Developing a Decision Support System for Logistics Service Provider Selection Employing Fuzzy MULTIMOORA & BWM in Mining Equipment Manufacturing

Abstract
Nowadays, maximizing the production by reducing the associated risks in the supply chain and enhancing the final product quality by selecting the best providers are among the most fundamental challenges encountered within the equipment manufacturing industry worldwide. The lack of timely delivery of machines to customers and unregulated purchase of goods associated with the delivery of the machines are among the many problems faced by the manufactures. The proposed research aims to evaluate a Decision Support System (DSS) for selecting the most appropriate logistic service provider out of three service providers companies. Three companies X1, X2 and X3 were weighted and ranked using two decision-making methods, namely Fuzzy best-worst Method (FBWM) and Multiple Objective Optimizations on the basis of Ratio Analysis plus full Multiplicative Form (MULTIMOORA), considering eight criteria and their corresponding sub-criteria, respectively. Once finished with constructing the decision matrix, the analytical data being obtained from the two methods were processed using Microsoft Excel and the Lingo software. According to the results, it is concluded that Company X3 is the best logistics service provider.

Keywords: decision support system, logistics services, best – worst method, MULTIMOORA method.

1. Introduction

In today's rapidly changing competitive business environment, companies need a comprehensive, economical and scientific approach to selecting the most appropriate logistics service providers [1]. An appropriate logistics provider shall offer a combination of reliability, performance, agility, and productivity to maintain retail competitiveness and margins [2]. Provider selection is a multiple-criteria decision-making (MCDM) problem that encompasses both quantitative and qualitative indicators [3, 4]. The provider selection process is the most important variable in the effective management of a modern supply chain network. It helps achieve high-quality products and customer satisfaction. An effective supplier selection requires robust analytical models and decision support tools for the ability to balance multiple subjective and objective criteria [5]. The goal in supplier selection is to identify one or more suppliers from a set of potential suppliers and determine the optimal order quantity for each of them [6].

Almost, every decision in the supply chain management is affected by supplier evaluation and selection [4]. The DSS is an important component of the proper decision making in a complex environment. The DSSs are usually interactive computer-based systems that employ the required data, models, documents, knowledge and communication technologies to support people who are going to solve complicated problems. It can be developed through an adaptive learning and evolution to accommodate changes in dynamic and uncertain environments at present and/or deemed in the future [7]. The decision-making process in a company can influence the performance of the company [8]. The DSS along with the management information system, enable the management to control and track, at any time, the effects of the organization's overall performance and monitor the effectiveness of their decisions [9]. It is a very important tool that encourages users to participate in the decision-making procedure [10]. High-efficiency DSSs cannot be used in all the cases due to their limitations, however. These systems can be rather used if (1) the objectives are clear, (2) the procedures are precisely specified, and (3) the system's performance is not affected by other uncertain factors/parameters. Otherwise, if the above conditions be not met, the use of a robust return system will not yield efficient results. Accordingly, the present study renders a DSS model for selecting a logistics service provider in the machine manufacturing industry using MULTIMOORA and FBWM under uncertainty. In general, either of two major approaches may be followed as: (1) decision analysis using MCDM and (2) application of mathematical planning. Evaluating each of these two approaches, attempts were made to fix the problems encountered when applying either of them for the logistics provider selection in a machine manufacturing company [11].

Given the lack of a fresh paradigm for logistics service provider selection in the Iranian machine manufacturing industry, here we considered a machine manufacturing company to identify the internal and external criteria affecting the company's performance. Finally, a DSS was established based on the identified criteria and sub-criteria for choosing the best logistics service provider in terms of machine design and engineering. As an innovation, appropriate high-quality weighting and ranking were performed to mitigate the supply chain risks. The main contributions of this work include: (1) providing a model for service logistics provider selection, 2) presenting hybrid MCDM techniques (fuzzy BWM and MULTIMOORA).

The rest of this paper is structured as follows. The research problem and the theoretical framework are stated in sections 2 and 3, respectively. Section 4 describes the research method and the results are presented in section 5. Following a discussion on the results in section 6, conclusions are drawn in section 7.

2. Problem statement

Logistics refers to integrating two or more activities with the purpose of planning, implementing, and/or efficiently controlling the flow of materials and products from the original location to the point of consumption. The logistics involves the integration of information, transportation, inventory, warehousing, freight handling and packaging [12]. Following this line of reasoning, the logistics is the supply chain integration. Since the design of machinery can build a bottleneck through an operating system, the mining machine manufacturers have greatly regarded the machine design. Delays in the design and delivery of the machineries put the entire supply chain at risk, causing scheduling disruptions. The reasons behind a late delivery can be defective design, operation, control, and manpower management or inefficient workforce operation [13].
Although the DSS supports managers' decision-making, it does not replace the manager. Indeed, the DSS is not an automatic decision-making system, but rather facilities the process of decision-making by humans. Key characteristics of the DSS include (1) it helps the user make decisions, (2) it facilitates the handling of unstructured problems, (3) it interacts with the user directly, (4) it is based on data and analytical models, and (5) it is a computer-assisted system [11]. The development of DSSs for product planning has been discussed previously [14]. DSSs, as earlier versions of information management systems, have drawn great deals of attention. This approach incorporates the MCDM into the DSS through optimization and mathematical programming. Designing a DSS is difficult and complicated. This process examines everything from the technical level, such as software selection at the behavioral level of human-machine interaction, and its effects on individuals and groups [15].
As a case study, the present research is focused on the Iranian mining machine manufactures. A frequent problem with the Iranian mining machine manufacturers is delayed delivery of the machines to customers due to failure to design a reliable traffic plan that may delay the delivery by 2 to 3 days, lack of well-defined schedules for purchasing the required goods, and lack of strategic inventory management. These problems can be addressed by choosing a decision-making system for the entire chain from the ordering until the final resolution of the order to prevent excessive space occupation by delayed orders. Any delay at the time of ordering is transferred to the construction phase and hence the project startup and further into the entire supply chain. Considering the mentioned problems, how can a DSS provide for choosing the best logistics service provider by a mining machine Manufacturer based on the customer orders?

3. Literature review

Logistics relates to all coordination activities intended to examine, study and estimate the basic needs of equipment, machinery, tools, facilities. Also It includes components related to the procurement, production, insurance, maintenance, warehousing, distribution, transport, arrangement and preparation of workflow, system design and instructions [13]. Transport and logistics vary for different types of trade and different modes and bases of transport in terms of price, quality and availability. In an integrated transport chain, different modes are linked together through the available bases of the main levels (physical, operational, information).
In 1970, the concept of "management decision systems" was first introduced by Michael Scott. Then, in the mid-1970s, the term DSS was coined by Peter et al. at MIT University. He addressed a system that supports the decision-making of managers, but does not replace the managers [11]. Therefore, if a problem is found to be completely made up, the computer can replace it with a manager and adopt an appropriate decision. However, if there is an unstructured problem, the manager should solve it without the help of a computer. Also, the semi-structured problems can be solved by the both manager and computer where the computer here acts as a decision support system [16].
DSSs are widely employed in: transportation, distribution, warehousing, inventory management, packaging and reverse logistics. They can be outsourced with the assistance of a logistics provider [17]. The DSS is a system that helps managers solve complex problems using human resources and computer capabilities and improve decision quality [18, 19]. It also possesses direct user interaction and it has data and analytical models [20]. The DSS consists of three parts: database, model database and software [18].
The failure to timely deliver the machines to customers is considered one of the problems of the manufacturing companies in making the mining machines [21]. The lack of proper use of the tool for the production is one of the problems with delivery delays. As a result, using a method called VIse Kriterijumsk Optimizacija Kompromisno Resenje (VIKOR) as a group decision-making tool is crucial for selecting the right machine tool for a manufacturing company because of its impact on the manufacturing process. It is suggested that its goal

is to choose the optimal option based on two ideal and anti-ideal solutions. In this study, it can be replaced by the fuzzy BWM method. The reason for choosing this method is because it requires fewer pairwise comparisons and less time for the accurate results [22].

