Evaluation of green lean production in Textile Industry: A hybrid fuzzy decision-making framework

Abstract

Textile industry is an old and effective industries 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 in 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 CO_2 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.

Green, lean production, textile industry, fuzzy, decision making techniques; evaluation framework

1. 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 (clothing), packaging weavings, sports weavings, automotive and aerospace fabrics (Sun et al., 2015; Founda et al., 2018). This weaving industry is a polluting industry as well as 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 Hagh, 2014). Lean production is one of the solutions that is very useful in reducing economic costs in the economic challenge.

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 (Abdulmalek, 2006; Paladugu, 2019). The use of lean manufacturing techniques can be effective in identifying and controlling various damages that cause environmental pollution in industry (Sullivan et al., 2018). 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 (Dhiyaneswaria, 2020). Have adopted green production programs that have results in reducing energy consumption, reducing waste generation, and reducing the use of hazardous materials.

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 lean manufacturing and sustainable green production both 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 (Parag Senb2020). 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, 2020). Therefore, using lean green 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.

2. Review of literature

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

In a work by Fu et al. (2017), a proposal including an operational strategy that can be implemented with a clean and green approach, concepts, ideas and new tools and was based on theoretical and practical perspectives was proposed. 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, defining a method to support developers and professionals in integrating production executive systems with a lean manufacturing approach. A case study in the field of aerospace is presented to validate the method (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, 2016)

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 ANP method. Green productivity analysis showed that the level of productivity is higher than environmental impacts in the production process (Darmawan 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 was evaluated the organizational readiness to improve the product and green process with the commitment of top management (Kaswan et al, 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, 2019).

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 Lean Green 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 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 (Antony et al., 2019).

Campos et al. (2020) evaluated and supported the integration of Lean & 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. It is assessed simultaneously, and the environmental impacts of lean practices such as Kanban are also discussed. While the results showed that the correlation between lean and green on performance indicators, prove a positive impact on trade (Campos et al, 2020).

The increasing development of the construction industry and the significant contribution of the industry to global energy consumption and CO_2 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 not only techniques to reduce business costs but also to improve the sustainability of companies. The purpose of the analysis is how technological innovations to achieve economic, social and environmental sustainability affect 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 (Saetta et al., 2020).

In order to make extensive use of water in wet processing operations of the weaving sector, saving in this industry is important which increases investment and costs for wastewater treatment as well as carbon emissions. Tayyab et al. Have provided a solution in their article .They should reduce their greenhouse gas emissions by updating through technological changes, and by treating environmental and electronic water in a multi-stage production system process. The profits of these investments can be obtained and used to improve environmental protection (Tayyab et al., 2019).

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., 2018).

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 et al. 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 et al., 2018).

Finally, a table is summarized from the background of reading articles on the study and use of lean green 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 lean green 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: 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	NancyDiaz-Elsayed	Germany, America	Decreased energy levels in production	2013	**Use of visual management and a lean and green integration approach**
3	Lean-Green 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 lean green 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	Lean-Green model strategy and model maturity	Toyota Automotive Company	Brunilde Verrie	France	Eradicate waste in Toyota production	2015	**Lean green maturity model and correlation between lean and green**
8	Application of green production model in	chemicals	Xiaoxi Fu	China	Lean adaptive model	2017	**Conceptual Model**

	developing countries Case study of China						
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	Stefano Saetta	Italy	Integrate it with Agile	2020	**Conceptual Model**
13	Criteria and methods for evaluating lean and green performance: A systematic review and conceptual framework	Review articles	Luana Marques Souza Farias	Brazil	Techniques to reduce business costs, but also to improve the sustainability	2019	**Qualitative model**
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	Mahender Singh Kaswan	India	Unique features of GLS electronic instruments	2020	**Six Sigma**
17	Ranking of drivers for green beef production for Indian industrial production	Foodstuffs	Nevil S. Gandh	India	Evaluation of drives for green production	2018	**TOPSIS**
18	A model for integration and monitoring of green and green in the coffee sector	Agriculture	Lucas Vinícius Reis	Brazil	Examine 20 criteria	2018	**SAW**
19	A simulation-based approach to realize the green plant of green unit production processes	Fluid industry	Amandeep Singh	India	A practical mathematical approach to the relationships of variables	2018	**Fuzzy**

