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A Decision Support System for Sustainable Supplier Selection Problem: Evidence from a Radiator Manufacturing Industry

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Abstract:

Supplier selection is the basis of a successful supply chain. It is also a key factor in improving the competitiveness of an organization. Being a complex process, the supplier selection plays an important role in upgrading the supply chain. The purpose of this research is to present an integrated approach based on fuzzy best-worst method (BWM) and failure mode and effects analysis (FMEA) for sustainable supplier selection considering seasonal quantity discounts and supplier risk for a radiator manufacturing company. Therefore, as the aim implies, this study addresses how organizations develop a sustainable supplier selection framework by integrating linear programming and decision-making in presence of seasonal discounts. To this end, fuzzy BWM and FMEA were employed to calculate weighting factors for different selection criteria and evaluate the supplier risk, respectively. Then, suppliers were ranked using the so-called technique for order of preference by similarity to ideal solution (TOPSIS). Finally, the discount type was examined by the LP-metric method. Results of the fuzzy BWM showed that the customer satisfaction was the criterion of highest priority, followed by long-term relationship, and then pollution control, among the total of 13 criteria considered in this work. Outputs of the TOPSIS referred to the supplier 3 as the top-ranked supplier, followed by supplier 6 and then supplier 1.

Keywords: Sustainable Supplier, Supplier Risk, FMEA, Fuzzy Best worst method

1. Introduction

The field of supply chain management (SCM) and the process of supplier selection have long been discussed in the literature. Many factories and industry owners have been looking for ways to cooperate with suppliers to enhance their management and competitiveness on a global stage (Asgharnezhad and Avakh Darestani, 2021). Since the 1960s, acknowledging the suppliers' crucial role in fulfilling the supply chain goals, several researchers have worked on supplier evaluation, shortlisting, and monitoring based on different criteria including quality, delivery deadline, and cost. A green supply chain is a particular type of supply chain where environmental requirements are considered. For instance, on a green supply chain, used products are set to return to the chain after their useful life. Such an approach brings about advantages such as preserving energy resources, mitigating emissions, waste elimination or reduction, making value for customers, and finally, increasing productivity for companies and organizations who adopt such environment-oriented investment strategy (Abbaszadeh Tavasoli et al., 2017).

Appropriate supplier selection can reduce the cost of purchasing significantly while simply improving the organization's competitiveness, since the cost of raw materials and product components constitutes a large portion of the product cost in most industries. A recently regarded major issue in operations and production management, especially in high-tech environments, is the supplier evaluation and selection. Reducing the purchasing risk, optimizing the total purchase value, and establishing long-term relationships to suppliers are among the immediate goals of the supplier selection process, with a very significant role in helping the company fulfil timely production. The contribution of this work is the application of the fuzzy best-worst method (BWM), technique for order of preference by similarity to ideal solution (TOPSIS), and failure mode and effects analysis (FMEA) to develop a model of supplier selection in presence of seasonal discounts in a radiator manufacturing company.

The rest of this paper is organized into sections on literature review, research methodology, results and discussion, and finally the conclusions and recommendations.2 Literature Review

Starting at the 21st century, on big challenge that the mankind faces is to find a fair and sustainable way of producing, consuming, and living (Peattie and Charter, 1999). The responsibilities of organizations towards society and the environment have long been considered by public institutions, and these institutions have tried to institutionalize organizational responsibility by various means, especially in production companies that are harmful to the environment. As a prerequisite for profitability and sustainable growth in organizations, special attention is paid to these responsibilities in today’s world (Seuring and Muller, 2008). Focusing on environmental, economic, and social issues at all stages of product production, including the raw materials purchase, production, distribution and sale, is the main goal of sustainable supply chain management. Hence, one of the most important steps towards a sustainable supply chain is supplier selection (Kuo and Wang, 2010).

Since 1980s, company’s procurement processes have been changed from fundamental supplies and raw materials to a network of joint firms (Rahiminezhad Galankashi, 2016). In the last decade, how to determine the most suitable supplier has been considered as a strategic factor in the supply chain design. Now if important parameters such as paying attention to sustainable development is to be also important for the continuation of the activity, the selection will not be easy (Tahanian and Nilforooshan, 2016). In recent years, the concept of supply chains has grown significantly and sustainable development in the supply chain is not limited to emphasizing economic performance to optimize costs or return on investment, but in this regard, pay attention to the impact of various activities in the supply chain on social life and environmental issues are also necessary (Khatami Firoozabadi et al., 2015). As a new and very influential discussion, supply chain sustainability has attracted the researchers’ attention in the field of supply chain management. As one of the key actors of the supply chain, suppliers can play an important role in creating a sustainable supply chain. The supplier selection process can be considered as the starting point for the formation of the supply chain, during which the selection of appropriate criteria is very important (Ashrafi and Chaharsouqi, 2011).

The supplier selection has a major impact on the organization's strategic and operational performance. In addition, good suppliers can reduce production costs and inventory, quality, flexibility and thus meet customer expectations (Çebi and Otay, 2016). The supplier selection is a complex process and plays an important role in upgrading the supply chain (Arabsheybani et al., 2018).

The management of social and environmental issues in the supply chain has attracted significant attention in recent years. Hence, a rapid increase in the awareness of the modern industries has taken place on the supply chain. Because many companies are heavily polluting the environment which greatly affects companies to consider environmental issues in their activities. While the world's population is rising, and available resources are decreasing. Companies have concluded that their suppliers need to be redesigned. From the view of the companies, they must embody the image of products, processes, systems, and technology (Zailani et al., 2012). Recently, in a work by Vahabi Nejat et al. (2021), social, environmental and production economic were amongst main criteria for the lean green performance evaluation. A study was conducted by Agharnezhad and Avakh Darestani (2021) entitled a green supplier selection framework in polyethylene industry evidence from Iran. They applied Dempster–Shafer theory and grey relational analysis (GRA) to evaluate and select supplier in a green environment.

Sustainable Supply Chain

The concept of supply chain, introduced many years ago, refers to a set of organizations, individuals, technologies, activities, information, and other resources involved in the transfer of a product or service from supplier to customer. At the same time, we recognize the sustainable supply chain as a system of integrated business activities in the product life cycle that not only creates value for stakeholders, but also is concerned with improving people's health (Hussain, 2011). As the first priority and the main source of any supply chain, organizations should select their suppliers by carefully evaluating the success factors (Kannan, 2018). Sustainable supply chain management refers to considering environmental, economic, and social issues in the supply chain management process with the aim of increasing the long-term economic goals of companies and their supply chain (Al-Odeh and Smallwood, 2012). Recently, a study was conducted by Hatice Gokler and Boran (2023) focusing on resilient and sustainable supplier selection model based on D-AHP and DEMATEL methods. They developed a supplier selection model for an automobile manufacturing company in Turkey.

Accordingly, although supply chain and sustainability are different concepts, they are very closely related. The key differences between sustainable supply chain and traditional supply chain are shown in Table 1 (Hossein, 2011).

Table 1 Sustainable and traditional supply chain differences (Hussain, 2011)

Sustainable supply chain	Traditional supply chain
Considering economic, social, and environmental concepts along the supply chain	Emphasizing the supply of goods from supplier to final customer
Complexity of flow of materials due to combining the three above-mentioned indicators	Linear flow of materials and information
high level of cooperation	Limited partnership
Reverse logistics as an important part of the supply chain process	Lack of attention to reverse logistics in the process

Supplier Risk

The integrated decision-making process from the raw materials supply to the consumption of goods by end customers is called supply chain management. One of the most important decision-making parameters in relation to supply chain management is the selection and identification of a high-performance supplier, and several qualitative and quantitative factors are involved in this regard. The level of uncertainty and risk increases with the complexity of the supply chain.

Therefore, it has been studies in which supply chain risk management, especially risk assessment of suppliers by organizations were considered (Abdolmaleki et al., 2015). Suppliers face dangers such as natural disaster or political change. The issue of risk in most cases is not a sustainable supplier choice problem. Suppliers with acceptable performance in sustainability factors may face a variety of challenges (Arabsheybani et al., 2018). The supply chain is a complex process with various types of parameters that are exposed to various dangers and challenges. This risk can range from natural disasters and political changes to labor strikes and currency fluctuations. The risk issue is widespread in supplier selection with respect to five failures as follows: delivery risk, cost, quality, public trust and flexibility (Li and Zeng, 2016; Kull and Talluri, 2008).