Several scholars examined provider selection using MCDM. Balzentis et al. [23] studied the process of personnel selection via the linguistic computing as in fuzzy MULTIMOORA. The problem of selecting the personnel of the group showed the group decision-making in accordance with MULTIMOORA-FG. The company forms a four-decision executive committee to select the best candidate from the four other candidates to fill the vacancy. Jayant et al. [24] evaluated the third-party logistics service providers which can effectively provide the reverse logistics operations for the companies. This work aimed to develop a decision support system for assisting the top management in selecting and evaluating different Third-Party Reverse Logistics (3PRL) service providers. They used the analytic hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS). Avakh Darestani et al. [25] solved the multi-objective supplier selection model using a compensatory approach. A compensatory fuzzy model was provided to satisfy the decision-maker's aspirations for a fuzzy goal to solve the problem. Kumar Kar [26] proposed an integrated approach to support the group decision-making for the supplier selection problems. The proposed integrated approach investigated two case studies. It was counteracted by another approach to agreed-upon group decision-making and other ways to prioritize using the AHP without reaching the agreement.

In this context, Akkaya et al. [27] evaluated the criteria for choosing the best supplier using the fuzzy AHP method, whereas the sections most commonly used in specific criteria are determined using the fuzzy MOORA method. As a result, the areas of greatest interest are technology, software/information and finance. Dweiri et al. [28] examined the AHP model to assist the automotive industry in the problem of choosing a design supplier. It should be noted that even for the expert selection, a pre-developed software package has a disadvantage that on which other TOPSIS and VIKOR methods are not implemented. Yazdani et al. [29] evaluated the supplier selection and making important strategic decisions to reduce operational costs and improve organizational competitiveness for the business opportunity development. Therefore, the objective of this study was to present an integrated approach to green supplier selection, taking into account different environmental criteria and requirements. They consider the proposed model of relationships between customer requirements with respect to the decision-making and experimental evaluation with decision-making trial and evaluation (DEMATEL).

In the following, Mohaghar et al. [30] investigated a fuzzy MCDM technique to select the appropriate supplier in a group decision environment. Based on the proposed criteria, including the product quality, delivery time, purchase cost, technology capability and financial capability, a numerical example for the supplier selection is given. It illustrates the application of the TOPSIS method [30]. Bai and Sarkis [31], for the first time, combined the neighborhood rough set (NRs) theory or the VIKOR and TOPSIS decision-making techniques. The 3PRL has been developed as a new multi-step, multi-purpose and multi-criteria approach. Given the economic growth and the introduction of new technologies in the marketing, another topic of interest today is the use of NRs as a data management and computing tool. It help to reduce the number of third–party reverse logistics provider selection (3PRLPS) for evaluating and ranking the decision-making tools using the combined TOPSIS and VIKOR method. Zarbakhshnia et al. [32] studied sustainable third-party reverse logistics provider evaluation and selection using the fuzzy SWARA and developed the Fuzzy COPRAS in the presence of risk criteria. The result showed that the most sustainable 3PRLP was selected. While incorporating the risk factors into the analysis, this study showed that the environmental and social drivers increasingly become dominant when selecting the 3PRLPs [32].

Among the recent research, Tavassoli and Avakh Darestani [33] studied the supplier selection and evaluation using the quality function deployment (QFD) and ELECTRE in the quality management system environment (case study: Faravari and Sakht Company). The results of this study showed that the supplier's index and related strategies are the least important relationships and also the resource obtained the highest weight, and design and development was determined as the highest rank. Galo et al. [34] evaluated a group decision approach for the supplier categorization based on the hesitant fuzzy and ELECTRE TRI. The ELECTRE method is a multivariate non-compensatory decision-making method used for the classification. The hesitant fuzzy was already used for the linguistic judgments by a combination of multiple decision makers. The analysis of results is a practical example in the automotive industry showing the consistent classification results using the ELECTRE (cynical) batch classification method.

Lo et al. [35] investigated a new combined model using the BWM method and modified fuzzy technique based on the similarity to the ideal TOPSIS fuzzy method and fuzzy multi-objective linear programming. They were used to solve the problem of green supplier selection and order allocation. The results showed that this model can effectively evaluate the performance of green suppliers and can also optimize the order allocation for the eligible suppliers. Kazancoglu et al. [36] analyzed the integrated framework of the disassembly line balancing with green and business objectives. To achieve this integration, the fuzzy MCDM and fuzzy AHP structure were used to determine the weight of each sub-criterion before using fuzzy MOORA for ranking the tasks.

Arabsheybani et al. [37] studied an integrated fuzzy MOORA method and FMEA technique for the sustainable supplier selection considering the quantity discounts and supplier's risk. The results showed that this model not only increases total profits, but also reduces the risks to sustainability. Car [38] examined the use of decision models to enable better irrigation decision support systems. For this purpose, the DSS designers create flexible systems that incorporate three decision-making modeling systems here. Kellner et al. [39] investigated a posteriori decision support methodology for solving the multi–criteria supplier selection problem. This system combines the multi-objective optimization with an analytical network process to meet the sustainability needs of the portfolio configuration. The proposed model consists of a combination of single modules.

Khalilzadeh and Fattohi [40] studied the risk evaluation using a novel combined method based on FMEA, extended MULTIMOORA, and AHP methods under the fuzzy environment. The results showed that the average of fuzzy weighted risk priority numbers (AFWRPNs) decreased by 56% compared to the average of corrected fuzzy weighted risk priority numbers (ACFWRPNs). Mohammadi and Avakh Darestani [41] examined the green supplier selection problem using TOPSIS extended by D numbers in the tractor manufacturing industry. Eight indicators were identified for the supplier selection. Zhang et al. [42] studied intuitionistic fuzzy MULTIMOORA approach for the multi-criteria assessment of the energy storage technologies. The sensitivity of fuzzy multivariate results was examined in two ways. Therefore, the results of MULTIMOORA - IFN2 are compared with those obtained from TOPSIS and VIKOR methods. Omrani et al. [43] reviewed the development of the communities using the human development index (HDI). Finally, the HDI scores of provinces were calculated based on the geometric mean of healthy living, population education and living standards. Accordingly, 'Kohgiluyeh and Boyerahmad' and 'Sistan and Baluchestan' provinces were identified as the most and least developed provinces, respectively. Finally, for the future study, the selection criteria and research method can change. Instead of MULTIMOORA, other multi-objective decision-making (MODM) and MCDM methods such as data envelopment analysis (DEA) can be used to evaluate HDI scores. The logistic service provider criteria and sub-criteria obtained from the past research are shown in Table 1.

Table 1
Reviewing of Literature

Author	Year	Country	Criterion	Sub criterion
Colicchia et al. [44]	2013	Italy	Collaboration with customers	Efforts towards CO_2 reduction; support on reverse logistics practices and managing the use of web-portals to calculate energy and CO_2 emissions associated with a customer's transportation link and storage
			External collaborations	Pursuing common environmental goals and efficiency, optimizing routes and freight loads
			Packaging management	Meaningful effects on environment and transport
				Treatment of packaging waste in a more environmentally benign manner
				Reducing the life cycle environmental impact of the entire packaging supply chain
				Freight load optimization, as reducing the weight and volume of packaging results in cargo efficiency and waste reduction
			Distribution strategies and transportation execution	Increasing attention to distribution and sustainable transportation execution, technological innovation and management strategies
				The use of cleaner vehicles and the use of alternative fuels
				Reducing greenhouse gases and CO_2
				Limiting the speeds at company equipment and reconsideration of network design and transport strategies
			Reverse logistics	The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or of proper disposal
				Increasing awareness of environmental issues and attention to logistics sustainability
				Waste reduction, transport and disposal, materials recycling and reuse, and consumption reduction
			Internal management	Personnel training and development of organizational sensitivity to sustainability issues