20	Improve green productivity and assess the sustainability of motorcycle tire production	motorcycle	Muhammad Arif Darmawan	Indonesia	Increase green productivity index	2018	**Qualitative model**
21	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**
22	Lean-Green Integration Focuses on waste reduction techniques	Production companies	Alain Fercoq	France	Focus on waste reduction techniques	2016	**Hierarchical method and use of experimental design**
23	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**
24	Ranking of drivers for integrated production and small companies in India	Transportation	Nevil S. Gandhi	India	Reduce waste and improve lean green performance	2018	**TOPSIS, in Fuzzy environment and SAW**
25	Evaluation of lean green 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**
26	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**
27	Analysis of green textile supply chain management barriers in	Textile	Abhijit Majumdar	Southeast Asia	Using interpretive structural modeling	2019	**Structural modeling**
28	Southeast Asia	Review	Luana Marques Souza Farias	Brazil	Systematic review and, conceptual framework	2019	**Conceptual Model**
29	Analysis of green weaving supply chain management barriers in	Used in all industries	Charanjit Singh	India	key performance parameters of Green - Lean methods	2020	**Analysis of the appropriate decision of several criteria**
30	An integrated green management model to improve environmental performance of textile industry towards sustainability	Textile	Roy et al.	India	Contribute to the development of a sustainable environment	2020	**EPM, DEMATEL, ANP**

31	Criteria and methods for evaluating green and lean performance	All industries	Mahender Singh Kaswan	Germany	Contribute to the optimal use of resources	2020	**KPP, MCDA**
32	Understand the main parameters of lean green performance	Textile	M. Mohan Prasad	India	The importance of thorough operation analysis, time adjustment and change time	2020	**Use of Kaizen**
33	Performance in manufacturing industries	Construction	Yadegaridehkordi	Malaysia	Aiming to identify and rank sustainability	2020	**Fuzzy MCDM**
34	An integrated green management model to improve the environment	Textile	Sivakumar Annamalai	India	Minimize losses and improve productivity	2020	**With ergonomics**
35	The performance of the Textile industry	Production companies	Ateekh Ur Rehman	Saudi Arabia	improving Productivity	2020	**Use lean tools**
36	Check the capabilities associated with running Green	Textile	Bhaskar B. Gardas	India	Find the cause and effect relationship	2018	**Delphi-DEMATEL**
37	Six Sigma Lean in the production sector using the best and worst methods	Construction	Heravi	Iran	Assess carbon emissions	2020	**Lean techniques**
38	A framework for implementing lean manufacturing in Indian weavings	Organizational services	Ananya Bhattacharya	Australia	Application and effect of lean and green	2019	**Qualitative model**
39	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 & Qualitative methods**

3. Framework of study

The methodology proposed for this work is according to Figure 1 and included nine steps as follows:

STEP1: Considering that one of the most important problems of the weaving industry is the discussion of losses in the fields of manpower, materials, machinery and especially energy consumption, so to optimize this industry and turn it into an entrepreneurial and growing industry, topics such as refinement in this industry should be implemented. This industry is not only a profitable and entrepreneurial industry but also one of the polluting industries. Noise pollution in this industry, industrial effluents and energy consumption are among them (Bakhtiari, 2012).

STEP2: 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.

STEP3: 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.

STEP4: 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.

STEP5: Using 54 articles in the field of lean green 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.

STEP 7: At this stage, using a combination of lean and green sub-criteria, lean green 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.

STEP9: The outcome of the study in this field is to identify the cases that have been obtained for the implementation of lean green production in the weaving industry, which is one of the polluting industries.

