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Evaluation of Performance of Chicken Meat Suppliers Using Fuzzy-MCDM Method (Case Study: Arak City-Iran)

A. Etebari[a], R. Arab[b,*] and M. Amirkhan[c]

[a]*Department of Industrial Engineering, Aliabad Katoul Branch, Islamic Azad University, Aliabad Katoul, Iran,*
[b]*Department of Industrial Engineering, Gorgan Faculty of Engineering, Golestan University, Gorgan, Iran,*
[c]*Department of Industrial Engineering, Aliabad Katoul Branch, Islamic Azad University, Aliabad Katoul, Iran.*

Abstract. Performance management encompasses important activities aimed at fostering effective and efficient behaviors within an organization. Performance evaluation, as one of the tools of performance management, can serve as a robust foundation for decision-making concerning personnel affairs, such as promotions, transfers, demotions, dismissals, and salary increases or decreases. Performance evaluation indicators for chicken meat suppliers in the city of Arak were identified. To collect opinions of chicken meat store managers (24 stores), instruments such as questionnaires were employed. Fuzzy Likert Scale (FLS) was utilized to convert verbal data obtained from the questionnaires. Following the validation of the questionnaire, fuzzy set theory and fuzzy decision-making techniques were used to rank the studied suppliers (six suppliers). Data analysis in MATLAB determined that Supplier 6 (Dorsa Chicken Company) exhibited the best performance, while Supplier 2 (Fakhrar Company) demonstrated the poorest performance.

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1. Introduction

Performance refers to employees' efforts to accomplish their tasks or achieve predetermined goals [60]. Every job entails responsibilities that must be carried out according to defined standards [52]. The history of performance evaluation dates back to ancient times [2]. As soon as humans initiated group living and established a rudimentary form of division of labor, some form of evaluation was implicitly implemented [27]. However, formalized evaluation systems emerged in the 19th century, when very basic tools were employed to assess the qualitative level of organizations [43]. In the present era, performance evaluation has evolved significantly compared to the past and has aligned with the evolving paradigms of management thought, its nature, and functions [54]. In the

*Corresponding author. Email: r.arab@gu.ac.ir

competitive environment business and organizations face fundamental issues and challenges. In a dynamic environment, organizational managers need to employ a comprehensive and integrated model for managing their organization's performance, encompassing all key and influential aspects of the organization [8,33].

A performance measurement system is a combination of performance attributes designed to create a conceptual framework for helping evaluators. Using these systems is recommended for facilitating strategy implementation and organizational performance enhancement [15]. The performance management system is a system that delineates performance planning, program formulation, program execution, evaluation using assessment systems, and ultimately performance enhancement through corrective actions based on feedback of the performance evaluation phase [26,38]. In the past, supply chains were managed in a traditional and operational manner with an emphasis on cost reduction [4]. Over the past two decades, businesses have realized the need for more effective strategies to enhance competitiveness within supply chains, wherein attention is given not only to costs but also to other attributes [10,19]. One of the most renowned and common methods for performance evaluation is Multi-Criteria Decision Making (MCDM) techniques [22,55], which is used in this research.

2. Problem statement

The food supply chain is one of the most complex and extensive sectors of the global industry, where ensuring food safety and quality is always a priority [30]. Many experts believe that in today's competitive world, competition has shifted from the company level to competition among their supply chains [23]. For business success, the supply chain requires continuous improvement [16]. To achieve this, we needed to evaluate the performance of various segments of the supply chain, including suppliers' performance [59]. Nili (2005) stated that performance measurement is a topic that has been extensively discussed, yet there are a few definitions of it. Therefore, he describes performance measurement as the quantification process of describing activities [48]. The comprehensive measurement process of businesses' performance using terms such as efficiency, effectiveness, empowerment, and responsiveness, within the framework of management scientific principles and concepts, to achieve organizational goals and tasks through executable plans, is termed performance evaluation [61]. Evaluating the performance of companies has always posed challenging issues in management domains. The measurement of efficiency, especially in the last two decades, has received significant attention due to its importance in performance assessment [50]. Since Farrell introduced a method for measuring efficiency in 1957, comprehensive and fundamental revisions have been made in the field of efficiency measurement. Furthermore, both parametric and non-parametric approaches are extensively utilized in assessing efficiency [5].