Author	Year	Country	Criterion	Sub criterion
				Establishment of new expertise and sustainability-dedicated intercompany groups
Chen et al. [2]	2018	China	Flexibility and reliability	To provide more flexibility to geographic distribution and may offer a larger variety of services to its customers
			Service quality	Accuracy of order fulfilment, on-time delivery, pre and post-sale services to customers, promptness in attending to complaints
			Credit	beliefs of LSPs market
			Business growth potential	Increasing the e-commerce shipments with smaller packages and more stock keeping units, providing greater opportunities for the LSPs to accommodate growing demand and to generate more profit
			Impact on environment	The omni-channel retail models, under greater pressure to outsource logistics services, may lose direct control over their environmental footprint and performance. Therefore, LSP must be able to estimate the same high standards for vehicular emissions reduction and noise pollution.
et al. Kellner [39]	2018	Germany	Supplier evaluation and selection, integrating supplier selection	Quality, followed by delivery, price/cost, manufacturing capability, service, management, technology, research and development, finance, flexibility, reputation, relationship, risk, and safety and environment
et al. Jayant [24]	2018	India	Accurate understanding of senior management to company goals	Minimizing supply chain costs and prevention including procurement, production, distribution, inventory, collection, disposal, collection and recycling costs
Dweiri et al. [28]	2016	Pakistan	Price	Unit price, free transportation, quantity discount
			quality management system	Rejection rate, compatibility
			Delivery	Lead-time, error, time of delivery
			Service	Order update, warranty, geographical location
Mohaghar et al. [30]; Chen et al.[2]	2017, 2018	Iran., China	Financial record and ability and purchase costs	The firm's return on investment, return on assets, and value-added services, supply chain management, reduce production costs, increase income, optimize inventory and business processes and cycle time and increase competitive power and customer satisfaction and profitability
			Technical ability and technology and product quality	Reduce supply chain risk, improve customer service

Equipment manufacturing is a fertile and underlying industry in which status in any country is one of the important indicators of its industrial and manufacturing development. The study of the Machine industry indicates that logistics and supply chains are of particular importance. A review of past studies has shown that has not conducted specific research on this subject given the importance of logistics in machine making. Also, despite studies in other areas, but studies have not used a hybrid of the fuzzy BWM and MULTIMOORA techniques such as Jayant et al. [24] used AHP and TOPSIS. Study of Lo et al. [35] has done using BWM and TOPSIS.

The research gap in the manufacturing of mining equipment has led to the selection and evaluation of a supplier considering the problems of logistics services (time, cost, warehousing, and delivery). In BWM technique, the research actually attempts to get the best value for the logistics services, taking into account the best - worst possible structure. Research and paper have not conducted in the machine manufacturing industry using the fuzzy MOOLTIMOORA method and the FBWM in an uncertainty environment. Various MCDM approaches such as VIKOR, TOPSIS, the preference ranking organization method for enrichment of evaluations (PROMETHEE), MOOLTIMOORA and BWM are separately or hybrid employed in different industries. They have selected and evaluated the best and most effective supplier based on their characteristics by ranking and weighting of data. Choosing the most ideal option leads to reduced risk in the supply chain and increases productivity and accelerates logistics service performance.

The novelty and distinction of this work rather than other investigations is the modeling and ranking of decision support systems in order to improve productivity with respect to the goal of selecting the best logistics service provider for manufacturing of mining equipment. As mentioned above, the final ranking and calculation of criteria weights are done by two methods or indeed two decision-making approaches. In fact, it can be said that Guo and Zhao [47] identified a fuzzy model of the BWM method utilizing the fuzzy reference comparisons regarding the best and worst criteria to create fuzzy weights. The fuzzy MOOLTIMOORA method proposed by Balzentis et al. [23] is the same as the MOOLTIMOORA approach leading to fuzzy environments and fuzzy numbers. This method uses three approaches of fuzzy ratio system, fuzzy reference point and fuzzy multiplicative approach. In fact, using all three of these approaches provides a ranking of alternatives and finally, by the theory of dominance, it offers the ultimate MOOLTIMOORA ranking. Decision Matrix of this method is similar to the decision matrix of fuzzy TOPSIS or fuzzy VIKOR, ie the matrix contains criteria and alternative. This method is also able to calculate the ranking of criteria, which can calculate the weight of the criteria in this topic from the new method like fuzzy BWM and give as input in this method.

4. Research methodology

The research revolves around the idea of incorporating uncertainties (within a fuzzy environment) for performance optimization. It describes and interprets a new model in selecting the best logistics service provider that has not yet attempted in reality within the Iranian Machinery Industry. Evaluation and ranking as well as weighting of main criteria are carried out to reduce supply chain risks. Data collection is performed through questionnaires. The software employed in this study includes Lingo and Microsoft Excel. This section describes the research method, how to collect the data and how to implement it. The research methodology developed for this work is in accordance with Fig. 1 as following steps:

First step: by analyzing internal and external research, criteria and sub-criteria were determined in a machine manufacturing company and a questionnaire was designed.
Second step: The questionnaire was distributed among nine experts. Content validity ratio (CVR) was obtained for finalizing criteria and sub-criteria. Questionnaires intended for data collection are: (1) CVR's questionnaire (content validity), (2) BWM's questionnaire, (3) MULTIMOORA's questionnaire**.**
Final step: weighting of the criteria was done by FBWM method. At the first, a set of decision criteria was determined and then the best and worst criteria were identified. Pairwise comparisons of the best criteria with the other criteria and the other criteria with the worst criteria were performed and the optimal weights were found. The ranking was done by method of FMULTIMOORA. The decision matrix was formed and then normalized, and the normal matrix was weighted, and the rankings were based on three approaches of MULTIMOORA. The final ranking was done by the theory of dominance. Finally, it provides suggestions and final reports by comparing the three companies with similar factors.

