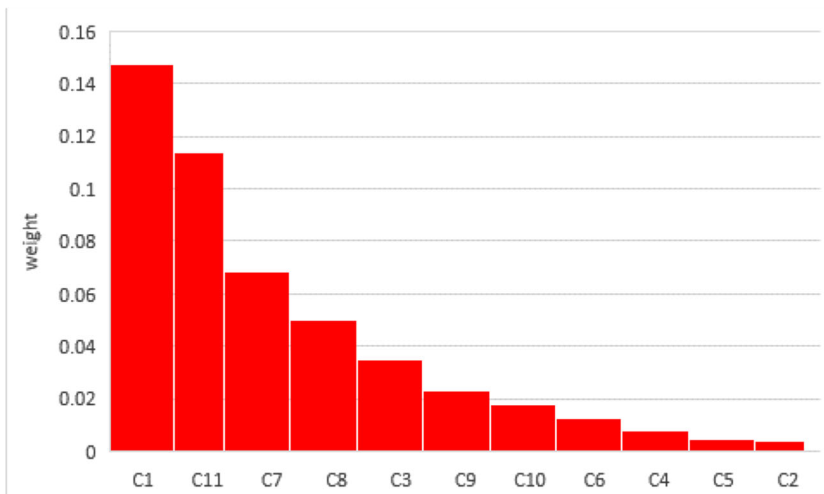


Fig. 9 Comparison of the weight of energy management sub-criteria

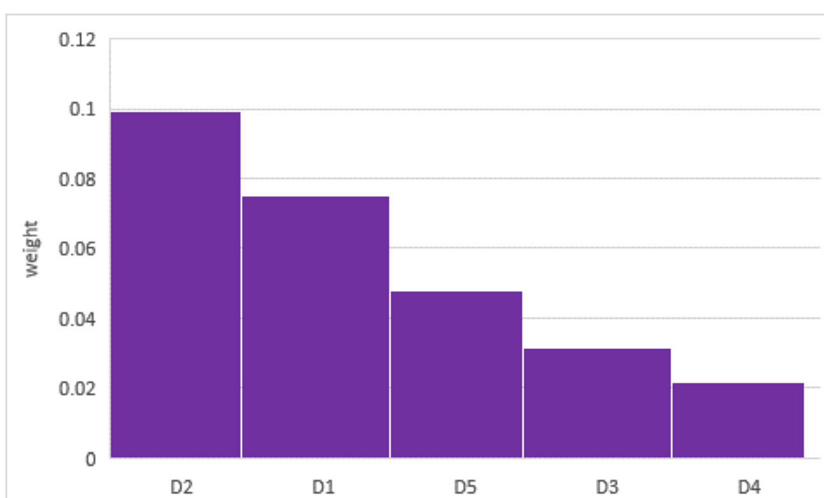


Fig. 10 Comparison of the weight of production-economic sub-criteria

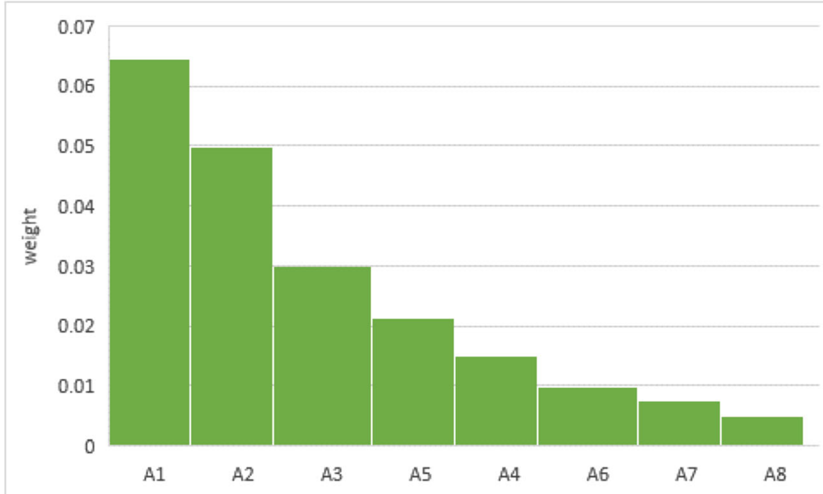


Fig. 11 Weight of sub-criteria of safety and health criteria

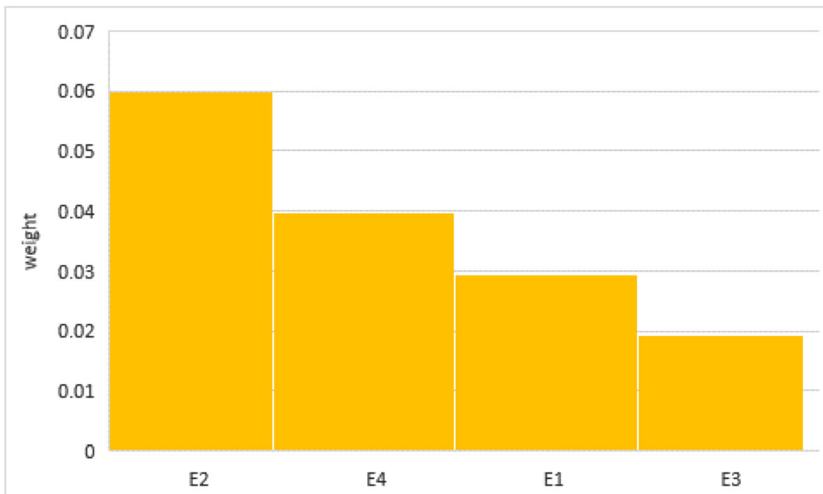
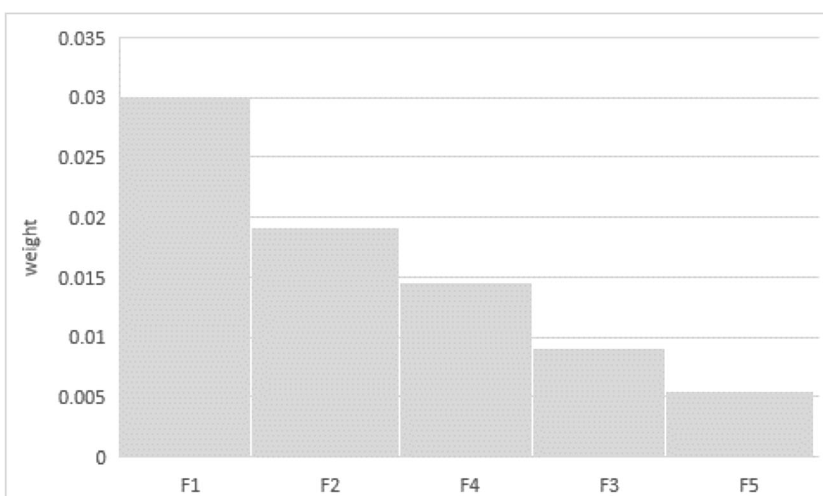