3. Literature review

Islam and Rasad (2006) proposed a model for evaluating employee performance using the Analytic Hierarchy Process (AHP) in an article titled "performance evaluation of employees using hierarchical analysis process." The main dimensions of performance evaluation included job quality, planning, innovation and commitment, teamwork, communication, and external factors [34]. Simmons (2008) studied the process management model of performance management. The model provided a holistic and higher-level perspective on the measurement and improvement of performance, addressing questions regarding how performance management should be carried out [57].

Austin and Beskese (2009) proposed a hierarchical model for assessing the performance of administrative employees. The main dimensions of the model encompassed job knowledge, job quality, efficiency and accuracy, analytical skills for

problem definition and solving, initiative, innovation and creativity, teamwork and collaboration, interpersonal and communication skills, customer relationship, and cost-effectiveness [20]. A hybrid model was used by Wu (2009) consisting of the data envelopment analysis (DEA), a decision tree (DT), and an artificial neural network (ANN) in a paper to evaluate suppliers. For this purpose, suppliers were first divided into efficient and inefficient classes, and data were then employed to train the DT and the ANN. Finally, the trained DT was utilized for new suppliers [62].

Manian et al. (2011) employed a combined fuzzy model for evaluating the performance of units within a gas company. The combined model involved TOPSIS and the Balanced Scorecard (BSC) method on IT units in the gas company [45]. Yakovleva et al. (2011) introduced a new method for measuring the stability of the supply chain. The researchers considered five distinct stages for evaluating the food supply chain. The indicators employed in this study included energy consumption, water consumption, employment figures, wage levels, and import reduction. The proposed framework was executed with the assistance of potato and poultry experts from England, utilizing the AHP method [63]. Mahaghar et al. conducted a study on the supplier selection. The method employed to calculate supplier efficiency involved a combined approach of Data Envelopment Analysis (DEA) and the VIKOR method [47]. Azizi et al. (2015) tried to identify the most crucial criteria and sub-criteria for suppliers in the automotive industry. They used the FTOPSIS technique to determine the best supplier. They demonstrated that the score obtained using the FTOPSIS method for the best supplier showed a significant gap from the scores of other suppliers [3]. Pitchipoo et al. (2018) addressed the supplier selection issue. They utilized a combined approach involving Data Envelopment Analysis (DEA), Shannon entropy, and the Analytic Hierarchy Process (AHP) to evaluate suppliers in a chemical company and ultimately determine the best alternative [51]. Jafari and EhsaniFar (2020), investigated some commonly used techniques in Multi-Criteria Decision Making (MADM) problems. They focused on extending the VIKOR method under uncertain conditions. The proposed method in this study was able to evaluate decision alternatives under interval conditions, and this capability was demonstrated through a numerical example [36].

In 2020, Fallah evaluated the performance of petrochemical companies in an article. Stock from the perspective of health indicators. In this study, using two-stage data envelopment analysis technique, the efficiency and effectiveness of petrochemical companies, were investigated from a health point of view and was done by using health indicators. The results show that Maroon and Jam petrochemical companies have been more efficient than other well-known companies and the Shazand Petrochemical Company in the second part of achieving the final result. Of the seven petrochemical companies in total, none have had full productivity, but Maroon and Jam Petrochemicals have been targeted first and second in productivity, respectively [21].

4. Importance and necessity of the research

The food industry comprises a complex network of activities related to food supply, consumption, and preparation of food and food services [58]. This sector plays a crucial role in the economic development of any country. Food industries are among the most dynamic economic sectors worldwide, and food is an essential part of our lives [28]. Performance evaluation and more broadly, performance management, is a process through which valuable information and insights can be obtained about how to effectively perform tasks, reinforce positive behaviors, and eliminate unnecessary behaviors [35]. In addition to providing informative feedback, performance evaluation serves other important functions, one of which is identifying training needs and developing human resources [49]. Therefore, evaluating the performance of suppliers in the food materials sector is essential

and important [42]. The purpose of this research is to evaluate the performance of chicken meat suppliers from the perspective of customers (i.e., chicken meat shops).

5. Research methodology

The statistical population in this research consisted of 24 individuals. These 24 individuals were managers of 24 different chicken meat stores in the city of Arak. Data collection was conducted in two ways: field method and library method. The field method was used to determine the evaluation model's indicators, and the library method was suitable for gathering data related to supplier performance (a total of six cases) in terms of the determined indicators. The data collection tool was a questionnaire, which will be further discussed below. In the implementation phase, the FSAW method was utilized to determine the scores of each of the suppliers.