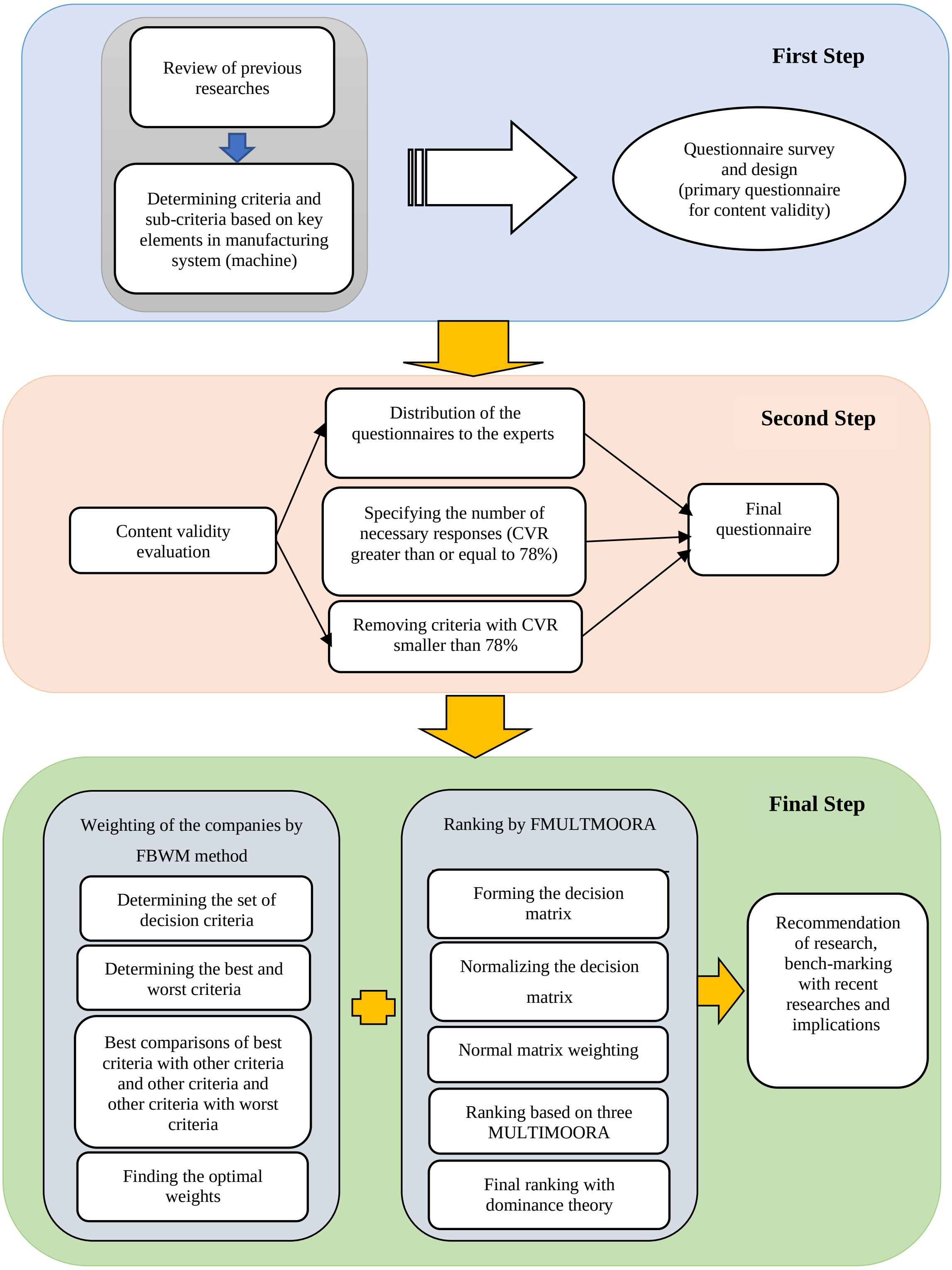

Fig. 1. Research Framework

4.1. Determination of criteria and sub-criteria

In this step, the criteria for selecting the appropriate supplier was identified from the previously published works. In fact, today, the most commonly used criteria and sub-criteria have been identified with the reality in the machine manufacturing sector, as shown in Table 1.

4.2. Calculation of CVR

According to the criteria obtained, a questionnaire is designed in the form of a CVR questionnaire. It separately examines and identifies common criteria for providing a decision support system to select the best logistics service provider in the machine manufacturing industry. Finally, the common criteria in the machine manufacturing industry are extracted and the research questionnaire is developed.

In the study done by Vazifehdan and Avakh Darestani [45], it was expressed that the number of experts as interviews should not be large. Thus, to determine the content validity of the criteria, the questionnaire is sent to nine experts of three companies (3 persons for each company). They are asked to respond to each of the criteria and sub-criteria in the questionnaire as "necessary", "useful but not necessary" and "not necessary". Then, the responses are calculated as follows:

$$CVR = n_{E- N/2}/(N/2) \quad (1)$$

In Eq. (1), n_E denotes the number of experts who responded the "necessary" option and N denotes the total number of experts. The responses are calculated based on the CVR formula where the numbers higher than 0.78 are accepted. Out of the 19 criteria, 8 criteria remain and 11 criteria are removed.

Customer Engagement Criteria, External Collaboration, Distribution, Warehousing and Transportation Strategies, Internal Management, Credit, Quality Management System, Services, Business Growth Potential, Impact on Environment, Accurate understanding of senior management to company goals, Flexibility and Reliability were completely removed. Because the range of responses is lower than 0.78 and, in fact, equal to zero. The criteria and sub-criteria of the final questionnaire are presented in Table 2.

Table 2
Questionnaire criteria (final questionnaire of research)

Criteria	Code	Sub Criteria	Code
Packaging management	A	Reducing the life cycle environmental impact of the entire packaging supply chain	a1
Reverse logistics	B	The process of planning	b1
		Cost-effective flow of raw materials	b2
		Related information from the point of consumption to the point of origin for the purpose of recapturing value or of proper disposal	b3
Service quality	C	Accuracy of order fulfilment	c1
		On-time delivery	c2
		Pre- and post-sale services to customers	c3
		Promptness in attending to complaints	c4
Price	D	Product unit price	d1
Delivery	E	Lead time	e1
		Delivery time	e2
Supplier evaluation and selection, integrating supplier selection	F	Quality followed by delivery	f1
		Price/cost	f2
		Manufacturing capability	f3
		Service	f4
		Technology	f5
Financial record and ability and purchase costs	G	The firm’s return on investment	g1
		Value added services	g2
		Increasing income	g3
		Reduce production costs	g4
		Optimizing inventory and business processes and cycle time	g5
		Increase competitive power and customer satisfaction and profitability	g6
Technical ability and technology and product quality	H	Reducing supply chain risk	h1
		Improving customer service	h2

4.3. Data gathering

Company X1 is located at Alborz province of Iran in a non-governmental industrial city. The company activities comprise of mining, design and manufacturing of mineral processing machinery. Company X2 is located in the north of Turkey in Marmara Industrial City. It is a part-casting company specialized in producing the alloy parts with special alloys. Company X3 is also located in north of Turkey in the Marmara Industrial

City. The company has started its activities since 1987 and is actively working in the field of mining, design and manufacturing of mineral processing machinery. Some products of the companies are provided in Fig. 2.

Head Wall Rod Mill Ball Mill

Fig. 2. Mining Equipment

4.4. Best-Worst Method

In the MCDM, a number of options are evaluated according to a number of indicators for selecting the best option. BWM is a new robust MADM technique for determining the subjective weights of criteria [8]. Based on the BWM proposed by Rezaei [46], the best and worst indicators are determined by the decision maker. The pairwise comparisons are made between each of the two indicators (best and worst) and the other indicators. Then, a maximal minimum problem is formulated and solved to determine the weight of various indicators. It also provides a formula for calculating the inconsistency ratio and evaluating the validity of the comparisons. By comparing this method with other MCDM methods, it can be stated that it requires fewer comparative data. Moreover, it leads to a more robust comparison, which means that it provides more reliable responses [46].

4.5. Fuzzy Best–Worst Method

This method was first proposed by Guo and Zhao [47] whose algorithms resemble the best-worst definitive method. Using the fuzzy numbers, as the verbal ambiguity of the respondents gives more accuracy and better results in the calculations, the steps of this method are as follows:

Suppose that there are *n* criteria. The pairwise comparisons of these *n* criteria are compared through the Linguistic terms (from 1= equally importance to 9= absolutely important) that are shown in Appendix 1.

The first step of this method is the creation of a criteria decision system. The research criteria to be compared, including *n* criteria, are extracted for the evaluation. The second step determines the best (most important) and the worst (least important) criterion. In this step, the most important criterion and the least important criterion should be identified as the best and worst criterion, which can be obtained from the expert opinions, group meetings or methods such as Delphi. They represent the best criteria with *CB* and the worst criteria with *CW*. The third step compares the best paired criteria with the other criteria. In this step, using Appendix 2, the comparison of *aij* should be made. *i* denotes the best criterion. That is, *CB* and *j* are other criteria. Comparing the best criterion with the worst criterion should always be the highest number than the others. The pairwise comparison of *aBB* is also (1,1,1).