Fig. 12 Comparison of the weights of the criteria of the culture of purification



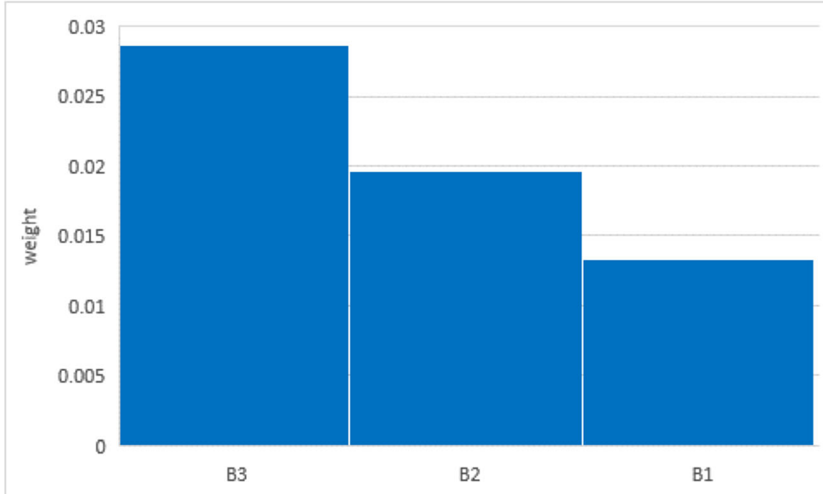


Fig. 13 Comparison of the weight of social sub-criteria

Table 8 Fuzzy COPRAS decision matrix

	A1	A2	A3	A4	A5	A6
CO1	(3.4,5.4,7.4)	(4.6,6.6,8.6)	(3,5,7)	(5,7,9)	(3.8,5.8,7.8)	(3.8,5.8,7.8)
CO2	(5,7,9)	(5,7,9)	(4.6,6.6,8.6)	(6.2,8.2,10.2)	(3.8,5.8,7.8)	(6.2,8.2,10.2)
CO3	(3,5,7)	(4.6,6.6,8.6)	(3,4.2,6.2)	(3.8,5.8,7.8)	(3.8,5.8,7.8)	(4.6,6.6,8.6)
CO4	(2.2,4.2,6.2)	(2.6,4.6,6.6)	(4.2,6.2,8.2)	(2.2,4.2,6.2)	(3.4,5.4,7.4)	(2.6,4.6,6.6)
CO5	(2.6,4.6,6.6)	(2.6,4.6,6.6)	(2.6,4.2,6.2)	(1.4,3,5)	(3,5,7)	(3,5,7)
	A7	A8	B1	B2	B3	C1
CO1	(3.8,5.8,7.8)	(3,5,7)	(3.8,5.8,7.8)	(3,5,7)	(1.8,3.8,5.8)	(3.4,5.4,7.4)
CO2	(5,7,9)	(5.4,7.4,9.4)	(5.8,7.8,9.8)	(4.6,6.6,8.6)	(3.8,5.8,7.8)	(4.2,6.2,8.2)
CO3	(4.2,5.4,7.4)	(3.8,5.4,7.4)	(3.8,5.4,7.4)	(2.6,4.6,6.6)	(2.2,4.2,6.2)	(3,3.8,5.8)
CO4	(3.8,5.8,7.8)	(4.2,6.2,8.2)	(2.6,4.6,6.6)	(3.8,5.8,7.8)	(4.6,6.6,8.6)	(4.6,6.6,8.6)
CO5	(2.2,4.2,6.2)	(1.4,3,5)	(2.2,3,5)	(1.4,2.6,4.6)	(2.2,3.4,5.4)	(3.8,5.4,7.4)
	C2	C3	C4	C5	C6	C7
CO1	(2.6,4.6,6.6)	(4.6,6.6,8.6)	(4.6,6.6,8.6)	(5.8,7.8,9.8)	(4.6,6.6,8.6)	(4.6,6.6,8.6)
CO2	(5.4,7.4,9.4)	(4.6,6.6,8.6)	(3.4,5.4,7.4)	(5.4,7.4,9.4)	(5,7,9)	(5.4,7.4,9.4)
CO3	(3.8,5,7)	(2.2,3.8,5.8)	(2.2,2.6,4.6)	(2.2,2.6,4.6)	(3.4,5,7)	(2.2,3,5)
CO4	(3.4,5.4,7.4)	(2.2,4.2,6.2)	(2.2,4.2,6.2)	(4.2,6.2,8.2)	(3,5,7)	(2.6,4.6,6.6)