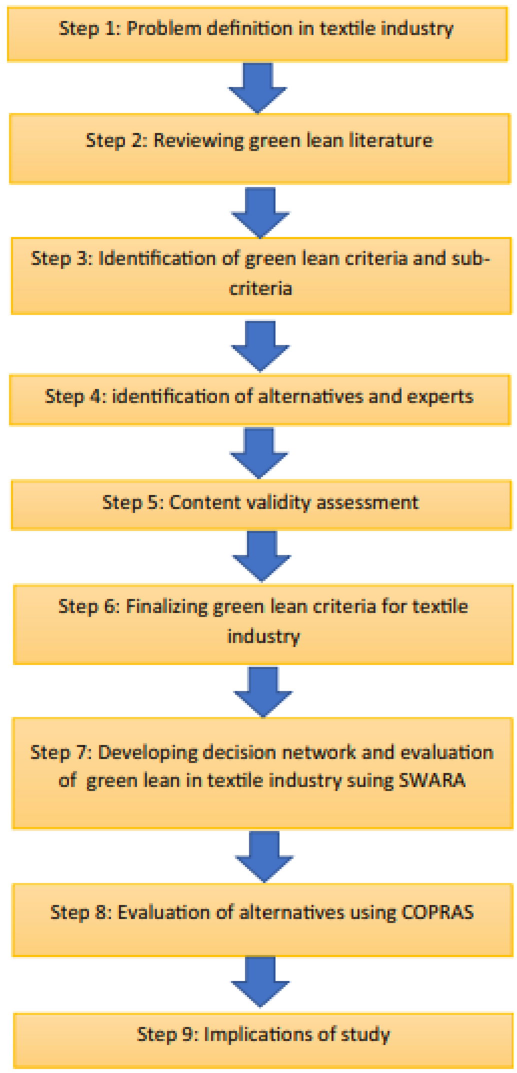

Figure 1: Framework of Study

3.1 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 Cresolin, Zavadskas and Torxis 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 (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 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 Sj.

Table 2- Fuzzy SWARA language expressions and numbers (Maui 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 3- Calculate the coefficient Kj

This coefficient is calculated from Equation 6:

$$\tilde{\boldsymbol{K}}_{\boldsymbol{j}} = \begin{cases} \tilde{\boldsymbol{1}} & \boldsymbol{j} = \boldsymbol{1} \\ \tilde{\boldsymbol{S}}_{\boldsymbol{j}} + \tilde{\boldsymbol{1}} & \boldsymbol{j} > \boldsymbol{1} \end{cases} \qquad (1)$$

Step 4- Calculate the fuzzy weights (qj)

Fuzzy weights are obtained from Equation 7:

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

Step 5- Calculate the relative weights

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

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.

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

3-2 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.

Table 3: Verbal expressions and corresponding fuzzy numbers for evaluating options (Patel 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 2: Defuzzification of the decision matrix

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

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

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 qi is the weight of the i-th criterion. And xij is the value of each option per criterion.

Step 4: Calculating the total weight of the benchmark

Normalized benchmark weight describing 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.

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

$$s_j^- = \sum d_{ij}^- \tag{8}$$

Step 5: Comparing the Alternatives

Comparative ranking of alternatives that 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:

$$Q_i = S_j^+ + \frac{\sum_{j=1}^{n} S_j^-}{S_j^- \sum_{j=1}^{n} \frac{1}{S_j^-}} \tag{9}$$

Step 6: Prioritizing alternatives based on Qj

The higher the value of Qj, 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 Nj 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 Aj alternatives is calculated based on the following formula:

$$N_i = \frac{Q_i}{Q_{max}} \times 100 \tag{10}$$

In this equation, Qj is the degree of importance of each alternative, and Qmax is the highest value that the ideal alternative has.

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	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	sigel et.al,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	Oxidation load of oxidants in industrial wastewater
15		Commercial waste	gardas et.al.2018	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	sigel et.al,2019	The degree of alkalinity of the effluent in the use of azoic dyes, alkalis, dispersions and ......
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	sigel et.al,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	sigel et.al,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
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	sigel et.al,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

4. 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.

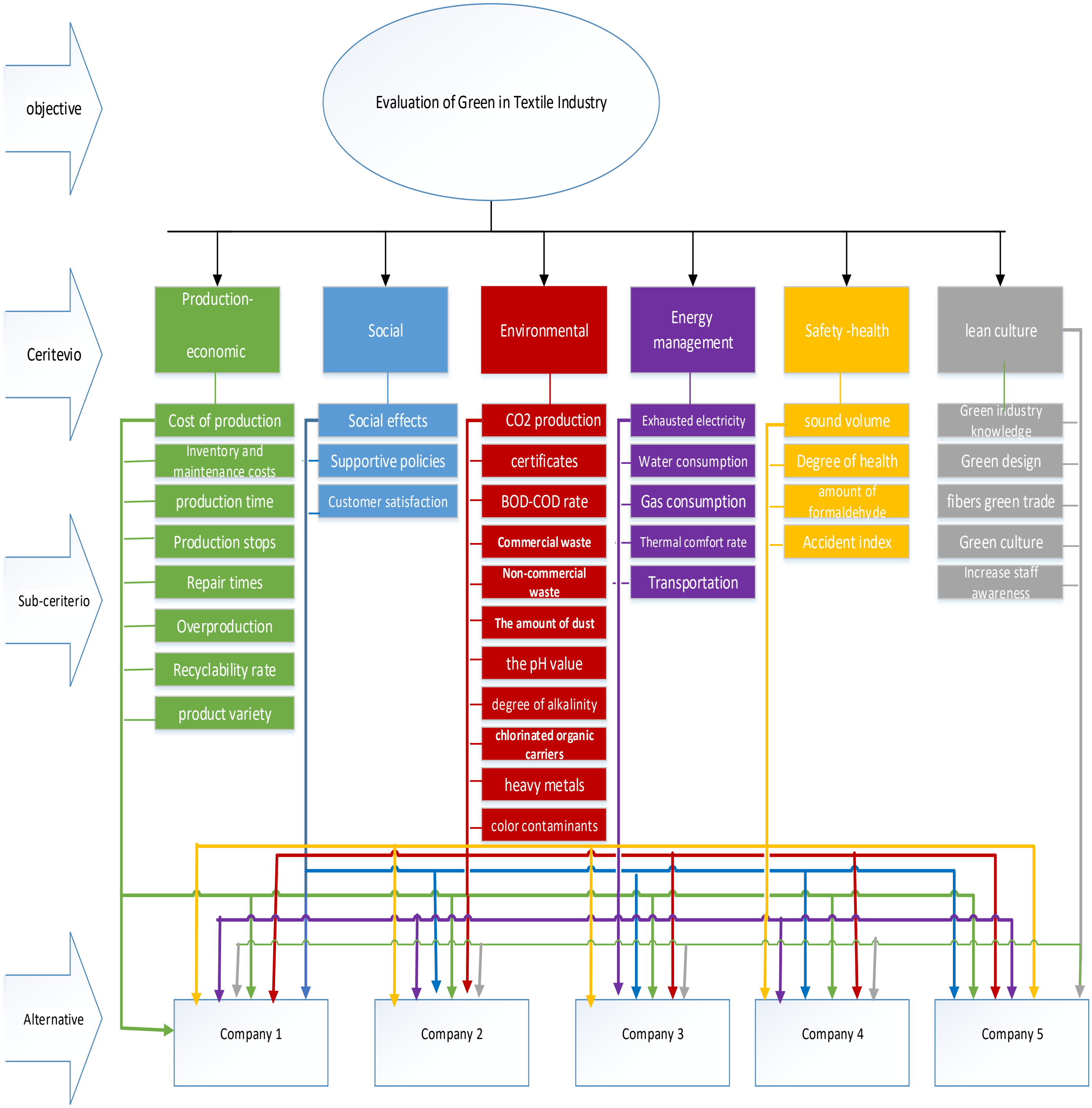

Figure 2: Decision Network

The decision tree is a concept that you can be used 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 lean green 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.

4.1 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).

Figure 3: Production of staple fibers (short, cut)

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).

Figure 4: Filament spinning

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).

Figure 5: Printing equipment

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).

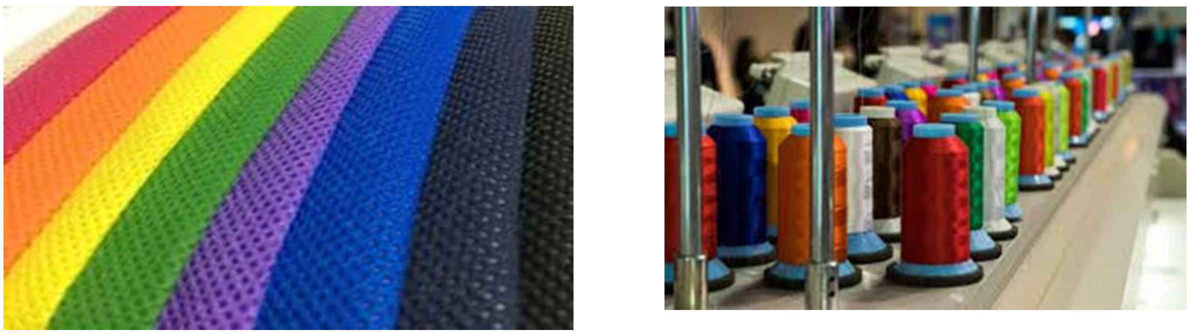

Figure 6: Textile Products, cloth, thread

4.2 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: 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 of having at least the rank of assistant professor with 4 years of experience and familiar with the subject of green lean and decision models.

4-3 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: 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	CO_2 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	

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 Wj column is the weight of the criteria. For example, for criterion "D" is calculated as follows:

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

$$q_D = \frac{q_{j-1}}{K_j} = \frac{q_C}{K_D} = \frac{(1{,}1{,}1)}{(1.742{,}1.952{,}2.241)} = (0.446{,}0.513{,}0.574)$$

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

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

Table 6: Weight of the main criteria

Criterion	Sj	Kj	qj	Fuzzy wj	Non Fuzzy wj
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

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

Table 7: Final weight of factors

Criterion	weight of Criterion	Sub-criteria	code	Relative weight of 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 and 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

In this section, the ranking chart of criteria and sub-criteria is illustrated in Figure 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 CO_2 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.

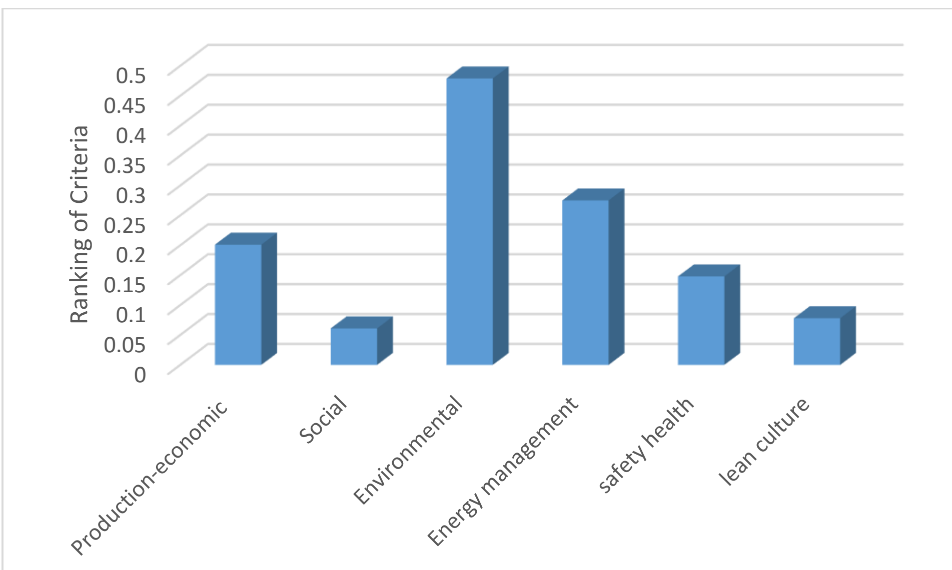

Figure 7: Ranking of criteria

As shown in Figure 8, 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 and machinery and raw materials used, as well as effluents that have different types of dyes, carriers and chemicals or the presence of noise pollution in the factory environment were closely monitored for the environment 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.

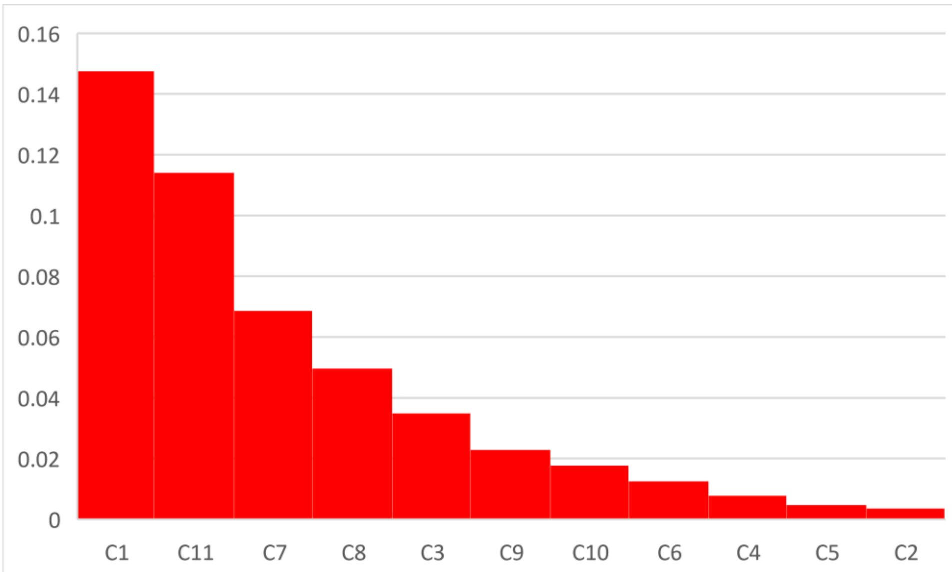

Figure 8: Comparison of the weight of environmental criteria

Figure 9 shows the amount of CO_2 due to the lack of proper filtration and also the use of old machines. Pigment contaminants in the dyeing and 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.

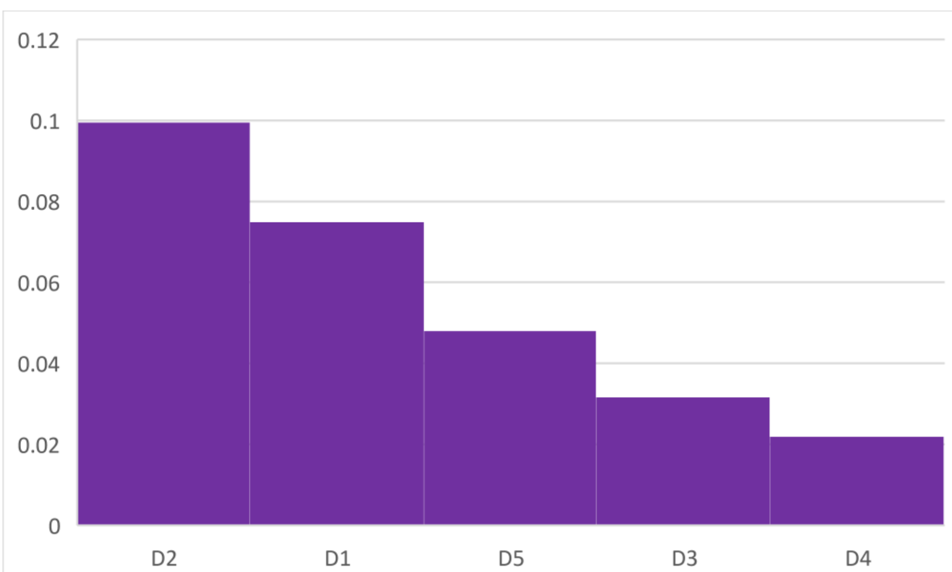

Figure 9: Comparison of the weight of energy management criteria sub-criteria

According to Figure 10, 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.

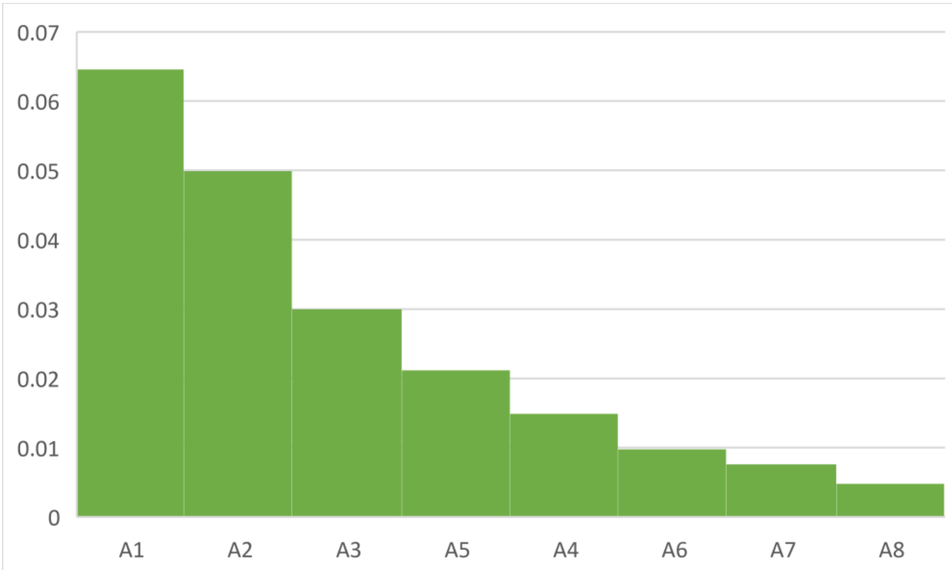

Figure 10: Comparison of the weight of production-economic criteria sub-criteria

As shown in Figure 11, 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.

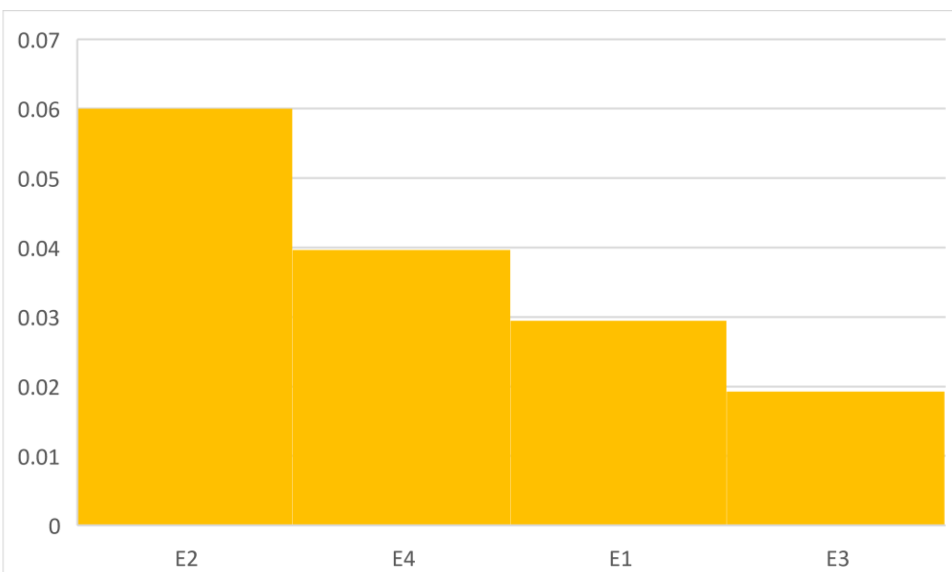

Figure 11: Weight of sub-criteria of safety and health criteria

According to Figure 12 in the safety and health criteria, considering the importance of the criterion of the degree of health of employees and also the accident index have the highest weight.

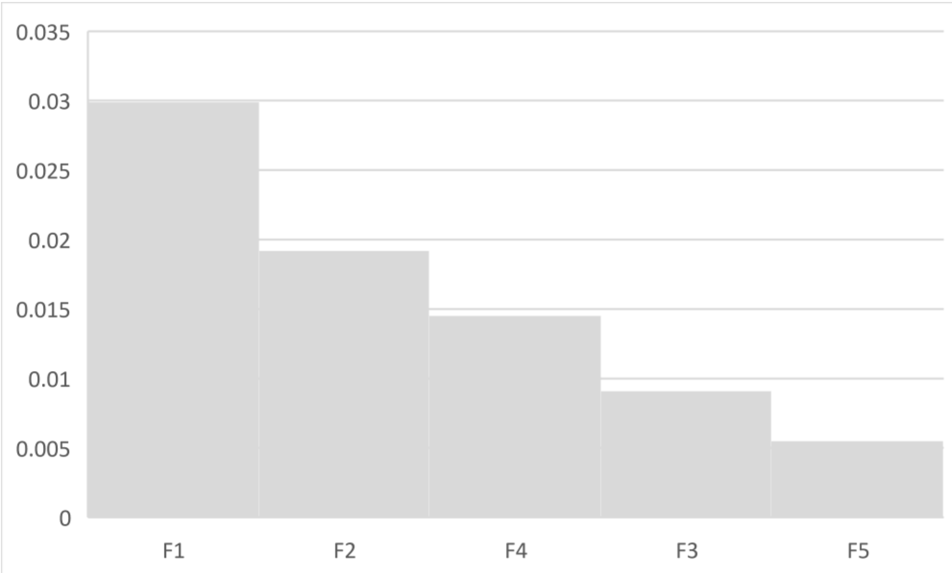

Figure 12: Comparison of the weights of the criteria of the culture of purification

As shown in Figure 13, green industry knowledge, green design and green culture have the most weight, because by paying attention and establishing and raising the level of awareness in these cases can help green production and environmental protection.