Generally, the comparison is made as Eq. (2):

$$\tilde{A}_B = (\tilde{a}_{B1}, \tilde{a}_{B2}, \dots, \tilde{a}_{B3}) \tag{2}$$

The pairwise comparison of the other criteria with the worst criterion is made in step 4. In this step, as in step 3, the other criteria are compared with the worst criterion according to Appendix 2. The pairwise comparison in this step is *a1B*. The pairwise comparison of *aww* is also (1,1,1). Generally, the comparison is made according to Eq. (3).

$$\tilde{A}_w = (\tilde{a}_{1w}, \tilde{a}_{2w}, \dots, \tilde{a}_{3w}) \tag{3}$$

Step five determines the optimal weights $\left(\widetilde{W_1}^*, \widetilde{W_2}^*, \ldots, \widetilde{W_n}^*\right)$. The optimal weights of the criteria areas for each pair $\widetilde{w}_b/\widetilde{w}_j$ and $\widetilde{w}_j/\widetilde{w}_w$ according to Eq. (4).

$$\widetilde{w}_j/\widetilde{w}_w = \widetilde{a}_{jw} \quad \text{and} \quad \widetilde{w}_b/\widetilde{w}_j = \widetilde{a}_{Bj} \tag{4}$$

To satisfy this condition for all *j*, a solution must be found where the maximum absolute difference means $(\widetilde{w}_b/\widetilde{w}_j) - \widetilde{a}_{Bj}$ and $(\widetilde{w}_j/\widetilde{w}_w) - \widetilde{a}_{jw}$ be minimum for all *j*.
The following problem can be obtained by considering the non-negative values and condition of the sum of the weights according to Eq. (5).

$$\begin{aligned} & \min \max J \{|(\widetilde{w}_b/\widetilde{w}_j) - \widetilde{a}_{Bj}|, |(\widetilde{w}_j/\widetilde{w}_w) - \widetilde{a}_{jw}|\} \\ & s.t. \\ & \textstyle\sum_j R(\widetilde{w}_j) = 1 \qquad l_j^w \le m_j^w \le u_j^w \quad , \quad l_j^w \ge 0 \quad \text{For all } j \end{aligned} \tag{5}$$

In this equation, $R(\widetilde{a}_i) = l_i + 4m_i + u_i/6$.
The equation model problem (5) can be transformed into the following problem according to Eq. (6).

$$\begin{aligned} & \min \tilde{\xi} \\ & s.t. \\ & |(\widetilde{w}_b/\widetilde{w}_j) - \widetilde{a}_{Bj}| \le \widetilde{a} \qquad \text{For all } j \\ & |(w_j/w_w) - \widetilde{a}_{jw}| \le \widetilde{a} \qquad \text{For all } j \\ & \textstyle\sum_j R(\widetilde{w}_j) = 1 \\ & l_j^w \le m_j^w \le u_j^w \quad , \quad l_j^w \ge 0 \quad Wj \ge 0, \text{ for all } j \end{aligned} \tag{6}$$

By solving the above problem, the optimal weights $\left(\widetilde{W_1}^*, \widetilde{W_2}^*, \ldots, \widetilde{W_n}^*\right)$ and $\tilde{\xi}^*$ are obtained.
Then, using $\tilde{\xi}^*$, the consistency ratio is introduced. When the value of $\tilde{\xi}^*$ is higher, the ratio of consistency is higher and the comparisons are less reliable.

The consistency ratio is done in the sixth step. The comparison is perfectly consistent when the following equation is applied to all *j*.
aBj × *ajw*= *aBW* where *aBj*, *ajw* and *aBw* are the priority of the best criteria relative to the *j* criterion, the priority of the *j* criterion relative to the worst criterion, and priority of the best criteria relative to the worst criterion, respectively.

Because *aBj* × *ajw* = *aBW* and $a_{BW} \in \{1,2,3,\ldots,9\}$, the maximum value of ξ can be obtained. Using the consistency ratio and its equation, the value of the inconsistency ratio is calculated. This inconsistency ratio is within the range [0, 1]; when the value is closer to zero, the comparisons are more consistent and have more stability, and when the value is closer to 1, the comparisons are less consistent and have less stability.
The consistency ratio can be calculated through Eq. (7).

$$\xi^2 - (1 + 2u_{BW})\xi + (u_{BW}^2 - u_{BW}) = 0 \tag{7}$$

4.6. MULTIMOORA Method in Problem

MULTIMOORA was first proposed by Brauers and Zavadskas [48]. They proposed two approaches to the MOORA method which are the ratio system approach and reference point approach. Then, in 2010, they also presented a more stable case than the MOORA method called MULTIMOORA [48, 49]. The general algorithm of MULTIMOORA method is shown in Fig. 3:

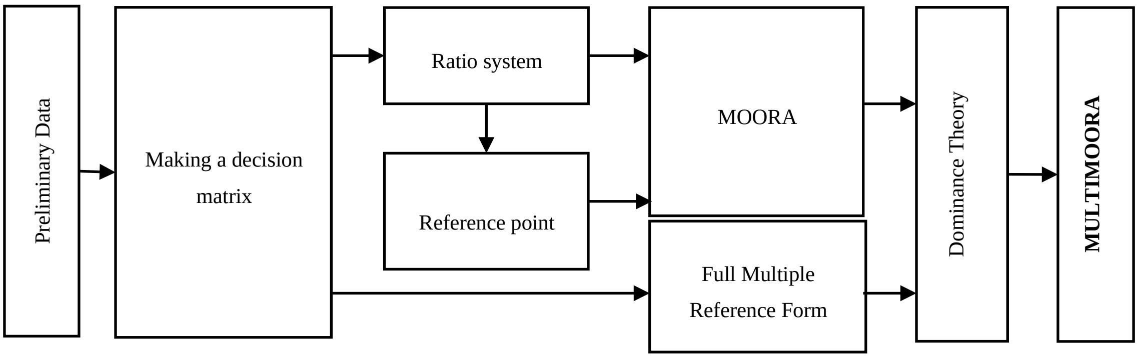

Fig. 3. MULTIMOORA Method Algorithm

4.7. Fuzzy MULTIMOORA Method

Using the fuzzy approach in the MCDM techniques has gained attention in the applications that contain uncertainties. Balezentis et al. [23] combined the fuzzy approach with the MULTIMOORA technique [23]. The ratio system responsible for the normalization will normalize the values of the fuzzy response matrix represented by $\tilde{X}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3})$ using Eq. (8).

$$\tilde{X}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}) = \begin{cases} x^*_{ij1} = x_{ij1} / \sqrt{\sum_{m}^{i=1} \left[(x_{ij1})^2 + (x_{ij2})^2 + (x_{ij3})^2 \right]} \\ x^*_{ij2} = x_{ij2} / \sqrt{\sum_{m}^{i=1} \left[(x_{ij1})^2 + (x_{ij2})^2 + (x_{ij3})^2 \right]} \\ x^*_{ij3} = x_{ij3} / \sqrt{\sum_{m}^{i=1} \left[(x_{ij1})^2 + (x_{ij2})^2 + (x_{ij3})^2 \right]} \end{cases} \quad (8)$$

In this study, the following linguistic scale and fuzzy numbers is used to evaluate the alternatives for each criterion (Table 3).

Table 3
Linguistic scale and corresponding fuzzy numbers for ranking alternatives [50]

Code	Priorities	fuzzy Phase of priorities		
		Lower limit	Medium limit	Upper limit
1	Very Poor	1	1	3
2	Poor	1	3	5
3	Medium	3	5	7
4	Good	5	7	9
5	Very Good	7	9	11

The value of y^*_{ij} in each of the alternatives is given by Eq. (9), depending on whether the criteria are useful or not.

$$\tilde{y}^*_i = \sum_{j=1}^{g} \tilde{x}^*_{ij} \widetilde{w}_j \ominus \sum_{j=g+1}^{n} \tilde{x}^*_{ij} \widetilde{w}_j \quad (9)$$

The value of $g = 1,2, ..., n$ represents the indices that are positive.

In this equation, $\widetilde{w}_j$ is the fuzzy weight of the criteria. Eq. (10) is also used to defuzzify the numbers:

$$BNP_i = ((y^*_{i3} - y^*_{i1}) + (y^*_{i2} - y^*_{i1}))/3 + y^*_{i1} \quad (10)$$

The fuzzy reference point method operates based on the fuzzy ratio system outputs. Each of the normalized matrix element is adjusted according to the coordinates of the selected reference point and the deviation is calculated using Eq. (11).

$$\min_i \left(\max_j d\left(\tilde{r}\widetilde{w}_{j_j}, \tilde{x}^*_{ij}\widetilde{w}_j \right) \right) \tag{11}$$

where $r^{\tilde{}}$ denotes the largest element of criterion columns for the positive criteria, and for the negative criteria equal to the smallest element of criteria column. The ascending order of the results of Eq. (11) indicates the ranking of the reference point method. The final utility of option *i* is calculated using the full multiplicative form Eq. (12).

$$\widetilde{U}'_i = \tilde{A}_i / \tilde{B}_i$$
$$\tilde{A}_i = (A_{i1}, A_{i2}, A_{i3}) = \prod_{j=1}^{g} \tilde{x}_{ij}\widetilde{w}_j \tag{12}$$
$$\tilde{B}_i = (B_{i1}, B_{i2}, B_{i3}) = \prod_{j=g+1}^{n} \tilde{x}_{ij}\,\widetilde{w}_j$$

where $\tilde{A}_i$ is the multiplication of positive criteria (useful) by the number $g = 1,2, ..., n$ and $\tilde{B}_i$ is the multiplication of negative criteria (useless) by the number n-g.