Significant amount of research has been done on the selection process of suppliers, which each of them has focused on this issue in a specific way. The results of the study by Azadnia et al. (2012) show that among the 31 suppliers, 6 suppliers are related to the best cluster. These six suppliers are identified as the most appropriate sustainable suppliers in all suppliers. Molamohamadi et al. (2013) in a study, they chose the supplier in a sustainable supply chain. The results of their research showed that in addition to the usual criteria such as price and quality, sustainability focuses on the importance of the environment in industrial activities. Mani et al. (2014) found that electricity manufacturers, automotive and cement industries can choose suppliers based on the degree of social sustainability. Ozlem Gurel et al. (2015) investigated the determinants of green selection. The list of proposed criteria is defined with eight main criteria and thirty-one sub-criteria that include green and non- green criteria: cost, delivery, quality, service, strategic alliance, pollution control, green product and environmental management. Also, Bohner and Minner (2016) conducted a study about the supplier selection for the risk of failure, volume, and discount of the business cycle. They considered a supply chain problem by selecting a simultaneous supplier and assigning orders for multiple products. Given the previously published findings, they showed the potential for improvement and obtained optimal solutions. In another research conducted by (Rahiminezhad Galankashi, 2016), a mixed **balanced scorecard–fuzzy AHP** model was also developed for s**upplier selection in automobile industry.** Yazdani et al. (2017) conducted a study about integrated Quality Function Deployment- Multiple Criteria Decision Making (QFD-MCDM) framework for green supplier selection. Their research findings provide important insights related to various features that significantly contribute to the performance and efficiency of suppliers. Because inefficient suppliers can focus on those features to improve their performance. The results of research of Kumar et al. (2018) showed that among the criteria (cost, delivery capability, product quality, performance, reputation) and the five suppliers of product quality and third supplier were the most preferable. Also, Jafarzadeh Ghoushchi et al. (2018) done a study in field of evaluation and selection of sustainable suppliers in supply chain using new GP-DEA model with imprecise data. The results showed that using this model could motivate companies to move in the direction of economic, social and environmental activities and a sustainable supplier can boost supply chain performance. Arabsheybani et al. (2018) was conducted a study on an integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk. They used a fuzzy multipurpose optimization model using fuzzy MOORA to evaluate the overall performance of the supplier. The results of their research showed that using the proposed model not only increases overall profit, but also reduces the amount of risks to stick to sustainability. According to a study conducted in the context of one of fuzzy MOORA method and an integrated FMEA method for sustainable supplier selection, based on the number of discounts and supplier risk in 2018. They suggested that other types of discounts, such as seasonal and geographical discounts, could be used as future research and since no research has been done in this regard, this work proposes an integrated fuzzy best-worst method and FMEA technique for sustainable supplier selection considering seasonal quantity discount and supplier's risk. Another research work was conducted in the scope of construction industry regarding performance evaluation of suppliers through the Ordinal Priority Approach (OPA) which allows decision-makers to estimate the weights of the evaluation criteria, the suppliers (Mahmoudi and javed, 2022). Zaretalab et al. (2023) developed a multi-objective model for optimizing the redundancy allocation, component supplier selection and evaluation problem considering reliable activities for multi-state systems.

Recently, Tavakoli Haji Abadi and Avakh Darestani (2021) carried out a research work regarding sustainable supply chain risk and revealed that one of the most important issues in SCM is the risk management and sustainability. Social, environmental, economic, organizational, supply, distribution, production, and information technology issues are elements of sustainability and need careful attention by researchers and practitioners in food industry. In service sector, Sustainable Technology Supplier Selection in the, a study was conducted by Barrera et al. (2023). They employed Analytic Hierarchy Process (AHP), Multi-attribute utility theory (MAUT) and Preference ranking organization method for enrichment evaluation (PROMETHEE) for a suitable supplier selection. In this area, another work was conducted by Mohamed et al. (2023) using an Adapted Multi-Objective Genetic Algorithm supplier selection decision in healthcare industry. To best of our knowledge, there are not many research have been done in the area of sustainable supplier selection in radiator manufacturing industry. The main contribution of this research is to develop a hybrid framework for Sustainable Supplier Selection Problem considering FMEA, BWM and TOPSIS.

Therefore, the main research question (RQ) is: how to develop an integrated linear programing and decision-making framework to select a sustainable supplier in a seasonal discounted space considering seasonal discount?

3 Research Methodology

In the present study, beginning by a statement of the problem followed by a review of the relevant literature, the supplier selection criteria were identified accordingly. Afterwards, experts were asked to choose the most significant criteria. The criteria were then weighted by the fuzzy BWM. We then proceeded to identify the risk factors and design FMEA to obtain the supplier risk. Integrating the results of the fuzzy BWM and FMEA through multiplication, the so-called "discount risk" was estimated and used as a parameter in the objective function to build a discount model. Next, the suppliers were ranked by the TOPSIS and the corresponding range of discount by the suppliers was determined. Given the results of previous steps, a comprehensive model of three objectives and several constraints (e.g., demand, supplier capacity and budget) was developed. With this model, data from a case study was analyzed using the proposed model. Finally, conclusions and the future recommendations will be presented. These steps are shown in Figure 1.

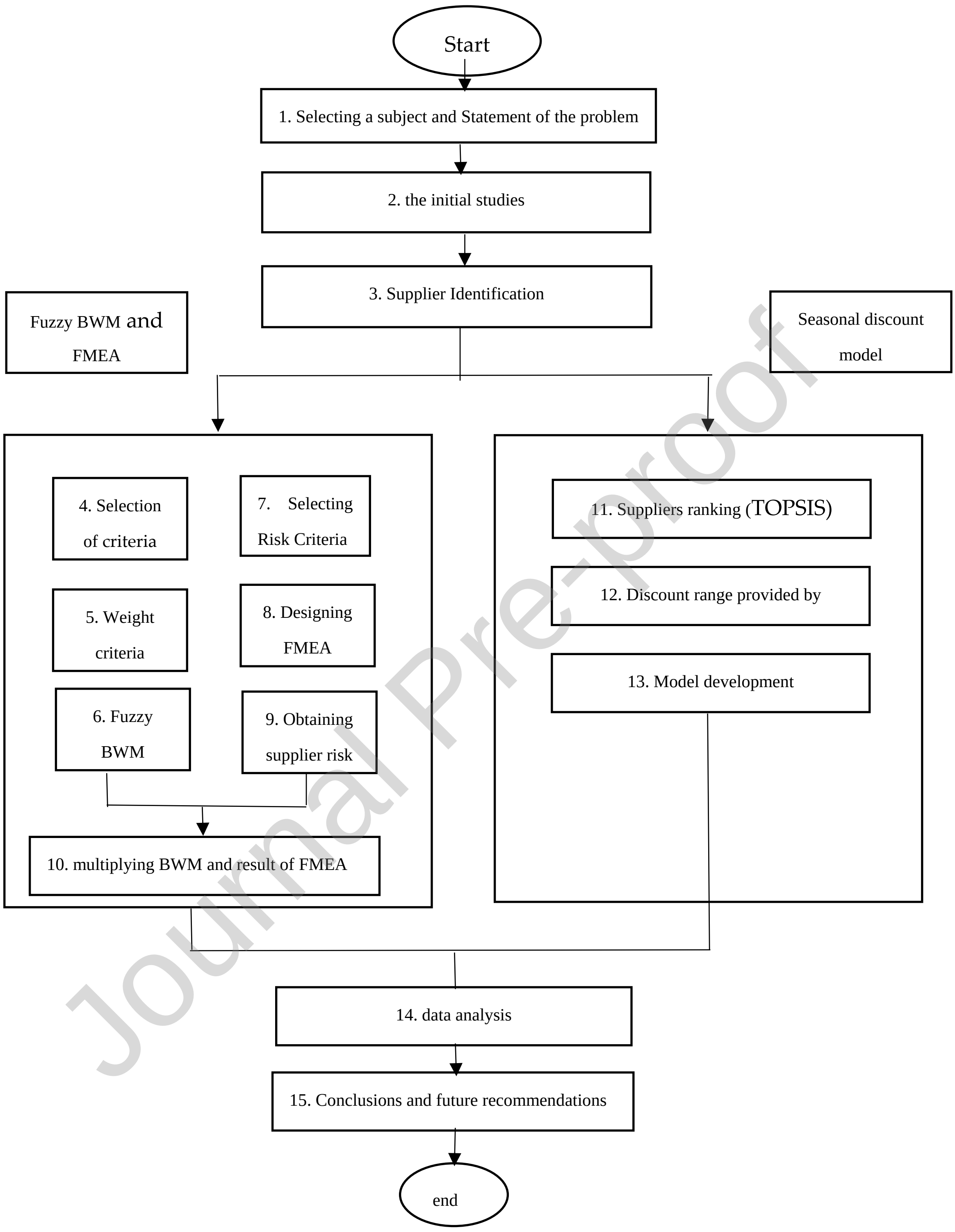

Fig.1 The Steps to conduct research

Research Variables

Numerous criteria have been used for supplier evaluation and selection, some of which were identified in the course of the research on sustainable supplier selection. In the present study, a total of 24 criteria were considered based on the literature review, as listed in Table 2.