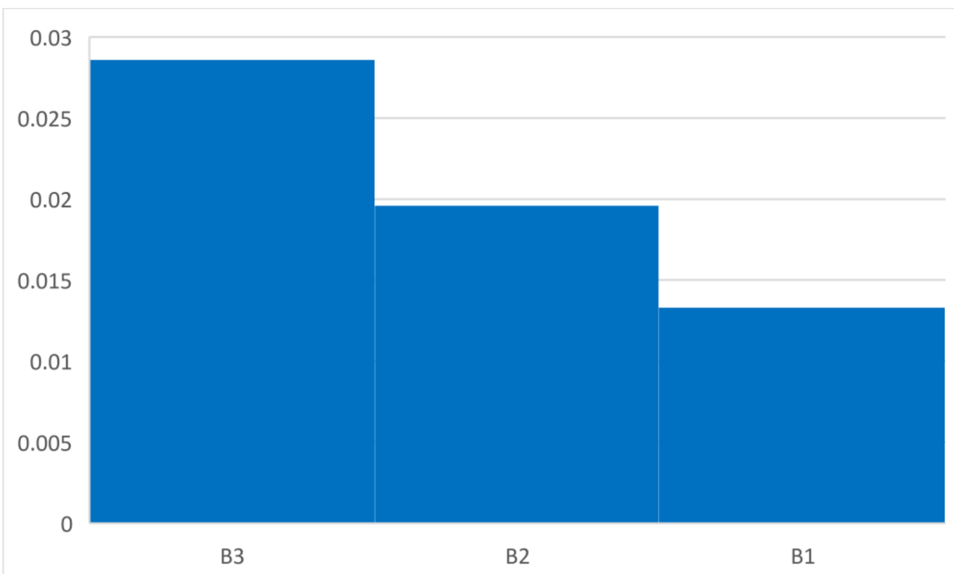

Figure 13: Comparison of the weight of social sub-criteria

Based on the results, 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 lean green production

4-4 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, then integrated 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.

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

	sj+	sj-	Qi	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 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.

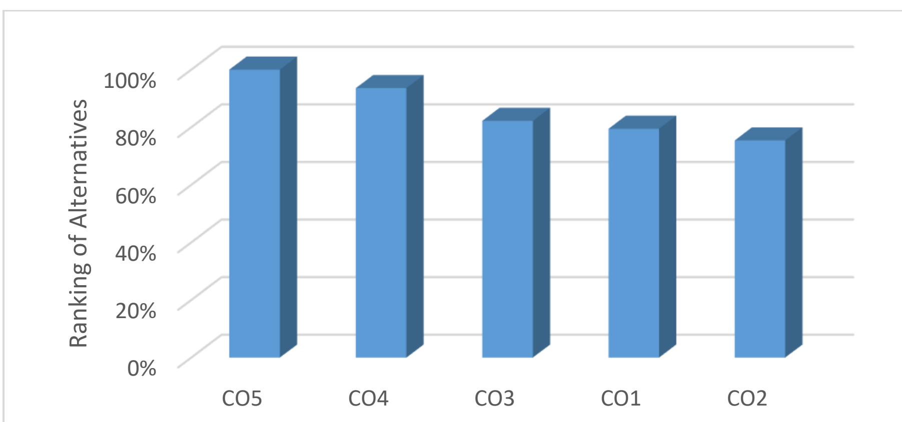

Figure 14: Ranking of Alternatives

4-5 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 are 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 lean green production will be a suitable and cost-effective production strategy.

5. Results and Benchmarking with other works

Because the weaving industry is one of the industries that cause environmental damage, therefore, by using and implementing lean green 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 Process Analytical Network (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 lean green 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 lean green production in the construction industry. In this study, the sub-criteria of 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 (Hormand.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 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 (Yucenur.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 were selected as 3 of the most important sub-criteria and then using the COPRAS method, the factories were ranked.

5-1 Conclusion

In this paper, using a multiple decision model for ranking and selecting criteria and sub-criteria, which is 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 were of great importance compared to other sub-criteria. Among the alternatives, factory number 5 ranked first in the rankings.

5-2 Suggestion for the further research

According to the study of green and lean indicators, these indicators can be used in other industries such as automotive, paint, petrochemical, etc., 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.

6 Declarations

6-1 Ethics approval and consent to participate

Not applicable

6-2 Consent for publication

Not applicable

6-3 Availability of data and materials

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

6-4 Competing interests

The authors declare that they have no competing interests

6-5 Funding

Not applicable

6-6 Authors' contributions

All authors contributed to the study. The conception and design were supported by Soroush Avakh Darestani, Manouchehr Omidvari and Mohammad Amin Adibi. Material preparation, data collection and analysis were performed by Shadi Vahabi Nejat. The first draft of the manuscript was written by Shadi Vahabi Nejat and Soroush Avakh Darestani. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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