CO5	(3,4.6,6.6)	(3.4,5,7)	(2.2,3.8,5.8)	(3.8,5.8,7.8)	(2.6,3.4,5.4)	(1.8,3,5)
	C8	C9	C10	C11	D1	D2
CO1	(3,5,7)	(4.2,6.2,8.2)	(5,7,9)	(2.6,4.6,6.6)	(3.8,5.8,7.8)	(5.4,7.4,9.4)
CO2	(6.2,8.2,10.2)	(4.6,6.6,8.6)	(5.4,7.4,9.4)	(5.8,7.8,9.8)	(5.4,7.4,9.4)	(5.8,7.8,9.8)
CO3	(3.8,5.8,7.8)	(3.4,5.4,7.4)	(5,7,9)	(3.8,5.4,7.4)	(3.4,5.4,7.4)	(2.6,4.6,6.6)
CO4	(4.2,6.2,8.2)	(4.2,6.2,8.2)	(3.4,5.4,7.4)	(2.6,4.6,6.6)	(1.8,3.8,5.8)	(3.8,5.8,7.8)
CO5	(1.4,3.4,5.4)	(3,4.6,6.6)	(3,5,7)	(2.6,4.2,6.2)	(1.8,3.8,5.8)	(1.8,3,5)
	D3	D4	D5	E1	E2	E3
CO1	(5,7,9)	(2.2,4.2,6.2)	(4.2,6.2,8.2)	(4.6,6.6,8.6)	(3.4,5.4,7.4)	(4.2,6.2,8.2)
CO2	(4.6,6.6,8.6)	(5,7,9)	(5.4,7.4,9.4)	(5.8,7.8,9.8)	(5.4,7.4,9.4)	(5.4,7.4,9.4)
CO3	(2.6,4.6,6.6)	(5.8,7.8,9.8)	(4.2,6.2,8.2)	(3.8,5.8,7.8)	(2.6,3.4,5.4)	(3,4.6,6.6)
CO4	(1.8,3.8,5.8)	(3,5,7)	(2.6,4.6,6.6)	(3.8,5.8,7.8)	(2.6,4.6,6.6)	(1.4,3.4,5.4)
CO5	(1.4,2.6,4.6)	(2.6,4.2,6.2)	(3,5,7)	(2.2,3.8,5.8)	(1.8,3.4,5.4)	(2.2,3.8,5.8)
	E4	F1	F2	F3	F4	F5
CO1	(3.4,5.4,7.4)	(5.8,7.8,9.8)	(5,7,9)	(3.4,5.4,7.4)	(2.6,4.6,6.6)	(4.6,6.6,8.6)
CO2	(4.2,6.2,8.2)	(5,7,9)	(5.8,7.8,9.8)	(4.2,6.2,8.2)	(5.4,7.4,9.4)	(5,7,9)
CO3	(4.6,6.6,8.6)	(3.8,5.4,7.4)	(2.6,4.2,6.2)	(3.8,5.8,7.8)	(3.8,5.8,7.8)	(5,7,9)
CO4	(3,5,7)	(3.4,5.4,7.4)	(2.2,4.2,6.2)	(2.6,4.6,6.6)	(3.8,5.8,7.8)	(3.4,5.4,7.4)
CO5	(2.6,4.2,6.2)	(3.4,5,7)	(1,2.2,4.2)	(2.6,4.6,6.6)	(3.4,5.4,7.4)	(3.4,5.4,7.4)