Table 2 Review on research criteria (Step 2)

Row	Criteria	References
1	Social Responsibility	Arabsheybani et al. (2018)
2	Cost	Arabsheybani et al. (2018), Zhao and Guo (2014), Jafarzadeh Ghoushchi (2018), Kumar & et al. (2018), Ozlem Gurel et al. (2015), Azadnia et al. (2012), Safaei Ghadikalaei & et al. (2015), Poormohammad Sarabi and Avakh Darestani (2021)
3	Environmental Performance	Arabsheybani et al. (2018), Abbaszadeh Tavasoli et al. (2017),
4	Delivery	Arabsheybani et al. (2018), Ozlem Gurel et al. (2015), Azadnia et al. (2012), Yazdani et al. (2017), Kumar & et al. (2018), Safaei Ghadikalaei et al. (2015), Poormohammad Sarabi and Avakh Darestani (2021)
5	Green design	Arabsheybani et al. (2018), Jafarzadeh Ghoushchi et al. (2018), Mirghafouri et al. (2014)
6	Environmental Management System (EMS)	Arabsheybani et al. (2018), Ozlem Gurel et al. (2015), Azadnia et al. (2012), Jafarzadeh Ghoushchi et al. (2018), Abbaszadeh Tavasoli et al. (2017), Safaei Ghadikalaei et al. (2015)
7	Financial performance	Arabsheybani et al. (2018), Jafarzadeh Ghoushchi et al. (2018)
8	Flexibility	Arabsheybani et al. (2018), Zhao and Guo (2014), Jafarzadeh Ghoushchi et al. (2018), Poormohammad Sarabi and Avakh Darestani (2021)
9	Green Vision	Arabsheybani et al. (2018), Asgharnezhad and Avakh Darestani (2022)
10	Quality	Arabsheybani et al. (2018), Jafarzadeh Ghoushchi et al. (2018), Yazdani et al. (2017), Kumar et al. (2018), Ozlem Gurel et al. (2015), Azadnia et al. (2012), Abbaszadeh Tavasoli et al. (2017), Babaei et al. (2017), Tahanian and Nilforooshan (2016), Safaei Ghadikalaei et al. (2015)

11	Selling Price	Arabsheybani et al. (2018), Ozlem Gurel et al. (2015), Yazdani et al. (2017), Rezaei (2015), Jafarzadeh Ghoushchi et al. (2018), Tahanian and Nilforooshan (2016)
12	Service level	Arabsheybani et al. (2018),
13	Technology	Arabsheybani et al. (2018), Jafarzadeh Ghoushchi et al. (2018), Babaei et al. (2017)
14	warranty cost	Babaei et al. (2017)
15	Long-Term Relationships	Ozlem Gurel et al. (2015), Safaei Ghadikalaei et al. (2015), Babaei et al. (2017)
16	Green Product	Ozlem Gurel et al. (2015), Azadnia et al. (2012), Haji Yakhchali et al.. (2017), Jafarzadeh Ghoushchi et al. (2018), Safaei Ghadikalaei et al. (2015)
17	Hazardous materials management	Haji Yakhchali et al. (2017)
18	Pollution Control	Ozlem Gurel et al. (2015), Azadnia et al. (2012), Jafarzadeh Ghoushchi et al. (2018), Safaei Ghadikalaei et al. (2015), Haji Yakhchali et al. (2017)
19	Green Innovativeness	Jafarzadeh Ghoushchi et al. (2018), Haji Yakhchali et al. (2017)
20	Training	Jafarzadeh Ghoushchi et al. (2018)
21	Customer Satisfaction	Safaei Ghadikalaei et al. (2015), Rezaei (2015)
22	Green production	Mirghafouri et al. (2014)
23	Reputation	Kumar & et al. (2018), Jafarzadeh Ghoushchi et al. (2018), Yazdani et al. (2017), Rezaei (2015)
24	Transportation Cost	Ozlem Gurel et al. (2015), Jafarzadeh Ghoushchi et al. (2018), Mirghafouri et al. (2014)

Method of Data Collection

In this study, the required data was collected through field surveys and library studies. The library studies refer to the literature review while the field survey was accomplished by asking experts to complete a questionnaire. The questionnaire was designed based on opinions of industry experts, relevant academics and managers. Reliability of the questionnaires was confirmed by calculating its Cronbach's alpha (0.86) in SPSS software. Content validity analysis was further done to validate the questionnaire.

Considering the crucial role of the participating experts in the quality and reliability of the results, one should opt for well-experienced and knowledgeable individuals in the same field of science/industry. The inclusion criteria for expert selection should be consistent with the research subject and the examined model. These include relevancy of the field of higher educations, possession of related experiences, authorship (or translation) of a relevant book, authorship of relevant scientific papers, and relevance of the field of work. After designing a draft questionnaire, it was presented to several experts to receive their comments and modify the questionnaire accordingly.

For the sake of this study, a total of eight suppliers and experts working with the studied radiator manufacturer were selected as qualified to complete the questionnaire and proceed to an interview. The optimal size of an FMEA team has been said to range from 4 to 6 (Omidvar and Niroomand, 2016). The main criterion for expert selection was his/her deal of experience in this field (> 18 years) followed by knowledge of safety and risk assessment. On this basis, we ended up with four active individuals. Various methods have been used to determine the sample size in research works. Saaty (2002) believed that 10 experts are sufficient for studies based on pairwise comparisons (Saaty, 2002). In this study, as a multi-criterion decision making (MCDM) method, BWM was used to determine the sample size by comparing the criteria at each level with the best and worst criteria at other levels. the radiator manufacturing company is one of the largest producer of aluminums radiators, wall radiator packages, and domestic and industrial burners in the Middle East. (Figure 2).

Informed consent was not required for this study because all data, information, results are anonymously mentioned in this work. Review and/or approval by an ethics committee was not needed for this study because to sake the of confidentially, the case study and participants and committees are anonymously reported in this work.

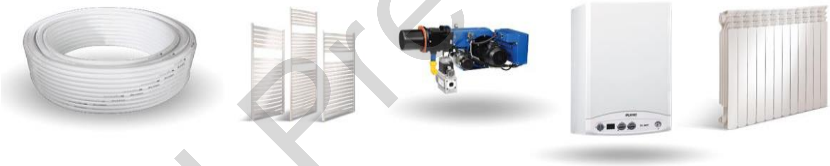

Fig.2 Some Iranian Radiator Products

4. Analysis and results

In this research, a combination of FMEA, fuzzy BWM, discount risk method, entropy technique, and TOPSIS were devised to develop the research model.

MCDM implies that a proper decision can be made through a sequence of stages, including statement of the goals, identification of possible solutions, evaluation of the feasibility, consequences, and outputs of different solutions, and thus selecting the most appropriate alternative solution. Quality management is essentially a function of decision quality. Indeed, it has been well established that the quality of the plans, the effectiveness and efficiency of the strategies, and the goodness of the final results are all driven by the quality of decisions made by the manager. In most cases, proper decisions can be made when multiple criteria, rather than a single criterion, are considered. Such criteria may be quantitative or qualitative. In the recent approaches to MCDM, multiple measures are used instead of a single measure of optimization (Asgharpour, 2013). Two categories of MCDM have been distinguished, namely multi-objective decision making (MODM) and multi-attribute decision making (MADM). The MODM applies to problems where the decision maker seeks to determine the best combination of a set of activities/parameters to realize multiple goals. The MADM, on the other hand, focuses on particular indicators, rather than the ultimate goal(s), and ranks different alternative solutions by their contribution to the indicators (i.e., attributes). Among numerous MADM models proposed so far, simple additive weighted (SAW), elimination and choice translating reality (ELECTERE), analytical hierarchy process (AHP), and TOPSIS are the most well-known alternatives (Asgharpour, 2013).