6. Fuzzy Set Theory

The necessity of addressing ambiguity and lack of clarity was highlighted 1920, but due to the lack of a strong logical foundation, it did not make significant progress until 1965 when Professor Lotfi A. Zadeh, an Iranian-born professor at the University of California, introduced the theory of "fuzzy sets" or in other words "fuzziness" as a tool to deal with ambiguity and imprecision in human systems and decision-making processes, which he referred to as being fuzzy. Fuzzy thinking aimed to address the inadequacies of Aristotelian Logic (AL) based on the gap between logic and reality [64]. Aristotelian Logic, which forms the basis of classical mathematics, assumes a binary world. In essence, Aristotelian logic sacrifices precision for simplicity [14]. Real phenomena are inherently fuzzy, meaning they are ambiguous and imprecise [1,40].

6.1 *Triangular fuzzy numbers*

Each triangular fuzzy number, denoted as $\tilde{A}$, is represented as $\tilde{A} = (a^l, a^m, a^u)$, where a^l is the left foot, a^m is the middle foot, and a^u is the right foot. The membership function of $\tilde{A}$ can be defined as follows [24]:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a^l}{a^m - a^l} & a^l \le x < a^m \\ \dfrac{a^u - x}{a^u - a^m} & a^m \le x < a^u \\ 0 & otherwise \end{cases} \tag{1}$$

Degree of membership $\mu_{\tilde{A}}(x)$ represents the extent to which an element x belongs to the fuzzy set A. If the degree of membership of an element from the set is equal to zero, that element is completely outside the set. Conversely, if the degree of membership is equal to one, the element is entirely within the set. If the degree of membership of an element lies between zero and one, this number indicates a gradual degree of membership [37]. As shown in Figure 1, the elements of the set $\tilde{A}$ lie between the two points a^l and a^u. The degree of membership of these values ranges from zero to one, with the highest degree of membership belonging to the point a^m [17].

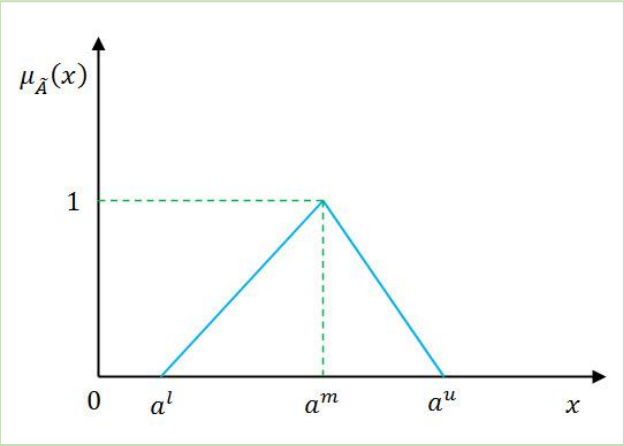

Figure 1. Triangular Membership Function [6].

6.2 *Fuzzy number calculations*

The operations of addition, subtraction, multiplication, and division for two triangular fuzzy numbers $\tilde{A} = (a^l, a^m, a^u)$ and $\tilde{B} = (b^l, b^m, b^u)$, as well as a scalar k, are as follows [39]:

$$\tilde{A} + \tilde{B} = (a^l + b^l, a^m + b^m, a^u + b^u) \quad (2)$$

$$\tilde{A} - \tilde{B} = (a^l - b^u, a^m - b^m, a^u - b^l) \quad (3)$$

$$\tilde{A} \times \tilde{B} = (min\{a^l b^l, a^l b^u, a^u b^l, a^u b^u\}, a^m b^m, max\{a^l b^l, a^l b^u, a^u b^l, a^u b^u\}) \quad (4)$$

$$\frac{\tilde{A}}{\tilde{B}} = (min\left\{\frac{a^l}{b^l}, \frac{a^l}{b^u}, \frac{a^u}{b^1}, \frac{a^u}{b^u}\right\}, \frac{a^m}{b^m}, max\left\{\frac{a^l}{b^l}, \frac{a^l}{b^u}, \frac{a^u}{b^1}, \frac{a^u}{b^u}\right\}); 0 \notin \tilde{B} \quad (5)$$

