A FUZZY MODELLING OF A HYBRID MCDM METHOD FOR SUPPLIER SELECTION

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Abstract

This article examines the significance of supplier selection in the procurement process, which has grown in prominence as a result of globalization and outsourcing. When selecting the best suppliers, supply chain managers must consider a variety of quantitative and qualitative aspects, as these have a substantial impact on supply chain performance. Multi-criteria decision-making (MCDM) approaches can help in this process by taking into account many competing considerations. However, due to uncertainties and ambiguity, supplier selection is a complex process, and fuzzy multi-criteria decision-making approaches can be used to determine the best supplier for the company's key operations. This research suggests a hybrid MCDM strategy that makes use of fuzzy modeling to help with complex decision-making processes. Organizations can improve their supply chain performance by selecting the best supplier based on numerous parameters such as cost, quality, delivery time, and supplier reputation.

Keywords: Fuzzy Model, Hybrid MCDM Method, supplier selection

Discipline: Engineering Sciences

Absztrakt

EGY HIBRID MCDM-MÓDSZER FUZZY MODELLEZÉSE A BESZÁLLÍTÓK KIVÁLASZTÁSÁHOZ

Jelen tanulmány a beszállítók kiválasztásának jelentőségét vizsgálja a beszerzési folyamatban, amely a globalizáció és a kiszervezés következtében egyre nagyobb jelentőségre tett szert. A legjobb beszállítók kiválasztásakor az ellátási lánc vezetőinek számos mennyiségi és minőségi szempontot kell figyelembe venniük, mivel ezek jelentős hatással vannak az ellátási lánc teljesítményére. A többkritériumos döntéshozatal (MCDM) megközelítések számos egymással versengő szempont figyelembevételével segíthetnek ebben a folyamatban. A bizonytalanságok és a többértelműség miatt azonban a beszállító kiválasztása összetett folyamat, és a fuzzy többkritériumú döntéshozatali megközelítések segítségével meghatározható a vállalat kulcsfontosságú műveleteihez legmegfelelőbb beszállító. Ez a kutatás egy hibrid MCDM stratégiát javasol, amely a fuzzy modellezést használja fel a komplex döntéshozatali folyamatok segítésére. A szervezetek számos paraméter, például a költségek, a minőség, a szállítási idő és a beszállító hírneve alapján a legjobb beszállító kiválasztásával javíthatják ellátási láncuk teljesítményét.

Kulcsszavak: Fuzzy modell, hibrid MCDM módszer, beszállító kiválasztás

Diszciplína: Mérnöki tudományok

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Introduction

A supply chain is made up of a complicated series of processing phases that range from raw material suppliers to part production, component and end-product assembly, and product distribution (Wu & Olson, 2008). In the context of supply chain management, supplier selection is regarded as one of the most important concerns that operations and purchase managers must address in order to remain competitive. Supplier selection and management can be used to a wide range of suppliers, from initial raw material purchase to end-of-life service providers. As a result, the breadth and diversity of providers complicate the process even further (Bai & Sarkis, 2010).

With globalization and the creation of the extended business of interdependent organizations, the outsourcing of components and services has steadily increased. As a result, corporations have priorityzed the purchasing function and the decisions that go with it. Because these decisions necessitate a long-term commitment and have an impact on the sector's strategic positioning, choosing the right supplier is one of the most critical issues. Supplier selection is a multi-criteria challenge with both tangible and intangible aspects to consider. According to de Boer et al. (2001), the supplier selection process includes several stages, including problem definition, decision criteria formulation, pre-qualification of possible providers, and final selection. The final quality is heavily influenced by the quality of all processes involved in the selecting process. According to the extensive supplier selection literature, the following features must be considered while resolving the supplier selection problem (Chen et al., 2006).

First, the supplier selection process necessitates the consideration of many conflicting criterias.

Second, many decision-makers are frequently involved in the decision-making process.

Third, in practice, ambiguity frequently influences decision-making. Supplier selection is a critical multi-criteria decision making (MCDM) challenge due to the necessity to trade-off various factors that exhibit ambiguity and imprecision.

Classical MCDM methods that consider deterministic or random processes are ineffective for dealing with decision issues that include imprecise and linguistic input. Fuzzy set theory is an effective tool for dealing with uncertainty and ambiguity.