FMEA Technique (Step 8)

The FMEA is considered as a risk assessment tool that is designed to reduce potential failures in systems, processes, designs, or services (Mirzaei and Avakh Darestani, 2016). The failure modes analysis represents a MCDM process that takes into account qualitative and quantitative criteria that may not be mutually exclusive, thereby complicating the decision-making process (Mirzaei et al., 2014). FMEA seeks to identify the flaw that may occur in the final product, system, service, or designed machinery. After identifying the defects, the FMEA looks for ways to diagnose and fix these defects and documents them properly to make them usable for future references. The FMEA is an analytical technique based on the "primordial prevention" principle for identifying potential failure factors. The focus of this technique is to increase the safety factor and, ultimately, customer satisfaction through the prevention of failure occurrence. FMEA is a tool that uses the least risk to predict problems and deficiencies in the design or development of processes and services in an organization (Dabiri et al., 2002).

FUZZY BWM (Step 6)

Presented by Rezaei (2015, 2016), the BWM is an MCDM method. Although this model was first proposed in a crisp environment, Guo and Zhao (2017) examined the BWM in a fuzzy environment and provided some examples. Application of fuzzy numbers in the fuzzy BWM captures possible ambiguities in the respondent's expressions. Different steps of fuzzy BWM are explained in the following:

1. Determining the best and worst criteria (i.e., the most and the least important criteria, respectively). This can be done based on expert judgments or the fuzzy Delphi method.

2. Pairwise comparison of the best criterion with other criteria and other criteria with the worst criterion. At this step, pairwise comparison can be done from any fuzzy spectrum, although the following five-phase fuzzy spectrum is the most common choice for fuzzy BWM: equally important, weakly important, relatively important, very important, and absolutely important.

3. Creating a fuzzy BWM model. At this step, weight factors are calculated using a nonlinear programming model. Zhou et al. (2017) recommended more than 3 criteria. To achieve better results, this nonlinear model is converted to a linear programming model.

4. Solving the model. Weights of different criteria are obtained by solving the created model.

TOPSIS Model (Step 11)

Presented by Hwang and Yoon (1981), TOPSIS is among the best and most popular MCDM models. In TOPSIS, m options are evaluated with n indices, with the core assumption being that the alternative option should be the nearest to the positive ideal solution (i.e., best possible case) and the farthest to the negative ideal solution (i.e., worst possible case). Thus, the utility of each index exhibits a uniformly upward or downward trend (Momeni, 2013).

With an ideal solution, the profit increases and the cost decreases. Thus, a desirable alternative must be at the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. In TOPSIS, the more the similarity of an alternative solution to the ideal solution, the higher its rank among other alternative solutions. In using the TOPSIS method in particular, the alternative with the most similarity to the ideal solution ranks higher. TOPSIS formulas are given below:

Step One: Formulate the data matrix based on m alternative and n index:

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

Step two: Standardize data and standard matrix formation by Equation 1:

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{1}$$

Step Three: Determine the weight of each indicator based on $\sum_{i=1}^{n} w_i = 1$

In this regard, the most important indicators are of higher weight. In fact, the matrix (v) is the product of the standard values of each index in its respective weights.

Step Four: Determine the distance alternative i^th from the ideal alternative (the highest performance of any index) that is indicated by A^*.

$$A^* = \left\{\left(\max_i v_{ij} \middle| j \in J\right), \left(\min_i v_{ij} \middle| j \in J'\right)\right\} \tag{2}$$

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\}$$

Step Five: Determine the minimum alternative i^th (the lowest performance of any index) that denotes by (A^-).

$$A^* = \left\{\left(\min_i v_{ij} \middle| j \in J\right), \left(\max_i v_{ij} \middle| j \in J'\right)\right\} \tag{3}$$

$$A^* = \{v_1^-. v_2^-. \ldots. v_n^-\}$$

Step Six: Determine the distance criterion for ideal alternative (S_i^*) and minimum alternative (S_i^-):

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2} \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \tag{5}$$

Step Seven: Determine a coefficient equal to the minimum alternative distance, divided by the sum of the minimum alternative distance S_i^-, and the ideal alternative distance S_i^* that is represented by C_i^* and calculated from the following Equation.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{6}$$

Step Eight: Ranking alternatives by quantity C_i^*

The above value fluctuates between $0 \leq C_i^* \leq 1$. In this regard, $C_i^* = 1$ represents the highest ranking and $C_i^* = 0$ is the lowest rank (Rahmati and Avakh Darestani, 2022).

Figure 4 shows the target space between the two criteria in the form of an example; A + and A- represents the ideal positive solution and the negative ideal solution, respectively. the option A1 has less distance from the positive ideal solution and more distance from the negative ideal than A2 (Habibi et al., 2013).

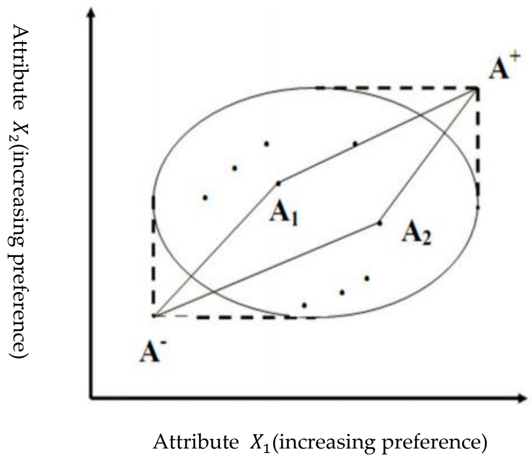

Fig. 4 Targeted space between two criteria (Balioti et al.., 2018)

The integration of FMEA and Fuzzy BWM is obtained by Equation (1) which is used to rank suppliers. It should be noted that the fuzzy BWM represents a desirable aspect and shows the risk factor of the negative points for each supplier. Therefore, the direct factor is not logical. Therefore, Equation (1) is used to integrate result of the fuzzy BWM and FMEA (Arabsheybani et al., 2018).

$$\text{Risk discount} = \text{risk} * (1 - \text{fuzzy BWM}) \quad (1)$$

Entropy Method

A very important concept in the field of theoretical approaches to information that is used in social sciences, physics and information theory is Shannon-entropy. The entropy method is used to evaluate weights when the data of a decision matrix are fully specified. In this method, more scatter in the values of an index indicates the greater importance of that index.

In information theory, entropy represents a level of uncertainty stated with distinct probability.

Research Model (Step 13)

The model presented in this study is a three-objective model with constraints such as demand, supplier capacity and budget. In order to explain the structure of the model, it is necessary first to express the assumptions, indicators, parameters and variables of the model decision.

Model parameters and indicators The model presented in this study is modeled according to the indicators described in Table (3).

Table 3 Indicators of model

Index	Index Explanation
t	Index of the time period t=1,2,…,T
i	Index of supplier i=1,2,…, n
j	Index of the discount range j=1,2,…, m(t,i)

The problem parameters used in the model are described in Table 4:

Table 4 Model Parameters

Parameters	An explanation for each parameter
p_{tij}	Price presented from supplier i in discount level j in time period t
k_{ti}(%)	Percentage of service quality presented from supplier i in time period t
r_{ti}(%)	Percentage of product quality from supplier i in time period t
D_t	Required amount of product demand in time period t
C_{ti}	Maximum amount of product that can be provided by supplier i time period t
b_{tij}	level of Price j of supplier i for the product in time period t
B_t	Budget allocated to the product in time period t
y_{tisj}	1= if for the product in discount range j of supplier i is selected in period t 0= if for the product in discount range j of supplier i isn't selected in period t
W_{ti}	Weight of supplier i to supply the product in time period t
m (t,i)	The numbers of discount presented of supplier i for the product in time period t

The decision variable of the problem is:

x_{tij}: the number purchased by the supplier i for the product at the discount level j in time period t.