Table 9 Final ranking of alternatives

	S_j^+	S_j^-	Q_i	Ni (%)	Rank
CO1	0.074	0.193	0.231	%79.46	4
CO2	0.090	0.236	0.219	%75.42	5
CO3	0.061	0.170	0.239	%82.21	3
CO4	0.078	0.156	0.272	%93.58	2
CO5	0.060	0.132	0.290	%100.00	1

in the estimation of all these cases using the fuzzy COPRAS method has gained the 1st rank

As mentioned, the reason for using the SWARA method has been to be able to define priorities based on the current state of the environment and the economy, based on the policies of companies or countries in order to move from the scientific field to the practical sector. All criteria have been reviewed in this paper based on their application in the manufacturing environment, because some of these values were not measurable but had no effect on the conclusion, for example, the amount of dust cannot be determined in manufacturing operations and is considered as approximate and fuzzy. But the amount of electricity consumed, water consumption, carbon dioxide emissions, or all the sub-criteria that were ranked higher than the other sub-criteria in their benchmark section have also had a greater impact on the industry. In fact, these cases can be investigated, and their use can be considered to increase optimization. Criteria that rank from one to three in the ranking are that items that can be clearly measured in the manufacturing industry and practical environment and can be changed if necessary to increase factory optimization, which will have a great effectiveness in increasing the efficiency of factories by determining new methods. And in fact, among the 5 factories surveyed, in the practical environment, factory no. 5 was able to obtain the highest rank because they had the best performance in examining the use of the sub-criteria that had found the highest weight. And then we can use the article to give examples of factories in India that were able to optimize water consumption by applying and changing the method. Considering the amount of water consumed in this industry and also due to water shortage and environmental concerns in reducing the use and proper consumption pattern as well as the protection of groundwater in India, it is an example of green and sustainable management in textile manufacturing according to these sub-criteria (Sazzadul Haque et al. 2021).

Suggestion for further research

According to the study of green and lean indicators, these indicators can be used in other industries such as automotive, paint, and petrochemical, which are among the polluting industries, and these industries can be studied. And other methods such as DEMATEL and BWM can be used for weighting and ranking in the same industry or other industries.

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Data availability All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Competing interests The authors declare no competing interests.

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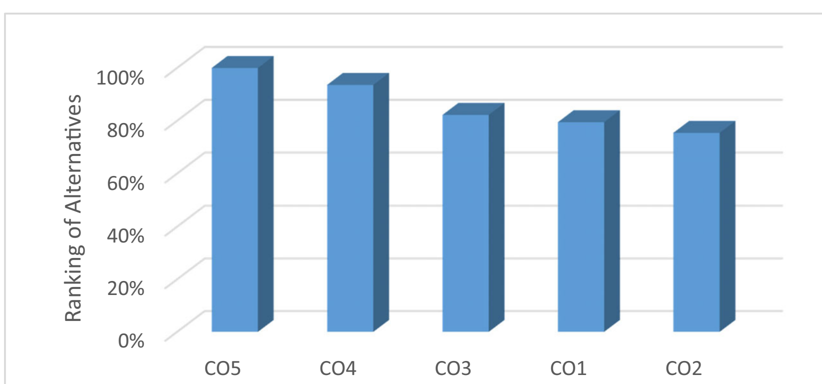

Figure 14 Ranking of alternatives

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