The goal of this study is to propose a fuzzy multi-criteria group decision making approach based on the Kesselring and AHP methodologies with the fusion of fuzzy information. In the supplier selection process, the company's ultimate goal is to have access to suppliers who guarantee a certain quality standard in terms of the characteristics of the purchased products or services (Bevilacqua, Ciarapica, & Giacchetta, 2006). Thus, building a house of quality (HOQ) is critical to determining how well each supplier characteristic succeeds in meeting the standards established for the product(s) being purchased.

Multi Criteria Decision Making (MCDM)

Because of the emphasis on outsourcing, strategic partnering, strategic alliances, and relationship marketing during the last two decades, many businesses have purchased not only raw materials and basic supplies, but also complicated fabricated components with very high value-added content and services. Supplier selection or evaluation is a critical component of the industrial purchasing process and appears to be one of the principal responsibilities of the professional industry (Patton, 1997), (Michaels et al., 1995). Choosing an ideal supplier is frequently a difficult undertaking requiring careful consideration of numerous aspects. However, many decision makers or experts choose suppliers based on their experience and intuition. These approaches are obviously subjecttive, and their shortcomings have been addressed in prior research (Yoon & Hwang, 1995; Kontio, 1996). Alternatively, multiple criteria decision-making (MCDM) or multiple attributes decision-making (MADM) is a method for ranking and selecting one or more suppliers from a pool of providers. Based on the evaluation of numerous conflict factors, the MCDM provides an effective framework for vendor comparison. (de Boer et al., 2001) provided an excellent review and classification of the MCDM approach for supplier selection. The analytic hierarchy process (AHP) is currently frequently utilized by both researchers and professionals to manage the difficulties of determining a vendor's performance on one criterion or the importance of some criterion with a high degree of precision (Ghodsypour & O'Brien, 1998; Min, 1992). Ghodsypour and O'Brien (1998) contend that AHP is more accurate than other supplier selection score techniques. The methodology is theoretically useful when the decision-making framework has a unidirectional hierarchical relationship between decision levels. However, Carney and Wallnau (1998) point out that alternative evaluation criteria are not necessarily independent of one another, but frequently interact with one another. In such a complex setting, an invalid outcome is possible. Furthermore, AHP is impractical when the number of choices and criteria is enormous, because the repetitive assessments may produce decision-making fatigue (Briand, 1998).

Although many methods like Data envelopment analysis (DEA), heuristics, analytic hierarchy process (AHP), fuzzy AHP, fuzzy goal programming, fuzzy analytic network process (ANP), and other mathematical techniques can be used to evaluate providers. When evaluating and selecting suppliers, both qualitative and quantitative variables must be addressed. Thus, supplier selection is a multiple criteria decision making (MCDM) problem that must be addressed using MCDM methodologies. The emphasis here is on the relationships between components. In Sustainable Engineering, standard decision-making methods are utilized in conjunction with theories of uncertainty such as the fuzzy approach, grey rough method, and so on (Stoji et al., 2019).

There is no specific and optimum strategy to evaluate suppliers because the criteria vary from company to company and there are a variety of approaches.

Fuzzy MCDM

Zadeh's (1965) fuzzy set theory has been widely employed to objectively represent ambiguities in human judgment and successfully resolve uncertainties in available information in an ill-defined multiple criteria decision making environment.

A fuzzy MCDM model is used by a committee of decision makers to assess alternatives versus selected criteria, where the suitability of alternatives versus criteria, as well as the importance weights of criteria, can be evaluated in linguistic values represented by fuzzy numbers (Shu-Jen Chen et al., 1992). To solve fuzzy MCDM challenges, numerous ways have been presented. Many of these strategies are reviewed and compared in (Shu-Jen Chen et al., 1992; Carlsson & Fullér, 1996; Ribeiro, 1996; Triantaphyllou & Lin, 1996). Some recent applications can be found in (Al-Najjar & Alsyouf, 2003; Chen et al., 2006; Chen, 2001; Chen & Chiou, 1999; Chou, 2007; Chou et al., 2006; Chou, 2006; Wang et al., 2008; Tsaur et al., 2002; Liang, 1999; Kahraman et al., 2003; Yeh et al., 1999).