The purpose of this section is to present the structure of the objective functions in the multi-objective supplier selection problem with multiple periods, taking into account the general discount.

Objectives functions: minimizing the total cost, maximizing the quality, including the quality of service provided by the suppliers and the quality of the products provided by the suppliers, and maximizing the purchases of the suppliers with the highest weight that each of them will be described.

The price and cost are the most important factors in buying goods and in a supplier selection. Given that, every buyer wants to reduce costs if it is possible. For many researchers, the price factor is the most important criterion in the purchase issue. In this research, the first objective function of the model addresses this issue.

In Equation (2), the cost function is presented. In this regard, the purchase cost is modeled according to the general discount.

$$\text{Min } Z_1 = \sum_{t=1}^{T}\sum_{i=1}^{n}\sum_{j=1}^{m(t,i)} p_{tij}\, x_{tij} \tag{2}$$

Where the maximum of a variable in time period t from the supplier i at different discount levels can be positive and the remaining values should be zero, and it assume that:

$$p_{tis1} > p_{tis2} > \cdots > p_{tism}\ (t.i.s)$$

Maximizing the quality: this objective function implies that the buyer wants to buy suppliers to maximize the overall quality level based on the percentage of service quality levels and product quality levels provided by the suppliers at any given time. The services provided by the suppliers includes the after-sales service, the good deal, and so on.

This goal is shown in Equation 3; In this Equation, the first part represents the level of quality of services and the second part represents the level of quality of product. To solve this Equation, the service quality level and the product quality level offered by each supplier for the product are multiplied by the total number purchased from that product, in each time period, while all discount levels are the same.

$$\boldsymbol{Max\ Z_2 = \sum_{t=1}^{T}\sum_{i=1}^{n} k_{ti} \sum_{j=1}^{m(t.i)} x_{tij} + \sum_{t=1}^{T}\sum_{i=1}^{n} r_{ti} \sum_{j=1}^{m\,(t.i)} x_{tij}} \tag{3}$$

Maximizing purchases from suppliers with the highest weight: considering the weight obtained from the suppliers, using TOPSIS method in the previous step, the intention is to provide the suppliers with the highest purchasing weight. For this purpose, the Equation is as follows (Equation 4):

$$\boldsymbol{Max\ Z_3 = \sum_{t=1}^{T}\sum_{i=1}^{n} W_{ti} \sum_{j=1}^{m(t.i)} x_{tij}} \tag{4}$$

Constraints: there are always real-world constraints for the buyer and the suppliers that need to be met. In fact, the constraints of the problem create the solution space.

The buyer requires at least a certain number of products in each period. Equation (5) represents this constraint, so that the total number of products purchased in each period from all suppliers at all discount levels should be greater than the demand for that product in that period.

$$\boldsymbol{\sum_{i=1}^{n}\sum_{j=1}^{m(t.i)} x_{tij} \geq D_t \quad \forall t} \tag{5}$$

Capacity Constraints: this constraint is presented in the form of Equation (6). This constraint indicates that each supplier has a production capacity for each product at any given time period, which if necessary, the buyer must do a purchase less than or equal to that amount from the supplier given the supplier's production capacity.

$$\boldsymbol{\sum_{j=1}^{m(t.i.s)} x_{tij} \leq C_{ti} \quad \forall t.i} \tag{6}$$

Discount Constraint: in the proposed model, by considering the discounts on the cost of purchasing, discount constraint should also be considered. These constraints are presented as Equations (7), (8) and (9).

Equation (7) states that if time period t supplier i buys at the discount level j, then the binary variable of that period and the same supplier and level of discount is 1 and otherwise, in the lack of a purchase in period t from the supplier $\boldsymbol{i}$, at the level of discount j, the binary variable will be zeroed.

$$y_{tij}\begin{cases}=0 & if \quad x_{tij}=0\\ =1 & if \quad x_{tij}>0\end{cases} \quad \forall t.i.j \tag{7}$$

If binary variable become 1, the discount constraint provided in Equation (8) is checked to ensure that the amount purchased in time period t from supplier t at level of discount apply or no and if it is true, the purchase at that discount level will be bought.

$$b_{tij}y_{tij} \le x_{tij} < b_{tij+1}y_{tij} \quad \forall t.i.j \tag{8}$$

As it should be purchased only a maximum of one level of discounts from each supplier at a certain time period, Equation (9) will guarantee this. Considering this constraint is allowed that maximum one of the values in period t for supplier *i* become 1. In other words, if it buys from a supplier *i* in time period t just one of its discount levels.

$$\sum_{j=1}^{m(t,i)} y_{tij} \le 1 \quad \forall\ t,i \tag{9}$$

Budget Constraints: buyers always allocate a high portion of the overall budget to buy a product in each time period and are willing to purchase so that the total cost of the product in that period is less than or equal to the budget allocated by the buyer for that product during the period by Equation (10).

$$\sum_{i=1}^{n}\sum_{j=1}^{m\,(t.i)} p_{tij}x_{tij} \le B_t \quad \forall t \tag{10}$$

Lp-Metric: the Lp-Metric method is used to integrate the objective functions. This method seeks to minimize the deviations of the objective functions from their optimal value. In this method, first, the individual answers are calculated for the optimality of each objective function, then the objective function is minimized by Equation (11).

$$Minimize\ \left(\sum_{k=1}^{q}\left[w_k\left|\frac{f_k^*-f_k(x)}{f_k^*}\right|^P\right]\right)^{\frac{1}{P}} \tag{11}$$

Subject to:

$$X_\propto, X_\propto=\{x/g(x)\le b_h\ ,h=1,2,\ldots,g\}$$

Which indicates the degree of importance (weight) for the objective i. The parameter 1≤p<∞ specifies the Lp family. The p value specifies the degree of emphasis on the deviations, so that the larger the p will be the greater the emphasis on the largest deviation (Kamali Ardakani et al.., 2009). Usually p = 1, p = 2, and p = ∞ are used in calculations which is considered the same importance for all deviations. p = 2 indicates that each of the deviations has a weight proportional to itself, the largest deviation allocates the highest weight to itself. When p moves to infinity that the largest deviation represents the distance. In fact, for the value of, this method is converted to the Min-Max approach if the variable is defined by Equation (12).

$$\lambda = Maximize\left(\sum_{k=1}^{q}\left[\omega_k\left|\frac{f_k^*-f_k(x)}{f_k^*}\right|\right]\right) \tag{12}$$

The multi-objective model is written as a single-objective model by Equation (13):

$$\text{MinZ} = \boldsymbol{\lambda}$$

Subject to:

$$\boldsymbol{\lambda} \geq \boldsymbol{W_1}\left|\frac{\boldsymbol{Z_1} - \boldsymbol{Z_1^*}}{\boldsymbol{Z_1^*}}\right|$$

$$\boldsymbol{\lambda} \geq \boldsymbol{W_2}\left|\frac{\boldsymbol{Z_2} - \boldsymbol{Z_2^*}}{\boldsymbol{Z_2^*}}\right|$$

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$$\boldsymbol{\lambda} \geq \boldsymbol{W_q}\left|\frac{\boldsymbol{Z_q} - \boldsymbol{Z_q^*}}{\boldsymbol{Z_q^*}}\right|$$

$$X_\propto, X_\propto = \{x / g(x) \leq b_h, h = 1,2,\ldots,g\} \qquad (13)$$

$\boldsymbol{P} = \infty$ has been used in this research

Model implementation: at this step, implementation of the model presented in the radiator producer company is addressed. The implementation steps are described in more detail below.

CVR Calculations: as a method for assessing variation, the CVR index was first introduced by Lawshem (Avakh Darestani and Hojjat Shamami, 2019). The experts' opinions are collected to calculate this index, and each question is based on a three-part Likert scale based on the test objectives and providing operational definitions of the questions: "Item is essential", "Item is useful but not essential" and Item is not essential at all". Then, Equation (14) is used to calculate the content validity ratio:

$$\text{CVR} = \frac{\boldsymbol{n_e} - \frac{\boldsymbol{N}}{2}}{\frac{\boldsymbol{N}}{2}} \qquad (14)$$

N: Total number of experts

$\boldsymbol{n_e}$: the number of experts who selected the necessary alternative. The minimum acceptable amount of CVR, based on the number of experts who evaluated the questions, should be in accordance with Table (5). Questions with the amount of CVR less than the desired amount due to the number of evaluators, should be excluded from the test because of not having acceptable content validity based on CVR Index (Habibi et al., 2013).