4.8. Dominance Theory

According to the principle of cardinal and ordinal numbers as well as the Kendall and Gibbons theory, it is not possible to apply the algebraic operations of cardinal numbers to the ordinal number space. These numbers can only be converted into the ordinal numbers of another kind. One of the benefits of the dominance theory is to perform all steps of problem solving in the ordinal number space.

The absolute dominance occurs when one option rank dominates others. In MULTIMOORA technique, the absolute dominance is seen under *1-1-1* conditions. The general dominance occurs when two out of three ranking options are better than others. For example, *d-a-a* has the general dominance of *C-b-b*. Since transferability holds in this theory, if *a* dominates *b* and *b* dominates *c*, then *a* dominates *c*. These rules apply to all three MULTIMOORA technique rankings and the final ranking is presented. The Network Decision Model is presented in Fig. 4.

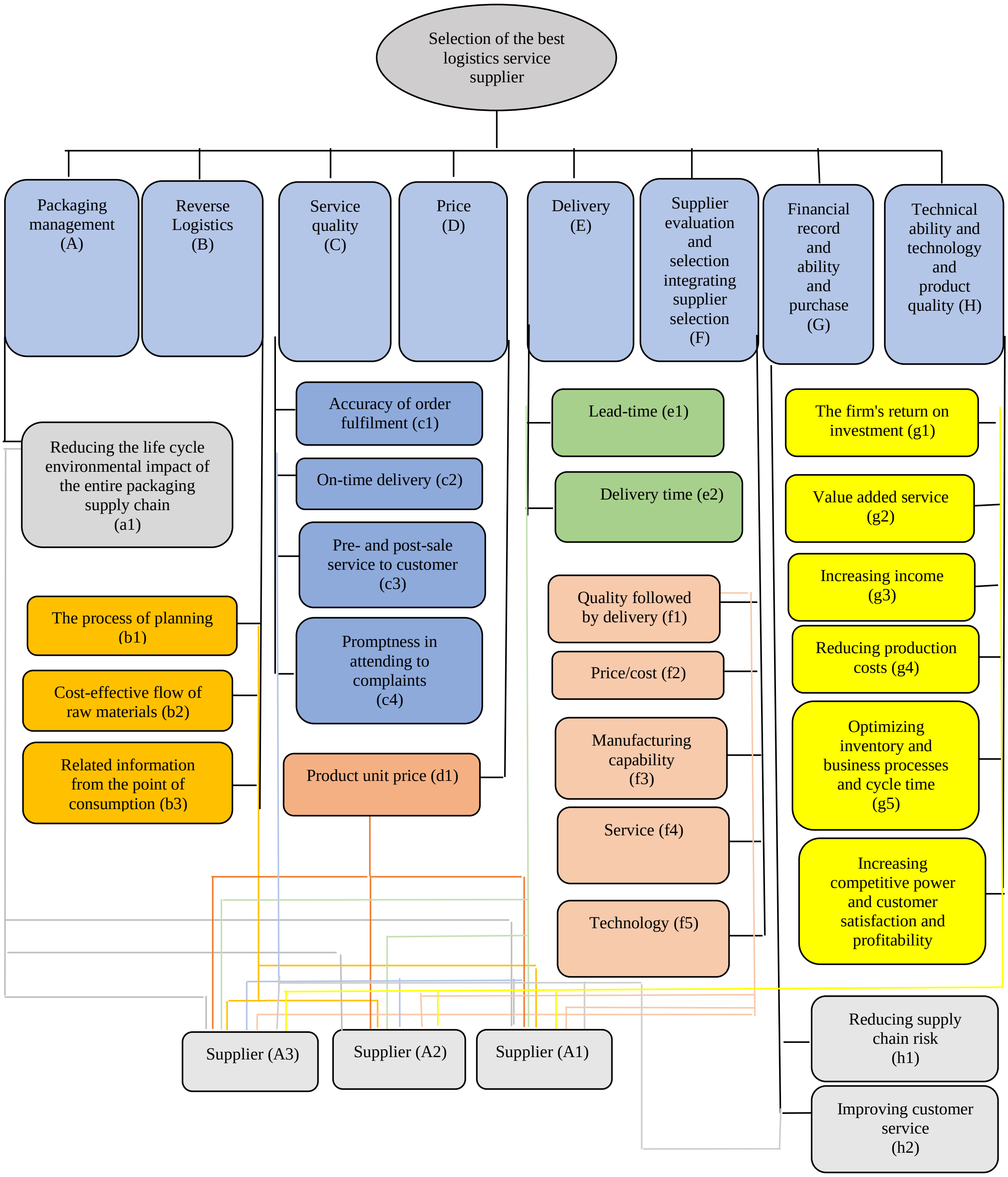

Fig. 4. Decision Network Model

5. Results

5.1. Research criteria

Initially, the criteria and sub-criteria were obtained by studying different research, as presented in Table 1. Then, after distributing the questionnaire among experts and obtaining the CVR, 24 sub-criteria in 8 criteria are obtained, as presented in Table 2.

5.2. Results of Fuzzy BWM

5.2.1 Determination of most important and least important criteria

In the first step, the BWM must identify the most important (best) and least important (worst) criteria. In this study, using the experts' opinions, the most important (best) and least important (worst) criteria are identified first in the main criteria and then among the sub-criteria of each criterion, as presented in Table 4.

Table 4
Best and Worst criteria

Factor	Best criteria	Worst criteria
Main criteria	Financial ability and purchase costs (G)	Packaging management (A)
Packaging management	-	-
Reverse logistics	The process of planning (b1)	Cost-effective flow of raw materials (b2)
Service quality	Pre- and post-sale services to customers (c3)	Promptness in attending to complaints (c4)
Price	-	-
Delivery	Delivery time (e2)	Lead-time (e1)
Supplier evaluation and selection, integrating supplier selection	Quality followed by delivery (f1)	Service (f4)
Financial record and ability and purchase costs	Increase Competitive Power and Customer Satisfaction and Profitability (g6)	Reduce Production Costs (g4)
Technical ability and technology and product quality	Reducing supply chain risk (h1)	Improving customer service (h2)

5.2.2 Formation of Pairwise Comparisons

In this section, the pairwise comparisons are made of the best criterion for other criteria (BO) and other criteria for the worst criterion (OW). In this study, the pairwise comparisons are first made, and 3 experts are selected to determine the preference of pairwise comparison according to Appendix 1. After giving the responses, the pairwise comparisons are merged with the geometric mean method as follows (Appendix 3).

5.2.3 Calculating Weight of Criteria

In this step, the nonlinear optimization model of the problem is developed using Eq. (5). Nevertheless, Guo and Zhao [47] stated that in the models with three or more criteria, it is better to convert them to a piecewise linear model. Therefore, the linear model of the fuzzy BWM method was developed and solved by Lingo 17 software. The weights of the criteria were obtained as follows (Table 5):

Table 5
Weight and Final Ranking of Main Criteria

Criterion	Fuzzy Weight	Definitive weight	Ranking
Packaging management (A)	(0.037, 0.037, 0.041)	0.038	8
Reverse logistics (B)	(0.078, 0.111, 0.126)	0.108	5
Service quality (C)	(0.084, 0.108, 0.159)	0.113	3
Price (D)	(0.076, 0.093, 0.133)	0.097	6
Delivery (E)	(0.053, 0.061, 0.096)	0.066	7
Supplier evaluation and selection, integrating supplier selection (F)	(0.083, 0.111, 0.148)	0.113	3
Financial record and ability and purchase costs (G)	(0.335, 0.337, 0.348)	0.339	1
Technical ability and technology and product quality (H)	(0.091, 0.121, 0.188)	0.127	2

According to Table 5, the fuzzy weight is obtained directly from the model solution in Lingo software. These fuzzy weights become a definite weight by the equation $R(\tilde{a}_i) = l_i + 4m_i + u_i/6$.
According to Table 5 and Fig. 5, the financial record and ability and purchase costs (*G*) was ranked first among the main criteria with the weight of 0.339. The technical ability and technology and product quality (*H*) with the weight of 0.128 and quality of service (*C*) with the weight of 0.113 were ranked as the second and third criteria, respectively.
In the same way for the sub-criteria, a linear optimization model was developed and solved by Lingo17 software to obtain the final weights. Among the inverse logistic sub-criteria, the planning process was ranked first with the weight of 0.5. The related information from the point of consumption to the point of origin for the purpose of recapturing the value or of the proper disposal with the weight of 0.293 was ranked second, and the cost-effective flow of raw materials with the weight of 0.121 was ranked as the third criterion. Among the service quality sub-criteria, the pre- and post-sale services to customers was ranked first with the weight of 0.482. The accuracy of order fulfilment with the weight of 0.229 was ranked second and the on-time delivery with the weight of 0.205 was ranked as the third criterion.
Among the delivery sub-criteria, the lead-time with the weight of 0.777 was ranked first and the time of delivery with the weight of 0.223 was ranked as the second criterion. Among "the sub-criteria of supplier evaluation and selection, integrating supplier selection", quality followed by delivery with the weight of 0.492 was obtained the first rank. The price/cost with the weight of 0.184 was ranked second and the manufacturing capability with the weight of 0.135 was ranked as the third criterion. Among "the sub-criteria of financial record and ability and purchase costs", increase competitive power and customer satisfaction and profitability with the weight of 0.384 was ranked first. Increase income with the weight of 0.158 was ranked as the second criterion and the firm's return on investment with the weight of 0.157 was ranked as the third criterion. Among "the technical ability and technology and product quality", reducing supply chain risk with the weight of 0.794 was ranked first, while improve customer service with the weight of 0.205 was ranked as the second criterion.

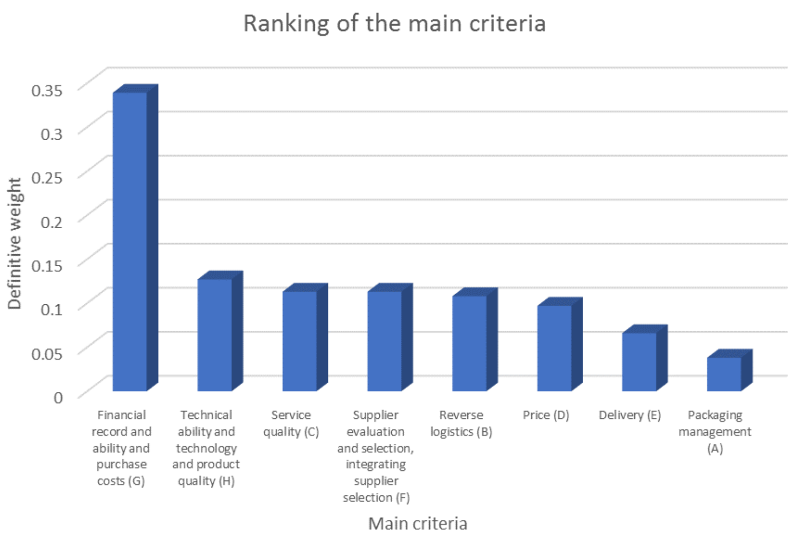

Fig. 5. Ranking of the main criteria

4.3. Calculation of Inconsistency Ratio

In this section, it is explained how to calculate the inconsistency ratio of pairwise comparisons. First, using Eq. (7) and solving a quadratic equation for each pairwise comparison table, the unknown value of ξ was calculated, which is the consistency ratio. Then, the optimal value of the objective function ($\tilde{\xi}$*) of each linear model for the pairwise comparison tables is divided by this value of the consistency ratio to obtain the inconsistency ratio. Mathematically, the inconsistency ratio is: $\tilde{\xi}*/\tilde{\xi}$. When the inconsistency ratio is closer to zero, it indicates the more consistent pairwise comparison. This ratio is given in Table 6.

Table 6
Consistency ratio of paired comparison

Factor	ξ	ξ̃ *	Inconsistency Ratio
Main criteria	13.300	0.523	0.036
Packaging management	-	-	-
Reverse logistics	9.702	0.260	0.027
Service quality	10.772	0.475	0.044
Price	-	-	-
Delivery	-	0	Always consistent
Supplier evaluation and selection, integrating supplier selection	12.531	0.557	0.044
Financial record and ability and purchase costs	10.772	0.596	0.055
Technical ability and technology and product quality	-	0	Always consistent

The final weight of the sub-criteria is obtained by multiplying the weight of the main criteria by the relative weight of their sub-criteria.

5.4. Results of Fuzzy MULTIMOORA Method

In this section, it is discussed how the three supplying companies are ranked using the Fuzzy MULTIMOORA. These three companies are Company X1, Company X2 and Company X3. First of all, the decision matrix of this method is formed. The decision matrix is a criterion-option matrix. The research options consist of the three mentioned companies and research criteria of 24 problem sub-criteria. The weight of the criteria is also the outputs of the fuzzy BWM method. Then, using Eq. (8), the decision matrix is normalized according to Appendix 4. After normalizing the matrix, the weighted matrix decision is made by multiplying the weights by the normal matrix and then by Eq. (9) to (12), the ranking of options is based on the three approaches of the ratio system, reference point and full multiplier. The results are presented in Table 7.

Table 7
Final ranking of alternatives

	Ratio system	Reference point	Full multiplier	Ratio system rank	Reference point rank	Full multiplier rank	Final ranking
X1	0.137	0.023	2.61*32-10	3	3	3	3
X2	0.203	0.012	4.06*30-10	2	2	2	2
X3	0.262	0.003	2.04*27-10	1	1	1	1

According to Fig. 6, Company X3 is selected as the best logistics service provider (alternative).

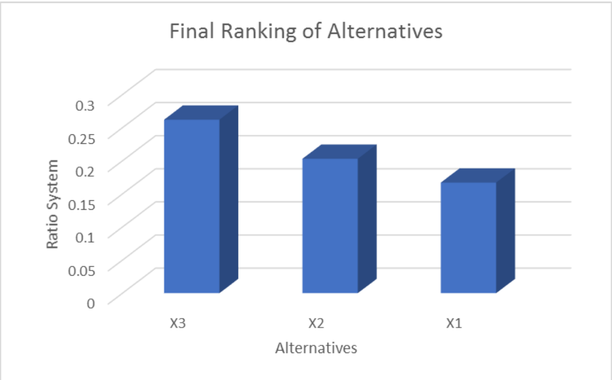

Fig. 6. Final Ranking of Companies

6. Discussion and Limitations

The provider selection system can be categorized as a MCDM problem, where experts and decision-makers can hardly establish a balance among various criteria to achieve a perfect solution. Depending on the provided services, selecting a good provider in the machine manufacturing industry is paramount as it thrives on external and internal services and that it imposes a profound effect on the product quality, customer satisfaction, and the ultimate profitability. As a result, a provider that has all the features required can be selected as the best logistics provider candidate. Accordingly, one should be diligent in the provider selection since each and every criterion in the machine manufacturing industry has an impact on the production process, delivery time, quality of products, and transportation market expansion. This is, however, based on the experts' judgments, and may or may not lead to the ideal solution. Moreover, difficulties in data collection in the mining industry and the large distance between the premises of mining companies poses some limitations in this study.

It is conjectured that any company, in the realm of mineral processing machinery, would meet the dominant criteria in the machinery industry. Most customers prefer to opt for domestic machineries. The machines can be produced from their own minerals up to the required standards, thereby booming the domestic market while minimizing the respective imports from the Europe and Asia.

Given the exploratory nature of the present study and its novel and innovative aspects, the research can further expand to other fields dealing with a variety of decision-making methods. Lo et al. [35] conducted a research for an electronic company, where they developed an evaluation model to address the complexities of green shopping. They used the FBWM and TOPSIS methods to solve the green supplier selection problem [23]. Other limitations of this work included the fact that the present research was focused on a single machine manufacturing company and that it drew examples based on only 8 criteria and 24 sub-criteria before being applied through the FBWM and MULTIMOORA methods utilizing 9 experts' judgments. The reason for using the fuzzy form was that the research focused on only three criteria, and since the FBWM requires fewer pair comparisons, the comparisons would be more robust and accurate. Although Lo et al. [35] based their work on 8 experts' judgments on three criteria and 10 sub-criteria, from which both works were similarly looking for selecting the best qualified supplier. In another work, environmental impact assessment (EIA) of urban industrial planning was performed in Istanbul, Turkey, where the fuzzy AHP was used instead of FBWM for measuring the criteria, and the fuzzy ELECTRE method as utilized instead of the fuzzy MULTIMOORA to rank the environmental impacts by three criteria and seven sub-criteria.

7. Conclusion

Based on the findings of the proposed research, it can be concluded that the BWM requires fewer comparative data, as compared to that in other decision-making methods, and that it provides a more reliable solution. In this research, the suggested relevant criteria and sub-criteria were weighted and the weights were utilized under a MULTIMOORA framework. The MULTIMOORA-based results out of the three rankings of the three approaches (i.e., ratio system, point of reference, full multiple) would lead to further research work to obtain further accurate results. In general, implementation of the two aforementioned decision-making methods led to the selection of the best logistics service providers with high accuracy and reliability. The statistical population was composed of three machine-design manufacturing companies, which were evaluated against 8 main criteria and 24 sub-criteria. These criteria/sub-criteria were selected based on guidelines provided in the literature. A hybrid model was formulated for ranking different logistics providers and selecting the best provider under a DSS framework using either the MULTIMOORA or the BWM MCDM technique in presence of model uncertainties. Optimal supplier selection was practiced by appropriate weighting of different criteria and quality ranking applied to mitigate the associated risks with the supply chain. The aim was to identify the decision-making system of a machine manufacturing company and then proceed to examine effective internal and external factors. Ultimately, this work provides a DSS that takes into account the previously-identified criteria and sub-criteria.

Based on the results obtained in this research, it is recommended to entertain the discussion further to other criteria such as: customer engagement, external collaboration, internal management, business growth potential, etc., most of which are yet to be considered by domestic companies. Future studies may also benefit from other emerging approaches beyond the FBWM and MULTIMOORA. This study can expand to other areas and disciplines, nevertheless. Regardless of the sector for which this study may be utilized, it can pave the way towards responding to customers' needs and demands by opting for the best supplier. Since large-scale modeling requires cumbersome computations, appropriate software design can facilitate the problem-solving process more effectively. Given the multitude of models available for decision-making, it is also recommended to evaluate the proposed research process using other models and to compare the results in an objective manner.

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Appendix

Appendix 1

Linguistic terms and corresponding fuzzy numbers

Code	Priorities	Fuzzy Phase of priorities		
		Lower limit	Medium limit	Upper limit
1	Equally importance	1	1	1
2	Equally to Fairly Important	1	2	3
3	Fairly Important	2	3	4
4	Fairly Important to Very important	3	4	5
5	High important	4	5	6
6	High to very high importance	5	6	7
7	very high importance	6	7	8
8	very high importance to Absolutely important	7	8	9
9	Absolutely important	8	9	10

Appendix 2

Measurement Scale

0	1	3	5	7	9	10
	too much	much	medium	little	very little	

Appendix 3

Paired comparison of the main criteria

	criteria							
BO	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
G	(6.604, 7.612, 8.618)	(2.52, 3.557, 4.579)	(1.587, 2.621, 3.634)	(2, 3107, 4.16)	(4, 5,6)	(2.52, 3.557, 4.579)	(1,1,1)	(1.26, 7.612, 3.302)

	criteria							
OW	A	B	C	D	E	F	G	H
A	(1,1,1)	(1.817,2.884,3.915)	(2.289, 3.42, 4.481)	(2.289, 2.714, 3.107)	(1,2,3)	(2.52, 3.557, 4.579)	(6.604, 7.612, 8.618)	(2.621, 3.634, 4.642)

Appendix 4

Weighted Normal Matrix

Alternatives	a1	b1	b2	b3	c1	c2
X1	(0.002,0.006,0.01)	(0.01,0.016,0.022)	(0.002,0.003,0.005)	(0.005,0.009,0.012)	(0.004,0.007,0.01)	(0.001,0.004,0.006)
X2	(0.01,0.014,0.018)	(0.016,0.022,0.029)	(0.003, 0.005, 0.006)	(0.005,0.009, 0.012)	(0.004, 0.007, 0.01)	(0.004, 0.006, 0.008)
X3	(0.01, 0.014, 0.018)	(0.016, 0.022, 0.029)	(0.003, 0.005, 0.006)	(0.009, 0.012, 0.016)	(0.007, 0.01, 0.013)	(0.008, 0.011, 0.013)
	c3	**c4**	**d1**	**e1**	**e2**	**f1**
X1	(0.008, 0.013, 0.019)	(0.001, 0.002, 0.003)	(0.029, 0.041, 0.053)	(0.016, 0.022, 0.028)	(0.004, 0.006, 0.008)	(0.013, 0.018, 0.023)
X2	(0.008, 0.013, 0.019)	(0.002, 0.003, 0.004)	(0.018, 0.029, 0.041)	(0.009, 0.016, 0.022)	(0.003, 0.004, 0.006)	(0.013, 0.018, 0.023)
X3	(0.019, 0.024, 0.029)	(0.003, 0.004, 0.005)	(0.006, 0.018, 0.029)	(0.003, 0.009, 0.016)	(0.001, 0.003, 0.004)	(0.013, 0.018, 0.023)
	f2	**f3**	**f4**	**f5**	**g1**	**g2**
X1	(0.005, 0.007, 0.009)	(0.003, 0.004, 0.006)	(0.001, 0.002, 0.003)	(0.003, 0.005, 0.006)	(0.009, 0.015, 0.021)	(0.005, 0.008, 0.012)
X2	(0.005, 0.007, 0.009)	(0.003, 0.004, 0.006)	(0.001, 0.002, 0.003)	(0.003, 0.005, 0.006)	(0.009, 0.015, 0.021)	(0.005, 0.008, 0.012)
X3	(0.003, 0.005, 0.007)	(0.004, 0.006, 0.008)	(0.002, 0.003, 0.004)	(0.002, 0.003, 0.005)	(0.015, 0.021, 0.27)	(0.008, 0.012, 0.015)
	g3	**g4**	**g5**	**g6**	**h1**	**h2**
X1	(0.008, 0.014, 0.019)	(0.001, 0.004, 0.006)	(0.009, 0.014, 0.02)	(0.026, 0.041, 0.058)	(0.007, 0.021, 0.036)	(0.004, 0.007, 0.009)
X2	(0.014, 0.019, 0.024)	(0.006, 0.009, 0.012)	(0.009, 0.014, 0.014)	(0.025, 0.041, 0.058)	(0.021, 0.036, 0.05)	(0.007, 0.009, 0.012)
X3	(0.014, 0.019, 0.024)	(0.004, 0.004, 0.009)	(0.014, 0.02, 0.026)	(0.025, 0.041, 0.058)	(0.021, 0.036, 0.05)	(0.007, 0.009, 0.012)