As a result, decision makers augment traditional MCDM methods with various types of fuzzy sets, such as type-1 fuzzy sets, type-2 fuzzy sets, Hesitant Fuzzy Sets(HFS), and Intuitionistic Fuzzy Sets(IFS). Fuzzy MCDM approaches provide for more realistic outcomes in decision-making issues. Fuzzy sets are typically employed with Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodologies. To reach more sensitive solutions, it has been observed that fuzzy Multicriteria Optimization and Compromise Solution (VIKOR), fuzzy Elimination and Choice Expressing the Reality (ELECTRE), fuzzy Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), fuzzy Axiomatic Design (AD), and fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) methods are used.

Fuzzy MCDM for Supplier Selection

Many real-world decision-making applications, such as supplier selection, inevitably entail the examination of data based on multiple factors, rather than a favored single criterion. Many researchers have worked on multi-criteria decision-making (MCDM) problems (Bouyssou, 1986; Gal and Hanne, 2006; Narasimhan and Vickery, 1988; Shyur and Shih, 2006; Wadhwa et al., 2009). The usage of fuzzy sets theory (FST) is required due to the flexibility required to cope with unclear information.

There have been numerous papers published on MCDM based on FST (Ashtiani et al., 2009, Chu and Lin, 2009, Deng and Liu, 2005a, Deng and Liu, 2005b, Deng, 2006, Hu, 2009, Hanaoka and Kunadhamraks, 2009, Olson and Wu, 2006, Wu and Olson, 2008, Yang et al., 2008, Yeh and Chang, 2009, Zhang et al, 2005). However, in many issues, human judg-ment is unreliable, and it is difficult for the decision-maker (DM) to offer precise numerical values for the criteria. As a result, most of the selection parameters cannot be presented explicitly, and the DMs frequently convey the evaluation data of the alternative suppliers' appropriateness for various subjective criteria and the weights of the criteria in language terms. It is also acknowledged that human assessment on qualitative characteristics is always subjective and thus imprecise. Fuzzy logic may be a more natural technique to modeling this type of uncertainty in human desire.

Method and Material

Which method we used in here and why:

Focus of the Research is to find the methods of Evaluating Qualitative data of Suppliers in SCM of Food chain industry. For Qualitative approach of MCDM specific Ordered Quality Scale, assessed for Each Criteria. This approach is applicable only to Clinical Diagnosis, Quality control and Customer satisfaction in any process. (González del Pozo, Dias, & García-Lapresta, 2020) It has been Observed in Research AHP is used most in Complex Decision Making rather than correct one. Limitation of AHP is described as its only applicable for Human Perception rather than actual Decision making which can be vary from person to person Another Limitation is that its only applicable for the comparison of 39 Suppliers at one Time. (Meng, 2010; Patil et al., 2016) AHP is defined as the method of "Multi Objective Ranking procedure" AHP is based on Multi Objective Utility Theory It used Pairwise Comparison of Different Criteria's and Sub Criteria's as well in the Hierarchal approach and Supplier is Selected based on Weights given to each Supplier according to predefined Criteria's (Alazzawi & Żak, 2020).

During the Research of Sustainable Supplier Selection formulation new Hybrid model has been formed, in which the Sustainability of Suppliers has been analysed with the Model of Kesselring pairwise comparison which used for Weighting the Criteria, and while the Alternative has been analysed with AHP matrix with Machine learning algorithms as well.

To implement the proposed method, we have used the Python programming language and the scikit-fuzzy library. The method is based on assigning weights to different criteria and calculating the weighted sum of each alternative using fuzzy logic. We have also cleaned the data to ensure that the results obtained are accurate and reliable.

Data description

The dataset used in this study contains information about deliveries of raw cashew nuts from the bush to port warehouses. The dataset spans three years and has around 200 arrivals per year. The aim of this study is to propose a method for multi-criteria decision making using fuzzy logic.

The dataset contains several attributes related to the delivery of cashew nuts, including the date of arrival, vehicle identification number, number of bags found in delivery, net weight of cashew nuts, origin ID, supplier ID, moisture percentage, nut count per kilogram, quality metric, rate of defective kernels, year, month, and day.