Table 5 The minimum acceptable CVR based on the Number of Graduate Experts

Number of Experts	Value of CVR	Number of Experts	Value of CVR	Number of Experts	Value of CVR
5	0.99	11	0.59	25	0.37
6	0.99	12	0.56	30	0.33
7	0.99	13	0.54	35	0.31

8	0.75	14	0.51	40	0.29
9	0.78	15	0.49		
10	0.62	20	0.42		

After extraction of variables from previous research, the amount of CVR acceptable for 8 of experts is 0.75. Output criteria with this value are shown in Table (6).

Table 6 acceptable criteria after calculation of CVR

row	Criteria	
1	Economic	Cost
2		Quality
3		Selling Price
4		Delivery
5		Warranty Cost
6		Technology
7	Environmental	Green design
8		EMS
9		Green production
10		Pollution Control
11	Social	Customer Satisfaction
12		Reputation
13		Long-Term Relationships

The fuzzy BWM is used to calculate the weight and importance of research criteria. To determine the most important (best) and least important (worst) criteria is the first step in this method. According to the experts' opinion, the criterion on customer satisfaction was chosen as the most important and the criterion of the environmental management system was the least important criterion. Then the pair comparisons of best criteria to other criteria (BO) and other criteria to worst criteria is done and so the nonlinear optimization model of the problem will be created. But Guo and Zhao (2017) stated that in models with three criteria or more, it is better the model be linear. The linear model of the problem was solved in software of Lingo 9 and the results are presented in Table (7).

Table 7 The weight and the final ranking of the criteria

Criterion	Fuzzy weight	Definitive weight	Ranking
Cost	(0.04,0.04,0.053)	0.042	9

Delivery	(0.046, 0.046, 0.047)	0.046	8
Green design	(0.055,0.055, 0.104)	0.063	4
EMS	(0.03, 0.033,0.046)	0.035	13
Quality	(0.04,0.04,0.053)	0.042	9
selling price	(0.036, 0.036, 0.046)	0.038	11
Technology	(0.046, 0.053, 0.063)	0.054	7
warranty cost	(0.055, 0.055, 0.104)	0.063	4
long-term relationships	(0.113, 0.113, 0.173)	0.123	2
Pollution Control	(0.067, 0.067, 0.084)	0.070	3
customer satisfaction	(0.325, 0.325, 0.325)	0.325	1
Green production	(0.055, 0.055, 0.104)	0.063	4
Reputation	(0.035, 0.035, 0.037)	0.035	12
Consistency Ratio= 0.015			

According to Table (7), the weight of the main criteria is calculated. The fuzzy weight is directly derived from the model solving in the Lingo software. Then these fuzzy weights are converted to definite weight by Equation $\boldsymbol{R}(\tilde{\boldsymbol{a}}_i) = \frac{l_i+4m_i+u_i}{6}$. The results are as follows that the criterion of customer satisfaction with the weight of 0.325 has gained the first priority among 13 criteria (Figure 5).

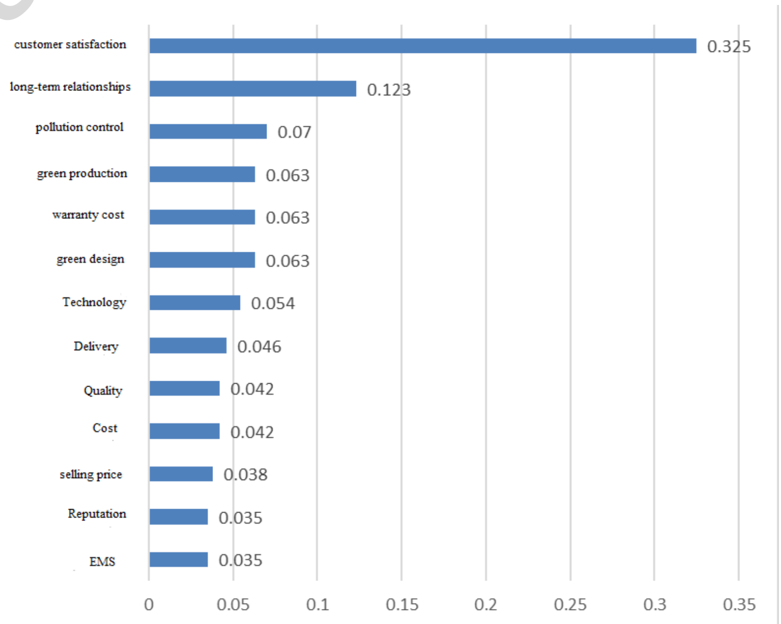

Fig. 5 The weight and the final ranking of the criteria

FMEA calculations: in this section, supplier risk is obtained using the FMEA technique. RPN calculations are shown in Table (8).

Table 8 RPN Calculation of FMEA

Risk of Failure modes	Severity (s)	Occurrence (O)	Detection (D)	L=S*O	ep=-0.1*D+1.55	R=$\left(\frac{(L-1)}{99}\right)^{ep} * \mathbf{100}$
Cost	1	8.06	1.05	10	5	10
Delivery	1	3.92	1.45	10	2	10
Green design	1	0	1.45	1	1	1
EMS	5	3.44	1.05	25	5	5
Quality	2	3.64	1.25	8	3	4
Selling Price	6	30.24	1.15	36	4	6
Technology	2	6.41	1.25	12	3	6
Warranty Cost	5	17.67	1.05	20	5	4
Long-Term Relationships	4	12.40	0.95	12	6	3
Pollution Control	3	3.22	1.15	6	4	2
Customer Satisfaction	7	64.34	0.75	56	8	8
Green production	2	3.64	1.25	8	3	4
Reputation	1	0	1.45	1	1	1

Finally, the integration of FMEA and fuzzy BWM is obtained by Equation (14).

$$\text{Risk discount} = \text{risk} * (1 - \text{fuzzy BWM}) \quad (14)$$

According to expert opinion, the relevant risk measures for current case study are customer satisfaction, selling price, warranty cost, and long-term relationships. The calculation of discount risk is shown in Table (9).

Table 9 Discount risk

Discount risk	Result
Discount risk of customer satisfaction	43.42
Discount risk of selling price	29.09
Discount risk of warranty cost	16.55
Discount risk of long-term relationships	10.87

The results of this method are called values of "discount risk" and used as a parameter in the objective function.

3.5.3 Results of TOPSIS calculation

The weights in the decision matrix are obtained from the Shannon entropy method. The closeness to the positive and negative ideal solution was also calculated by ranking the alternatives which is shown in Table (10).

Table 10 Closeness to the positive and negative ideal solution as well as the ranking of alternatives

Result		Closeness Coefficient
1	Supplier 3	0.745527
2	Supplier 6	0.653849
3	Supplier 1	0.53882
4	Supplier 7	0.523506
5	Supplier 5	0.51984
6	Supplier 8	0.515239
7	Supplier 4	0.460671
8	Supplier 2	0.432038

According to the results obtained, the comparison chart of the alternatives is shown in Figure 6.