$$k \times \tilde{A} = (ka^l, ka^m, ka^u);\ k \geq 0 \quad (6)$$

6.3 *Simple fuzzy weighted average technique*

The Simple weighted average or simple additive weighting (SAW) method is the simplest multi-criteria decision-making technique. This method was introduced by Hwang and Yoon in 1981 [31]. Due to its simplicity, the SAW method is the most popular and common approach in multiple attribute decision making (MADM) [32]. The SAW method can be considered the most straightforward and direct approach to dealing with multi-criteria decision-making problems. In this method, only the decision matrix and the weight vector of evaluation criteria are needed for decision-making [7]. If the data is fuzzy, the fuzzy version of SAW, known as fuzzy SAW (FSAW), can be used [53].

6.4 *Algorithm for fuzzy simple weighted average technique*

The FSAW method includes the following steps [9]:

Step (1): Normalization of the decision matrix $\widetilde{D} = (\tilde{d}_{i,j})_{m\times n}$. If set B represents the set of positive-aspect criteria (benefit) and set C represents the set of negative-aspect criteria (cost), normalization of the matrix $\widetilde{D}$ is performed. To normalize the matrix and form the normalized matrix ($\tilde{R} = (\tilde{r}_{i,j})_{m\times n}$), we have:

$$\begin{cases} \tilde{r}_{ij} = \left(\frac{a_{i,j}}{c_j^+}, \frac{b_{i,j}}{c_j^+}, \frac{b_{i,j}}{c_j^+}\right) \ if \quad j \in B \\ \tilde{r}_{ij} = \left(\frac{a_j^-}{c_{i,j}}, \frac{a_j^-}{b_{i,j}}, \frac{a_j^-}{a_{i,j}}\right) \ if \quad j \in C \end{cases} \tag{7}$$

So that:

$$\begin{cases} c_j^+ = max_{1 \le i \le m} \{c_{i,j}\} \ ; \ j \in B \\ a_j^- = min_{1 \le i \le m} \{a_{i,j}\} \ ; \ j \in C \end{cases} \tag{8}$$

Step (2): Obtaining the weighted normalized matrix ($\tilde{V} = (\tilde{v}_{i,j})_{m \times n}$). In this step, the normalized matrix $\tilde{R}$ is multiplied by the weight matrix ($\widetilde{W}_{1 \times n}$).

$$\tilde{v}_{i,j} = \tilde{r}_{i,j} \times \widetilde{w}_j \ ; \ i = 1, 2, \dots, m \ \ and \ \ j = 1, 2, \dots, n \tag{9}$$

Where $\widetilde{w}_j$ represents the weight of criterion j.

Step (3): The fuzzy weighted average for each alternative is calculated using the following equation (Equation (10)):

$$M(A_i) = \frac{\sum_{j=1}^{n} \tilde{v}_{i,j}}{\sum_{j=1}^{n} \widetilde{w}_j} \ ; \quad i = 1, 2, \dots, m \tag{10}$$

Where $M(A_i)$ represents the fuzzy weighted average for the i^{th} alternative.

Step (4): Defuzzification of the obtained fuzzy averages from Step (3).

Step (5): Rank the alternatives based on the values obtained for each alternative in Step 4. The alternative with a higher value will be ranked higher.

For defuzzification of the scores of each supplier, the following equations were used [55]:

$$Crisp\left(\widetilde{Score}\right) = \frac{score^l + 2score^m + score^u}{4} \tag{11}$$

7. Case study

Companies must be able to identify their suppliers effectively and efficiently in order to survive in competitive market conditions [18]. As mentioned, the objective of this research was to evaluate the performance of chicken meat suppliers from the perspective of customers (i.e., managers of chicken meat stores). Six chicken meat suppliers and twenty-four chicken meat stores in Arak City were identified. By conducting face-to-face interviews with the managers of these stores and a group of university professors, and research background study [11,13,30,44,46], important and influential indicators (or criteria) for selecting a chicken meat supplier were identified. These indicators included 1) Price of chicken meat, 2) Quality of chicken meat, 3) Timely delivery, 4) Packaging method, and 5) Hygiene.

As mentioned earlier, the statistical population of this research included 24 people, eleven of whom had a diploma, seven of them had a post-graduate degree, and the rest had a bachelor's degree. Furthermore, the chicken meat supplying companies included 1) Sabine Trading Company, 2) Fakhrar Company, 3) Makian Behsa Chicken Company, 4) Arak Tihoo Company, 5) AmirAn Star Company, and 6) Dorsa Chicken Company.

Each store manager was asked to fill-out a questionnaire designed by the researcher,

using linguistic variables (Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH)). The questionnaire consists of 35 questions, where the first five questions pertain to the importance of the indicators, and the subsequent 30 questions concern the performance of each chicken meat supplier in the identified five indicators.

After collecting all the questionnaires, using the Fuzzy Likert Scale (FLS) as provided in Table 1, all linguistic variables were transformed into Triangular Fuzzy Numbers (TFN). For better clarity, this fuzzy system is depicted in Figure 2.

Table 1. Fuzzy Membership Functions [25].

Verbal term	Fuzzy number	Membership function
Very Low (VL)	$\tilde{1}$	(1,1,2)
Low (L)	$\tilde{2}$	(1,2,3)
Medium (M)	$\tilde{3}$	(2,3,4)
High (H)	$\tilde{4}$	(3,4,5)
Very high (VH)	$\tilde{5}$	(4,5,5)

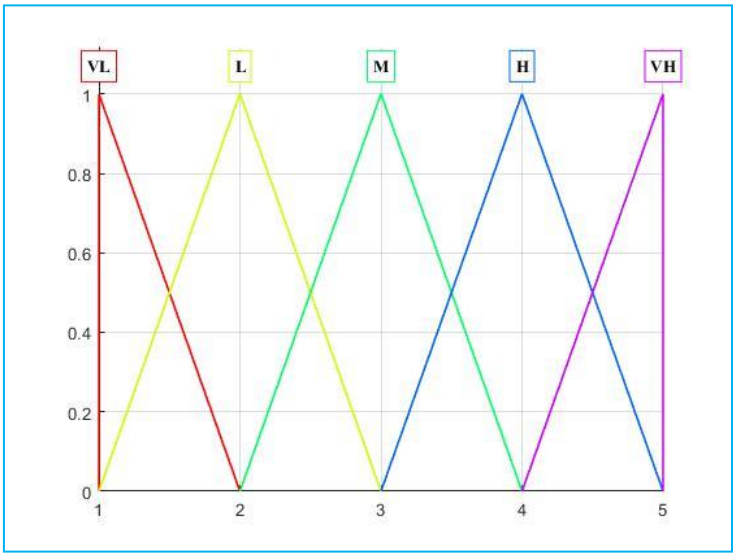

Figure 2. Linguistic fuzzy system [25].

7.1 *Questionnaire validity assessment*

The concept of validity addresses the extent to which a measurement tool assesses the desired characteristic of the researcher [56]. To ensure the validity of the questionnaire, it was provided to experienced experts (a team of university professors) multiple times in both partial and complete forms, undergoing necessary revisions. After discussions and consultations with experts regarding the utility of questions and their role in determining variable relationships, their suggestions for improvements were incorporated. Following these modifications, the integrated textual questionnaire was submitted to them, and ultimately its validity was confirmed.

7.2 *Questionnaire reliability assessment*

The reliability or consistency of a questionnaire demonstrates its stability and coherence in measuring a concept. Reliability is concerned with the extent to which a measurement tool yields consistent results under consistent conditions. The reliability coefficient typically ranges from zero (no relationship) to one (perfect relationship). In this study, Cronbach's alpha (α) method was employed to assess the reliability of the utilized questionnaires. The formula for Cronbach's alpha is as follows [12]:

$$\alpha = \left(\frac{k}{k-1}\right)\left(1 - \frac{\sum_{i=1}^{k} \delta_i^2}{\delta^2}\right) \tag{12}$$

Where k represents the number of questions, δ_i^2 is the variance of the ith question, and δ_i^2 is the total variance of the questions.

The Cronbach's alpha value obtained from the questionnaire was 0.78. Given that the value of alpha exceeds 0.7, it can be concluded that the utilized questionnaire is deemed reliable (note that defuzzification data was used to compute Cronbach's alpha). Table 2 presents the average opinions of store managers.

Table 3 lists the normalized decision matrix. Table 4 lists the weighted matrix. Table 5 lists the final scores of the alternatives. Additionally, Figure 3 depicts the fuzzy and crisp scores related to the six studied suppliers.