Kesselring

Fritz Kesselring pioneered the Product Comparison technique in 1953. This method was mostly utilized for assessing technical aspects that can be determined using a ratio or interval factors. Because we know that the units of each parameter varied, some common factors were assumed to fix this. Kesselring discussed and addressed this challenge by comparing the data of the products under inquiry to the data of the best product with a predetermined ideal value. These were the best data and received a score of 4.

Kesselring is a 0-5 scale metric that compares the actual value of a product to the ideal value. It is explained as

- 5 points – Excellent
- 4 points – Very Good
- 3 points – Good
- 2 points – Satisfying
- 1 points – Acceptable
- 0 points – Insufficient

After collection of data, Kesselring is used to calculate the technical value of complex systemsas:

$$\mathbf{X} = \frac{\frac{\sum_{i=1}^{n} Pi}{n}}{Pmax} = \frac{\overline{P}}{Pmax}$$

Where

X – technical value of

Pi – point value of parameters P – arithmetic mean

P_{max} – point value of ideal solution

n– number of technical parameters

Each parameter has a unique unit. Kesselring created a scale with dimensions that have a common denominator. The downside of this strategy is that it does not take into account the varied weights of parameters.

The Kesselring Weighing Method was used to solve it. The weighted factor of parameter 'v_i' was coded on a scale of 0-10. Taking the weight of parameters into account, the technical values of the product were computed as follows:

$$\acute{\mathbf{x}} = \frac{\sum vi \times pi}{\sum pmax \times vi}$$

Here, $\acute{\mathbf{x}}$ can be up to 1 for complex system value.

Kesselring is also used for product ranking, both relative and absolute. The system's complexity is measured as:-

- $1 \geq \acute{\mathbf{x}} \geq 0.8$ = system is very good
- $0.8 \geq \acute{\mathbf{x}} \geq 0.6$ = system is good
- $0.6 \geq \acute{\mathbf{x}} \geq 0.5$ = system is appropriate
- $\acute{\mathbf{x}} \leq 0.5$ = system is unsatisfactory

The Kesselring approach was originally intended to measure machine tools, but it may easily be applied to a complicated system. To be effective, this method was created to work on assessment factors that may be quantified on a ratio and interval scale. This approach is a scoring method in which the systems are not interconnected in comparison to an ideal system in order to obtain an order of preference. From a standpoint, it is a challenge since an ideal system can be specified in either its original or modified form.

The steps for matching procedures are as follows:

1. Select an alternative
2. Select evaluation criteria
3. Specify the target function. For instance, Minimum for better smaller values and Maximum for better greater value functions.
4. Specify the scale-based rating factor value.
5. Determine the weight of the rating factor. For instance, a pair-based or preference-based comparison.

Analytical Hierarchy Process AHP

AHP is a strategy for ranking choice alternatives and picking the best one when the decision maker has several criteria (Taylor, 2004). It answers the question, "Which one?" With AHP, the decision maker selects the alternative that best fulfills his or her choice criteria, creating a numerical score to rank each decision alternative depending on how well each alternative meets them. In AHP, preferences between alternatives are generated by pairwise comparisons in which the decision maker assesses two alternatives using one criterion and signals a preference. These comparisons are done using a preference scale, which assigns numerical values to different levels of preference (Taha, 2003). The usual preference scale for AHP is a 1-9 scale that ranges from "equal importance" to "extreme importance," while various evaluation scales, such as 1 to 5, may be employed at times. In the pairwise comparison matrix, the value 9 indicates that one component is extremely more significant than the other, the value 1/9 indicates that one element is extremely less essential than the other, and the value 1 shows equal importance (Sarkis ve Talluri, 2004). As a result, if the importance of one element in relation to another is stated, the importance of the second factor in relation to the first is the reciprocal. Weighting quantifiable and non-quantifiable elements is done using a ratio scale and verbal comparisons (Pohekar ve Ramachandran, 2004). Saaty (1980) proposed AHP as a decision aid to help address unstructured problems in economics, social sciences, and management sciences since 1977. AHP has been used in a wide range of circumstances, from the simple everyday challenge of selecting a school to the difficult problems of planning alternative future outcomes for a growing country, evaluating political candidate, allocating energy resources, and so on. The AHP enables decision-makers to structure a complicated problem in the shape of a simple hierarchy and to evaluate a large number of quantitative and qualitative aspects in a systematic manner under different criteria environments in conflict (Cheng et al,1999).

According to (Cheng et al, 1999), the application of the AHP to a complicated problem typically comprises four major steps:

1. Divide the complex problem into a number of minor constituent elements, then organise the elements hierarchically.
2. Perform a series of pair-wise comparesons between the items using a ratio scale.
3. Calculate the relative weights of the items using the eigenvalue approach.
4. Add these relative weights together and synthesis them for the final assessment of the offered decision possibilities.

The AHP is a robust and adaptable multi-criteria decision-making technique for dealing with complicated problems that require both qualitative and quantitative considerations. It assists analysts in organizing the important components of a problem into a tree-like hierarchy (Bevilacqua et al, 2004). The essence of the process is the breakdown of a complicated problem into a hierarchy with the aim (criterion) at the top, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision options at the bottom. Elements at different levels of the hierarchy are compared in pairs to determine their relative preference with respect to the elements at the next higher level.

The approach computes and aggregates the eigenvectors of the alternatives until the composite final vector of weight coefficients is obtained. The final weight coefficients vector entries represent the relative relevance (value) of each choice in relation to the aim stated at the top of the hierarchy (Pohekar and Ramachandran, 2004).

This vector can be used by a decision maker based on his or her specific needs and interests. To elicit paired comparisons at a given level, a matrix A is generated by inserting the result of the pairwise comparison of element i with element j into position aji, as shown below.

$$
\mathbf{A} = \begin{array}{c} \\ C1 \\ C2 \\ C3 \\ C4 \\ \ldots \\ Cn \end{array}
\begin{array}{c} \begin{array}{cccccc} C1 & C2 & C3 & C4 & \ldots & Cn \end{array} \\
\begin{bmatrix}
1 & a12 & a13 & a14 & \ldots & a1n \\
a21 & 1 & a23 & a24 & \ldots & a2n \\
a31 & a32 & 1 & a34 & \ldots & a3n \\
a41 & a42 & a43 & 1 & \ldots & a4n \\
\ldots & \ldots & \ldots & \ldots & 1 & a5n \\
an1 & an2 & an3 & an4 & \ldots & 1
\end{bmatrix} \end{array}
$$

Where

n = criteria number to be evaluated

C_i= i. criteria,

A_{ij} = importance of i. criteria according to jth criteria

After obtaining the weight vector, it is multiplied by the weight coefficient of the element at a higher level (which was used as a criterion for pairwise comparisons). The technique is continued for each level until the top of the hierarchy is reached (Saaty, 1994). The overall weight coefficient with respect to the aim for each decision alternative is then calculated. The best alternative is the one with the highest weight coefficient value. Saaty's AHP is a well-known decision-making analytical method used for modeling unstructured situations in a variety of fields, including social, economic, and management sciences (Bard and Sousk, 1990; Triantaphyllou and Mann, 1995; Wabalickis, 1988).

Result

How to apply Kesselring and AHP

In the Research calculations made based on the following steps:

First for implications of MCDM methods we must Choose the number of alternatives in which It is applied.

Here we have 6 alternatives. We have used the Pairwise comparison for Criteria ranking and to Normalized it (Table 1-6).

After the normalization of the dataset based on the Criteria, we constructed the AHP basic matrix for 6 criteria and then the Consistency Ratio have been calculated in order to determine if the weight assign in the pairwise matrix is either consistent or not as it's based on the human perception its always important to check the CR during AHP calculations.

After the application of AHP matrix to the dataset we have got the results as the Highest weight is given for Quality of Outruns as 0.25, Qty number of nuts supplied as 0.23, and 0.18 to number of deliveries made in each period and other 3 criteria had less weightage.

Table 1. Performance Of Criteria by Pairwise Comparison. Source: Authors.

Variable	**Price**	**Defect**	**Moisture**	**Quality (outturn)**	**Qty ie the no of nuts supplied**	**Number of deliveries made in a given period**
Price	1	1/5	3	1/5	3	1/7
Defect	5	1	1/5	1/3	1/7	1/3
Moisture	1/3	5	1	1/3	5	1/5
Quality (outturn)	5	3	3	1	1/3	7
Qty ie the no of nuts supplied	1/3	7	1/5	3	1	3
Number of deliveries made in a given period	7	3	5	1/7	1/3	1
Total	**18.67**	**19.20**	**12.40**	**5.01**	**9.81**	**11.68**

Table 2. Normalized Criteria. Source: Authors.

Variable	Price	Defect	Moisture	Quality (outturn)	Qty ie the no of nuts supplied	Number of deliveries made in a given period	Average
Price	0.05	0.01	0.24	0.04	0.31	0.01	0.11
Defect	0.27	0.05	0.02	0.07	0.01	0.03	0.07
Moisture	0.02	0.26	0.08	0.07	0.51	0.02	0.16
Quality (outturn)	0.27	0.16	0.24	0.20	0.03	0.60	0.25
Qty ie the no of nuts supplied	0.02	0.36	0.02	0.60	0.10	0.26	0.23
Number of deliveries made in a given period	0.38	0.16	0.40	0.03	0.03	0.09	0.18

Table 3. AHP Basic Matrix for Criteria. Source: Authors.

Variable	Price	Defect	Moisture	Quality (outturn)	Qty ie the no of nuts supplied	Number of deliveries made in a given period
Price	1.00	0.20	3.00	0.20	3.00	0.14
Defect	5.00	1.00	0.20	0.33	0.14	0.33
Moisture	0.33	5.00	1.00	0.33	5.00	0.20
Quality (outturn)	5.00	3.00	3.00	1.00	0.33	7.00
Qty ie the no of nuts supplied	0.33	7.00	0.20	3.00	1.00	3.00
Number of deliveries made in a given period	7.00	3.00	5.00	0.14	0.33	1.00
Wi	0.11	0.07	0.16	0.25	0.23	0.18

Table 4. CR during AHP calculations. Source: Authors.

Variable	Price	Defect	Moisture	Quality (outturn)	Qty ie the no of nuts supplied	Number of deliveries made in a given period	Sum of Row	WI	Ratio
Price	0.11	0.01	0.48	0.05	0.68	0.03	1.36	0.11	12.25
Defect	0.55	0.07	0.03	0.08	0.03	0.06	0.84	0.07	11.24
Moisture	0.04	0.37	0.16	0.08	1.13	0.04	1.82	0.16	11.45
Quality (outturn)	0.55	0.22	0.48	0.25	0.08	1.26	2.84	0.25	11.37
Qty ie the no of nuts supplied	0.04	0.52	0.03	0.75	0.23	0.54	2.11	0.23	9.31
Number of deliveries made in a given period	0.77	0.22	0.79	0.04	0.08	0.18	2.08	0.18	11.54

Table 5. Consistency Ratio Calculations. Source: Authors.

Lmx	11.19
Ci = (Lmax-n)/n-1	4.19
	0.6989319
Cr (Consistent CR<1)	0.529493863

Table 6. Rank list of alternatives. Source: Authors.

Rank	Price	Defect	Moisture	Quality (outturn)	Qty ie the no of nuts supplied	Number of deliveries made in a given period	Weighted Sum
1	0.333	5.0	1.0	0.333	5.000	0.200000	13.389735
2	0.333	7.0	0.2	3.000	1.000	3.000000	10.435238
3	7.000	3.0	5.0	0.142	0.333	1.000000	7.641270
4	5.000	3.0	3.0	1.000	0.333	7.000000	7.024603
5	1.000	0.2	3.0	0.200	3.000	0.142857	6.616417
6	5.000	1.0	0.2	0.333	0.142	0.333333	1.625147

Application of Fuzzy on the obtained data

The obtained data was used with fuzzy logic to calculate the weighted sum of each alternative. Fuzzy logic was used to handle the uncertainty and imprecision associated with the decision-making process. The criteria were weighted equally, and the membership functions for each criterion were determined using fuzzy sets (Figure 1 and Figure 2).

Figure 1. The box plots for each criterion. Source: Authors.

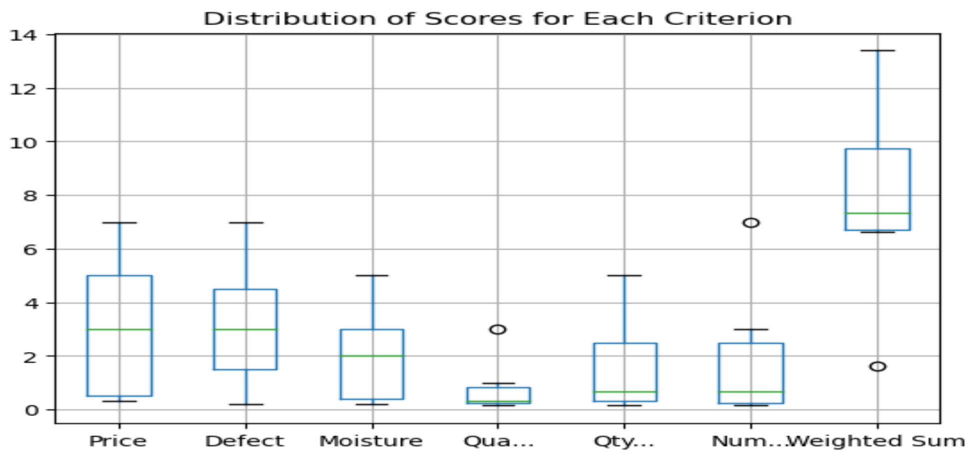
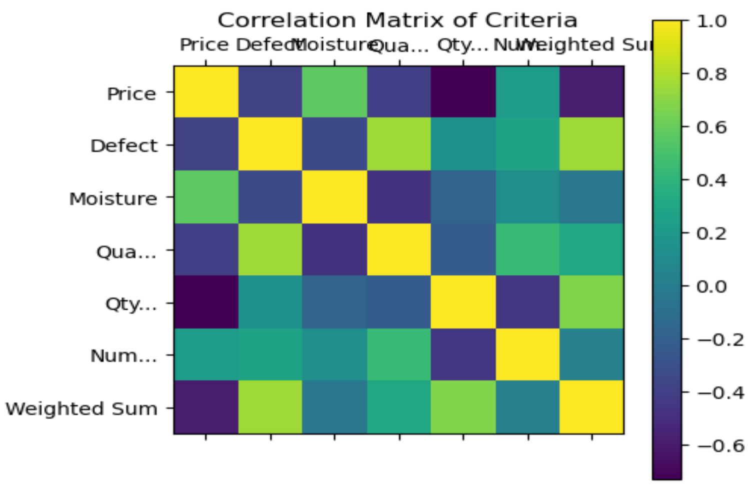


Figure 2. A correlation matrix for the criteria. Source: Authors.



The weighted sum of each alternative was calculated using the following formula:

$$Weighted\ Sum = (w_1 \times (mf_1 \times v_1 + mf_2 \times v_2 + mf_3 \times v_3)) + (w_2 \times (mf_4 \times v_4 + mf_5 \times v_5 + mf_6 \times v_6)) + \ldots + (w_n \times (mf_7 \times v_n + mf_n + 1 \times v_n + 1 + mf_n + 2 \times v_n + 2))$$

Where $w_1, w_2, \ldots, w_n$ are the weights of the criteria, $mf_1, mf_2, \ldots, mf_{n+2}$ are the membership functions of the fuzzy sets for the criteria, $v_1, v_2, \ldots, v_{n+2}$ are the values of the alternatives for the criteria.

The result of the fuzzy MCDM on the dataset is a ranked list of alternatives based on their weighted sum. The top-ranked alternative has the highest weighted sum and is considered the best alternative. The ranked list of alternatives is shown below (Table 6).

Conclusion

In conclusion, the proposed Fuzzy-AHP-Kesselring Hybrid MCDM method, used to rank alternatives based on multiple criteria handles uncertainty and imprecision associated with the decision-making process. Overall, a fuzzy modeling of a hybrid MCDM for supplier selection would provide a comprehensive and objective approach to selecting suppliers based on a range of performance criteria, while also accounting for the uncertainty and imprecision that often arises in real-world decision-making scenarios. The results provide useful information for decision-makers to select the best alternative based on their preferences and requirements. Overall, the future scope of our research is broad, and there is significant potential for further development and application of this methodology in different contexts.

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