Fig. 6 Comparison of alternatives

Multi-objective model solving results: in this numerical example, the buyer needs to buy a product within four periods (spring, summer, autumn and winter) of the best suppliers and allocate the optimal amount to each of the suppliers. It is assumed that eight suppliers compete for supplying each product. Parameters related to the purchase price of the product time period t from the supplier i were obtained at three levels of price (p tij). Other parameters of the above model (the percentage of product quality in time period t from the supplier i (rti(%)) , the percentage of the quality of service provided by the supplier i in time period t for the product (kti(%)), the percentage of the product from the supplier i delivered on time, the budget al.located to the product (Bt), the supplier's capacity to supply the product in each period (Cti), the amount of demand for the product in each period t from the buyer (Dt) and the weight received from the suppliers from the previous step was also achieved. Optimal values for each goal are obtained by solving each of objective with all model constraints using the Lingo software version 8 that the result is shown in Table (11):

Table 11 The upper and lower limit values for each objective

	Z_1	Z_2	Z_3
Z_k^*	140780000	26195	2176

By placing the optimal values obtained for each purpose in Table 11 in the Lp metrics method, it can say:

Min λ

S.t:

$$\lambda \geq \left(\frac{1}{3}\right)\left(\frac{Z_1 - 140780000}{140780000}\right)$$

$$\lambda \geq \left(\frac{1}{3}\right)\left(\frac{26195 - Z_2}{26195}\right)$$

$$\lambda \geq \left(\frac{1}{3}\right)\left(\frac{2176 - Z_3}{2176}\right)$$

(15)

$x \in X_\alpha, X_\alpha = \{x \,/\, g\,(x) \leq \boldsymbol{b_h},\ h=1,2,\ldots,g\}$

The results obtained from the model solving using Lingo software version 8 are shown in Table (12):

Table 12 The results of solving the model using the Lp metric method

λ	x_{132}	x_{232}	x_{331}	x_{363}	x_{432}	x_{462}
0.036	2298	2626	377	2623	2500	1500

According to the results for the first time period from the third supplier at the second discount level, the second time period from the third supplier at the second discount level, the third time period from the third supplier at the first discount level and the sixth supplier at the third discount level, in the fourth time period from the third and sixth suppliers at the second discount level will be bought.

5. Conclusion and Future Recommendations

Presenting a comprehensive review of the literature on the states of the modern supply chain management and supplier selection process, the present research proposed an integrated model of fuzzy BWM and FMEA for sustainable supplier selection considering seasonal quantity discounts and supplier risk. Results of the fuzzy BWM showed that the customer satisfaction is the most important criterion, as indicated by the highest weight of 0.325 among the 13 criteria considered in this study. Outputs of the FMEA revealed that the main risk criteria include customer satisfaction, selling price, warranty cost, and long-term relationships. The findings from the TOPSIS indicated that the supplier 3 is the best option, followed by supplier 6 and then supplier 1. Solving the model using the LP-metric method confirmed that the purchase in the first-time period should be made from the supplier 3 at the discount level 2, purchase in the second-time period should be made from the supplier 3 at the discount level 2, the purchase in the third-time period should be made from the supplier 3 at the discount level 1 and the supplier 6 at the discount level 3, and the purchase in the fourth-time period should be made from the suppliers 3 and 6 at the discount level 2.

Safaei Ghadikalaei et al. (2015) studied the prioritization of a conceptual model for sustainable supplier selection (case study: Saipa Company). They showed that proper selection of sustainable suppliers depends on a few main criteria including social welfare, and economic and environmental criteria, further explaining the priorities of different sub-indices to the main criteria. Sustainable supplier selection was also studied by Azadnia et al. (2012) who based their work on neural network self-organization map and MCDM approaches. In this regard, an integrated approach to solving the problem of sustainable supply selection was developed including clustering and MCDM parts. According to them, as an important decision, sustainable supplier selection can affect overall sustainability of the supply chain. Out of the 31 suppliers they studied, 6 were categorized in the best cluster, nominating them as the most suitable suppliers. Evaluation and selection of sustainable suppliers in the supply chain using the new goal programming-data envelopment analysis (GP-DEA) model with fuzzy data was reviewed in a study by Jafarzadeh Ghoshchi et al. (2018). Based on their results, companies can use this model to boost their motivations towards economic, social and environmental activities, and a sustainable supplier can improve the overall performance of the supply chain. Arab Sheibani et al. (2018) investigated an integrated fuzzy method combined with FMEA for sustainable supplier selection considering quantity discounts and supplier risk. According to their results, the proposed model could attenuate the level of risk although it tends to reduce the profit.

According to our findings, given the top priority of the customer satisfaction among the 13 criteria considered in this research, it is recommended to pay more attention to this criterion. We further recommend future studies on the application of other decision making tools and techniques and comparison of their results with those of the present study. Also, other types of discounts, such as seasonal and geographical discounts, can be considered in future works. The main limitation of this study was the difficulty in accessing a sufficient number of qualified experts for doing the research.

Ethics Declarations

- Informed consent was not required for this study because all data, information, results are anonymously mentioned in this work.
- Review and/or approval by an ethics committee was not needed for this study because to sake the of confidentially, the case study and participants and committees are anonymously reported in this work.

References

Abbaszadeh Tavasoli,S., Avakh Darestani,S., Abbaszadeh Tavasoli,M.: Assessment and selection of green supplier using DEMATEL & TOPSIS (Case study: Gilan Steel Complex). J. Industrial Management. Faculty of Humanities. Islamic Azad University. Sanandaj Branch. 12 (39), 15-27 (2017).

Abdolmaleki,M., Sayadi,A.R., Hayati,M.: Supplier selection Based on Supplier Risk by ELECTRE III Method 3. J.Resource Management Researches. 5(2). 97-120 (2015).

Al-Odeh, M., Smallwood, J.: Sustainable Supply Chain Management: Literature Review, Trends, and Framework. IJCEM International journal of computational Engineering & Management.15(1), 2230- 7893 (2012).

Arabsheybani, A., Paydar, M.M., Safaei, S.: An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk. J. Cleaner Production, 190, 577- 591 (2018).

Asgharnezhad, A. and Avakh Darestani, S.: A green supplier selection framework in polyethylene industry, Management Research Review, 45(12), 1572-1591 (2022). https://doi.org/10.1108/MRR-01-2021-0010

Asgharpoor,M.J.: multi-criteria decision making. 10th edition, Tehran, Tehran University (2013).

Ashrafi,M., Chaharsoghi,S.K.: Sustainable supplier selection criteria. Second International Conference and 4th National Conference on Logistics and Supply Chain, Tehran, Institute of Industrial Conference, https://www.civilica.com/Paper-NCLSC04-NCLSC04_084.html (2011).

Avakh Darestani,S., Hojjat Shamsi,N.: Performance evaluation of lean production based on balanced score card method using ANP and SIR: a case from Iranian home appliance industry. OPSEARCH, (2019)

Azadnia, A.H., Zameri MatSaman, M., Yew Wong, K., Ghadimi, P., Zakuan, N.: Sustainable Supplier Selection based on Self-organizing Map Neural Network and Multi Criteria Decision Making Approaches. J. Procedia - Social and Behavioral Sciences. 65(3), 879-884 (2012).

Babaei, L., Rabieh,M., Nikbakhsh, A., Smaeili,M.: Multi-objective mathematical model for selection of green suppliers (Case Study: Iran Khodro Supply Chain). J. New Research in Decision Making. 2 (2), 51-83 (2017).

Balioti, V.; Tzimopoulos, C.; Evangelides, C. Multi-Criteria Decision Making Using TOPSIS Method Under Fuzzy Environment. Application in Spillway Selection. Proceedings, 2, 637 (2018). https://doi.org/10.3390/proceedings2110637

Barrera, F.; Segura, M.; Maroto, C. Sustainable Technology Supplier Selection in the Banking Sector. Mathematics, 10, 1919 (2022). https://doi.org/10.3390/math10111919

Bohner, Ch., Minner, S.: Supplier Selection under Failure Risk, Quantity and Business Volume Discounts. Computers & Industrial Engineering. 104: PP. 145-155 (2016).

Çebi, F., Otay, İ.: A two-stage fuzzy approach for supplier evaluation and order allocation problem with quantity discounts and lead time. Inf. Sci, 339, 143-157 (2016).

Dabiri,Gh., Ghadiri Sani,M., Vadaye Kheiri,H.: Failure Mode Effects Analysis (FMEA). Concepts and Methods of Implementation, Iran Khodro Design and Engineering Design and Supply Co. (Sapko).(2002).

Habibi,A., Izadyar,C., Sarafrazi,A.(2013). Fuzzy Multi-Criteria Decision Making. Gil's Inscription.

Hajiyakhchali,S., Parchami,J.,Asadi,M.K.: Selection of suppliers in the green supply chain of oil and gas industry projects by combining fuzzy multi-criteria decision-making methods, environmental risk management (extrinsic hazard knowledge), 4(3), 231-246 (2017).

Hatice Gökler, S., Boran, S. (2023). Journal of Engineering Research, https://doi.org/10.1016/j.jer.2023.07.015

Hussain, M.: Modeling The Enablers and Alternators for Sustainable Supply Chain Management. Concordia University, A Thesis for the Degree Master of Applied Science (Quality Systems Engineering). The Department of Concordia Institute for In. (2011).