As shown, Supplier 6 (Dorsa Chicken Company) exhibits the best performance, while Supplier 2 (Fakhrrar Company) demonstrates the least favorable performance. Furthermore, another objective of this study was to identify the top three suppliers. According to Figure 3, these top suppliers are: 1) Dorsa Chicken Company, 2) Arak Tihoo Company, and 3) Makian Behsa Chicken Company.

Table 2. Average opinions of store managers.

	Satisfaction with the price (↑)	Satisfaction with the quality (↑)	Satisfaction with timely delivery (↑)	Satisfaction with packaging (↑)	Satisfaction with hygiene (↑)
Weight	(2.96,3.96,4.71)	(3.63,4.63,5)	(3,4,5)	(1.63,2.29,3.29)	(2.63,3.63,4.33)
Sabine Trading Company	(2.54,3.5,4.21)	(1.96,2.83,3.71)	(2.13,2.92,3.75)	(2.17,2.92,3.79)	(2.29,3.17,3.96)
Fakhrar Company	(2.08,3.04,3.83)	(2.21,3.04,3.83)	(2,2.88,3.79)	(2.29,3.21,4.08)	(2.25,3.04,3.88)
Makian Behsa Chicken Company	(2.17,3,3.83)	(2.58,3.46,4.13)	(2.38,3.25,4.04)	(2.08,2.88,3.71)	(2.25,3.17,4.04)
Arak Tihoo Company	(2.46,3.42,4.21)	(2.46,3.25,4)	(2.29,3.17,4)	(2.25,3.21,4)	(2.13,3.04,3.96)
Amiran Star Company	(2.5,3.46,4.17)	(2.58,3.42,4.13)	(2.08,2.92,3.75)	(1.83,2.58,3.46)	(1.92,2.75,3.58)
Dorsa Chicken Company	(2.29,3.25,4.13)	(2.25,3.08,3.96)	(2.38,3.17,3.96)	(2.46,3.46,4.29)	(2.38,3.25,4.04)

Table 3. Normalized decision matrix by FSAW method.

	Satisfaction with the price	Satisfaction with the quality	Satisfaction with timely delivery	Satisfaction with packaging	Satisfaction with hygiene
Sabine Trading Company	(0.6,0.83,1)	(0.47,0.69,0.9)	(0.53,0.72,0.93)	(0.51,0.68,0.88)	(0.57,0.78,0.98)
Fakhrar Company	(0.49,0.72,0.91)	(0.54,0.74,0.93)	(0.5,0.71,0.94)	(0.53,0.75,0.95)	(0.56,0.75,0.96)
Makian Behsa Chicken Company	(0.52,0.71,0.91)	(0.62,0.84,1)	(0.59,0.8,1)	(0.48,0.67,0.86)	(0.56,0.78,1)
Arak Tihoo Company	(0.58,0.81,1)	(0.6,0.79,0.97)	(0.57,0.78,0.99)	(0.52,0.75,0.93)	(0.53,0.75,0.98)
Amiran Star Company	(0.59,0.82,0.99)	(0.62,0.83,1)	(0.51,0.72,0.93)	(0.43,0.6,0.81)	(0.48,0.68,0.89)
Dorsa Chicken Company	(0.54,0.77,0.98)	(0.54,0.75,0.96)	(0.59,0.78,0.98)	(0.57,0.81,1)	(0.59,0.8,1)

Table 4. Weighted matrix by FSAW method.

	Satisfaction with the price	Satisfaction with the quality	Satisfaction with timely delivery	Satisfaction with packaging	Satisfaction with hygiene
Sabine Trading Company	(1.79,3.29,4.71)	(1.72,3.17,4.49)	(1.58,2.89,4.64)	(0.82,1.56,2.91)	(1.49,2.85,4.24)
Fakhrar Company	(1.46,2.86,4.28)	(1.94,3.41,4.64)	(1.49,2.85,4.69)	(0.87,1.71,3.13)	(1.46,2.73,4.16)
Makian Behsa Chicken Company	(1.53,2.82,4.28)	(2.27,3.88,5)	(1.77,3.22,5)	(0.79,1.54,2.85)	(1.46,2.85,4.33)
Arak Tihoo Company	(1.73,3.22,4.71)	(2.16,3.64,4.84)	(1.7,3.14,4.95)	(0.85,1.71,3.07)	(1.39,2.73,4.24)
Amiran Star Company	(1.76,3.25,4.67)	(2.27,3.83,5)	(1.54,2.89,4.64)	(0.7,1.38,2.65)	(1.25,2.47,3.84)
Dorsa Chicken Company	(1.61,3.06,4.62)	(1.98,3.45,4.79)	(1.77,3.14,4.9)	(0.93,1.85,3.29)	(1.55,2.92,4.33)

Table 5. Final scores of alternatives by FSAW method.

	Fuzzy Score	Crisp Score	Rank	Accept or Reject
Sabine Trading Company	(0.33 , 0.74 , 1.5)	0.834	4	Reject
Fakhrar Company	(0.32 , 0.73 , 1.5)	0.825	6	Reject
Makian Behsa Chicken Company	(0.35 , 0.77 , 1.5)	0.861	3	Accept
Arak Tihoo Company	(0.35 , 0.78 , 1.6)	0.872	2	Accept
Amiran Star Company	(0.34 , 0.75 , 1.5)	0.833	5	Reject
Dorsa Chicken Company	(0.35 , 0.78 , 1.6)	0.873	1	Accept

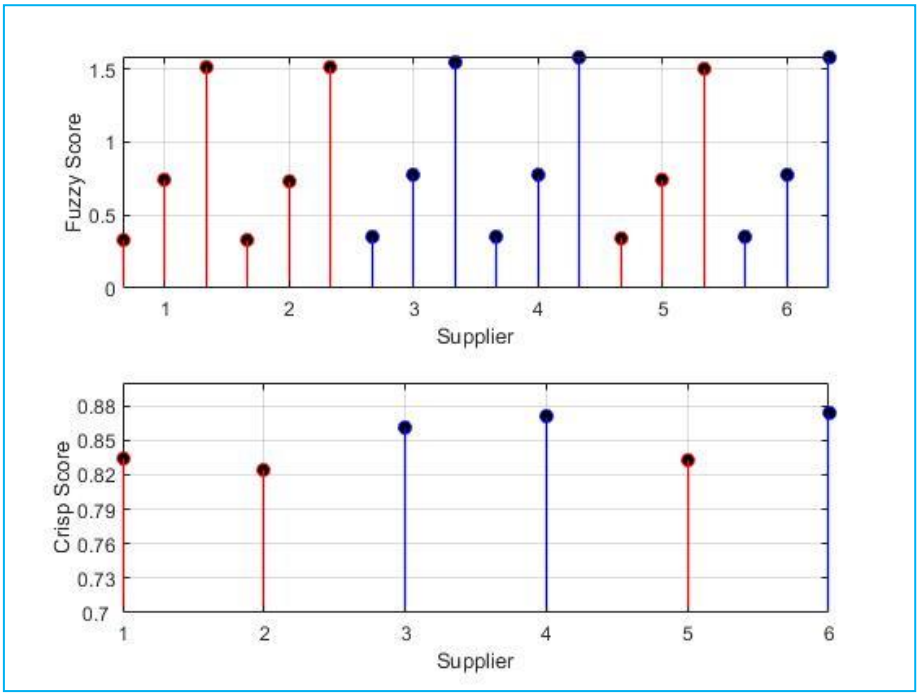

Figure 3. Scores obtained from the FSAW method.

8. Conclusion

The food industry is recognized as one of the oldest and most vital industries globally. This industry comprises a complex network of industries encompassing all processes from agricultural cultivation, animal husbandry, and fishing to processing, production, and distribution. Logistics and supply chain in the food industry involves various food items, including meats, vegetables, and processed products. This article focused on identifying evaluation indices for the performance of chicken meat suppliers in Arak City. Utilizing fuzzy set theory and employing the established FSAW model, the performance of six chicken meat suppliers in 2023 was analyzed. The identified indices consisted of five aspects, while the chicken meat supplier companies were six. Data analysis conducted through MATLAB, which illustrated that in 2023, Supplier 6 (Dorsa Chicken Company) achieved the best performance, whereas Supplier 2 (Fakhrrar Company) had the least satisfactory performance.

For future researchers, it is recommended to assess the performance of beef and lamb suppliers using MCDM techniques under uncertain conditions.

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