Jafarzadeh Ghoushchi, S., Dodkanloi Milan, M., Jahangoshai Rezaee, M.: Evaluation and selection of sustainable suppliers in supply chain using new GP-DEA model with imprecise data, J Ind Eng Int, 14: 613–625. https://doi.org/10.1007/s40092-017-0246-2. (2018).

Kamali Ardakani, M., Akhavan Niaki, S.T., Noorossana, R., Lahijanian, H.: Robust Parameter Design Using the Weighted Metric Method—The Case of 'the Smaller the Better', International J. Applied Mathematics and Computer Science 19(1), 59-68 (2009).

Kannan, D.: Role of multiple stakeholders and the critical success factor theory for the sustainable supplier selection process. International J. Production Economics, 195, 391-418 (2018).

Khatami Firoozabadi,S.M.A., Olfat,L., Dolabi,S.: Selection of Suppliers in the Sustained Supply Chain Using Fuzzy Multi Criteria Decision Model (Case Study: manufacturing parts), J. Engineering Decision, 1(3), 7-38 .(2015).

Kull, T.J., Talluri, S.: A supply risk reduction model using integrated multi criteria decision making. IEEE Trans. Eng. Manag, 55, 409-419 (2008). doi: 10.1109/TEM.2008.922627.

Kumar, S., Kumar, S., Barman, A.G.: Supplier selection using fuzzy TOPSIS multi criteria model for a small scale steel manufacturing unit. International Conference on Robotics and Smart Manufacturing. Procedia Computer Science. 133, 905–912 (2018).

Kuo, R., Wang Y. T.: Integration of artificial neural network and MADA methods for green supplier selection. J. Cleaner Production. 18, 1161-1170 (2010). https://doi.org/10.1016/j.jclepro.2010.03.020

Li, S., Zeng, W.: Risk analysis for the supplier selection problem using failure modes and effects analysis (FMEA). Journal of Intelligent Manufacturing, 27, 1309–1321 (2016). https://doi.org/10.1007/s10845-014-0953-0

Mahmoudi, A., Saad Ahmed, J.: Performance Evaluation of Construction Sub-contractors using Ordinal Priority Approach. Evaluation and Program Planning, 91, 1-22 (2022). https://doi.org/10.1016/j.evalprogplan.2021.102022

Mani, V., Agarwal, R., Sharma, V.: Supplier selection using social sustainability: AHP based approach in India. International Strategic Management Review. 2(2), 98- 112 (2014).

Mirghafoori,S,H,A., Sadeghi Arani,Z., Azizi, F.: Providing a Model for Selecting Green Supplier with Multi Criteria Decision Approach (Case Study: Selected Tile and Ceramic Companies in Yazd Province). Environmental Researches. 5(10), 83-96 (2014).

Mirzaei,S., Avakhdarestani,S.: Development of failure mode and effects analysis using fuzzy analytical network process. Int. J. Productivity and Quality Management. 17(2), 215-235 (2016)

Mirzaei,S., Moradi Tadi,A., Pirzadeh,N., Avakh Darestani,S.: DEVELOPMENT OF FAILURE MODES AND EFFECTS ANALYSIS USING ANP AND FUZZY SAW Int. J. DAMA International. 3(3), 425-432 (2014)

Moemeni,M.(2013). New Issues in Operations Research, Faculty of Management University of Tehran.

Mohamed, M.F.; Eltoukhy, M.M.; Al Ruqeishi, K.; Salah, A. An Adapted Multi-Objective Genetic Algorithm for Healthcare Supplier Selection Decision. Mathematics 2023, 11, 1537. https://doi.org/10.3390/math11061537

Molamohamadi, Z., Ismail, N., Leman, Z., Zulkifli, N.: Supplier Selection in a Sustainable Supply Chain. J.Advanced Management Science. 1(3), 278-281 (2013).

Omidvar,M., Niroomand,,F.: Risk Assessment Using FMEA Method Based on Multicriteria Decision Making Principles (MCDM), Fuzzy Logic and Gray Theory - Case Study of Ceiling Cranes. J. Health and Safety at Work. 7 (1), 63-76 (2016).

Ozlem Gurel, A., Acar, Z., Onden, I., Gumus, I.: Determinants of the green supplier selection. 3rd International Conference on Leadership, Technology and Innovation Management, Procedia Social and Behavioral Sciences, 181, 131 – 139 (2015).

Peattie, K., Charter, M.: Green Marketing. In chapter 28. (1999)

Rahmati, S, Avakh Darestani, S.: Performance evaluation of insurance sector using balanced scorecard and hybrid BWM-TOPSIS: evidence from Iran. International Journal of Productivity and Quality Management, 36(3), pp 382–402. (2022). https://doi.org/10.1504/IJPQM.2022.124729

Rahiminezhad Galankashi, M., Helmi, S. A., Hashemzahi, Pooria. Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach, Alexandria Engineering Journal, Volume 55, Issue 1, 2016, Pages 93-100

Rezaei, J.: Best-worst multi-criteria decision-making method. J. Omega. 53, 49–57 (2015). https://doi.org/10.1016/j.omega.2014.11.009

Saaty, T.L.: Decision making with the Analytic Hierarchy Process. Scientia Iranica. 9(3), 215-229 (2002). http://scientiairanica.sharif.edu/article_2696.html

Safaei Ghadikalaei,A.H., Madhooshi,M., Jamalian,A.: Prioritizing factors " a sustainable Supplier selection" in the Automotive Industry by Analytical Gray Hierarchy Process (Case Study: Saipa Corporation). The first national conference on industrial engineering and management research, (2015).

Safaei Ghadikalaei,A.H., Madhooshi,M., Jamalian,A.: Prioritizing a Conceptual Model for sustainable Suppliers selection (Case Study: Saipa company). Industrial Management, Faculty of Management, University of Tehran. 7(4), 767- 784 (2015).

Seuring, S., Muller, M.: From a literature review to a conceptual framework for sustainable supply chain management. J.Cleaner Production,.16, 1699–1710 (2008).

Sarabi, E.P. and Darestani, S.A. : Developing a decision support system for logistics service provider selection employing fuzzy MULTIMOORA and BWM in mining equipment manufacturing", Applied Soft Computing Journal, Vol. 98, p. 106849, (2021) available at: https://doi.org/ 10.1016/j.asoc.2020.106849

Tahanian,A.R., Nilforoshan,N.: Supplier selection in Green Supply Chain (Sustainable) to Purchase Colors Required for Lines - Case Study: Transportation Assistant and Nik Andish Engineering Copany, J. Decision Making and Operations Research, 1(2), 112-131 (2016).

Tavakoli Haji Abadi, Y. and Avakh Darestani, S. : Evaluation of sustainable supply chain risk: evidence from the Iranian food industry, Journal of Science and Technology Policy Management, Vol. ahead-of-print No. ahead-of-print.(2021), https://doi.org/10.1108/JSTPM-08-2020-0121

Vahabi Nejat, S., Avakh Darestani, S., Omidvari, M. et al.. Evaluation of green lean production in textile industry: a hybrid fuzzy decision-making framework. Environ Sci Pollut Res (2021). https://doi.org/10.1007/s11356-021-16211-4

Yazdani, M., Chatterjee, P., Kazimieras Zavadskas, E., Hashemkhani Zolfani, S.: Integrated QFD-MCDM framework for green supplier selection. J. Cleaner Production. 142, 3728-3740 (2017). https://doi.org/10.1016/j.jclepro.2016.10.095

Zailani, S., Jeyaraman, K., Vengadasan, G., Premkumer, P.: Sustainable supply chain management (SSCM) in Malaysia: A survey. International J. Production Economics, doi:10.1016/j.ijpe.2012.02.008. (2012).

Zaretalab, A., Sharifi, M., Pourkarim Guilani, P., Taghipour, S., Akhavan Niaki, S. T. A multi-objective model for optimizing the redundancy allocation, component supplier selection, and reliable activities for multi-state systems, Reliability Engineering & System Safety, Volume 222, 2022, 108394 (2023)

Zhao, H., Guo, S.: Selecting green supplier of thermal power equipment by using a hybrid MCDM method for sustainability. Sustainability. 6(1), 217–235 (2014). https://doi.org/10.3390/su6010217

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: