International Journal of Artificial Intelegence Research
Vol. 8, No. 1, June 2024, pp. 117-127

ISSN 2579-7298

# Fuzzy Preference Relations-Based AHP for Multi-Criteria Supplier Segmentation

Heri Nurdiyanto[a,b], Chairani Fauzi[a], Sri Lestari[a]

[a] Master of Technology Management, Institute of Informatics and Business Darmajaya, Bandar Lampung, Indonesia
[b] Industrial Engineering, Faculty of Engineering, Universitas Negeri Yogyakarta,Indonesia
[1] herinurdiyanto@gmail.com*; [2] chairani@darmajaya.ac.id ;
* corresponding author

ARTICLE INFO

**Article history**
Received 21 Jan 2024
Revised 05 Mar 2024
Accepted 30 Apr 2024

**Keywords**
Supplier segmentation
Supply chain management
Fuzzy AHP
Fuzzy preference relations

ABSTRACT

Supplier segmentation is a strategic activity for businesses. It involves dividing suppliers into distinct categories and managing them differently. Various supplier typologies based on different dimensions and factors are available in the existing literature. By highlighting two main characteristics the skills and the desire of suppliers to work with a specific company this article integrates many typologies. Almost all of the supplier segmentation criteria stated in the literature are covered by these dimensions. These dimensions can be defined utilizing a multi-criteria decision-making process for each specific case. To account for the inherent ambiguities and uncertainties in human judgment, a fuzzy Analytic Hierarchy Process (AHP) is suggested as part of the technique. This approach makes use of fuzzy preference relations. A broiler firm uses the suggested process to divide up its suppliers. A categorization of vendors according to two aggregated criteria is the end outcome. Lastly, we offer some suggestions for future research, draw some conclusions, and talk about some techniques to address distinct sectors.



## 1. Introduction

After choosing a provider, the next obvious step is to divide them into several categories. It basically means that a company divides its suppliers into different categories, which is crucial for a purchasing company that wishes to communicate with its suppliers in a structured manner. Instead of using a "one-size-fits-all" approach, businesses should take a more strategic stance when managing their relationships with suppliers[1]. Two dimensions have long been used to categorize providers. A matrix is used to divide suppliers into four groups[2]. Some of the earliest scholars to suggest the idea of supplier segmentation were Parasuraman and Kraljic. Using two dimensionsprofit effect and supply risk for products given and two levels (low and high) for each, Kraljic clearly offered a strategy to divide supplies (the things delivered) into four groups[3]. Consequently, supplies are divided into four groups: (1) non-critical items, which have a low profit impact and supply risk; (2) leverage items, which have a low profit impact and supply risk; (3) bottleneck items, which have a high profit impact and supply risk; and (4) strategic items, which have a high profit impact and supply risk. Each segment's suppliers are addressed using a different strategy. Some two-dimensional supplier segmentation strategies have been suggested, all of which follow Kraljic's so-called portfolio approach[4]. Here are a few examples: the following factors can affect the purchase: the supplier's commitment, the commodity's importance, the buyer's and supplier's specific investments, technology, and collaboration. Look at Rezaei and Ortt and Day for a rundown of methods for supplier segmentation[5]. More than two criteria need to be examined when segmenting providers, since various researchers utilize different criteria to do so. The

segmentation problem, thus, is really a multi-criteria problem. In a recent literature analysis on supplier segmentation, offered a system for categorizing the criteria in various supplier segmentation methods according to two main dimensions: supplier capabilities and willingness[6]. Considering the factors utilized for supplier segmentation as well as the criteria used for supplier selection, the suggested framework offers the following advantages. In contrast to the majority of current supplier segmentation approaches, which rely on just two criteria, it enables the consideration of many factors. It offers a rationale for combining various standards[7]. Using the standard 2 x 2 grid, it provides a sufficient foundation for supplier segmentation. Because the dimensions are based on numerous criteria, the resulting matrix is far more inclusive than those employed by other approaches[8].

Following is a description of the supplier segmentation strategy that was utilized in this particular piece of writing. The definition of supplier segmentation is "the identification of the capabilities of the available suppliers."in addition to the desire of suppliers on the part of a specific buyer in order for the buyer to participate in a strategic and efficient relationship with the suppliers in relation to a collection of evolving business roles and activities in the supply chain[9]. According to this concept, there are two factors capabilities and willingness that can be used to separate suppliers. These dimensions are the basis for the segmentation. It is possible to divide suppliers into distinct categories according to each function, such as purchasing, production, research and development, financing, and marketing and sales[10]. The dimensions, capabilities, and willingness are considered to be notions that consist of multiple criteria. For example, the capabilities of a supplier can be evaluated using different criteria such as the quality of the products, the technical capability of the supplier in question the design capability of the supplier[11]. In order to assess the willingness of the supplier, it is possible to utilize a variety of criteria, including communication and commitment to continuous improvement in both product and process[12].

When it comes to evaluating and categorizing its suppliers, each buyer may take into consideration a unique set of capabilities and willingness criteria[13]. The tables 1 and 2 provide a complete sampling of the numerous possible criteria for capabilities and willingness. For further information, please refer to the tables. As was indicated earlier, the process of supplier segmentation acts as a stage between the selection of suppliers and the management of relationships with those suppliers[14]. In light of this, a company ought to choose the criteria in such a way that there is coherence between the supplier-related strategic actions that were discussed before. The drivers and objectives of participating in collaboration with suppliers, for example, can serve as a helpful reference for picking the segmentation criteria[15]. These include things like cost savings, marketing advantages, and customer happiness, among other things. If, for instance, lowering costs is one of the primary motivating factors behind entering into a partnership, then price may be considered one of the criteria for determining the skills of the supplier. Taking into consideration the specifications of the methodology that is being utilized is another important aspect to take into account[16]. When applying a version of crisp or fuzzy AHP, for instance, it is necessary to select some independent criteria for each dimension. several statistical tests are utilized in order to guarantee that the criteria are independent of one another[17]. When all of the criteria have been chosen, a two-dimensional matrix is produced by adding together the capabilities and willingness criteria. Due to the fact that in each of the two dimensions there is the potential for a certain number of levels, this matrix will be an X Y matrix. The XY segments are produced by such a matrix. For instance, if two levels (low and high) are selected for each dimension, the resulting matrix is a 2x2 matrix, which may be utilized to divide the suppliers into four distinct parts[18].

The purpose of this research is to offer a methodology that may be used to categorize suppliers based on numerous characteristics. For the purpose of determining the relative importance of the criteria contained within each dimension, a Fuzzy Analytic Hierarchy Process (FAHP), which is a multi-criteria decision-making (MCDM) technique, is utilized.

## 2. Method

A methodology for the segmentation of suppliers is broken down into five steps and detailed in this section. Through screening, the decisionmaker will determine a number of capabilities and willingness factors to be used in the selection process. Determine the weights of the different

capabilities and willingness criteria by employing an MCDM approach (in this study, a fuzzy AHP) to arrive at the corresponding weights.

The third step is for the decision-maker to assign a score to each supplier after taking into account each capability criterion and willingness criterion. This score is based on the evaluation of the supplier i with regard to the kth capability criterion and the evaluation of the supplier i with regard to the jth willingness criterion, where K and J represent the number of capabilities criteria and the number of willingness criteria, respectively. Determine the final aggregated scores representing each supplier's capability and willingness to provide the service.

Based on the final aggregated scores of the providers, divide them into XY segments, where X and Y represent the number of levels that are taken into consideration for capabilities and willingness, respectively. In the case of a conventional two-two segmentation, for instance, there would be four segments (types), where a and b represent the highest possible values of the aggregated capabilities and willingness ratings of the supplier, respectively. a 2 and b 2 are the cut-off positions for the dimensions of supplier capabilities and willingness, respectively, for a common 2x2 segmentation. These cut-off points are determined by dividing the dimensions into two equal portions, Low and High. Within the context of a decision support system for evaluating the quality of suppliers, the study investigates the application of Machine Learning and MCDM-Aggregation algorithms[19].

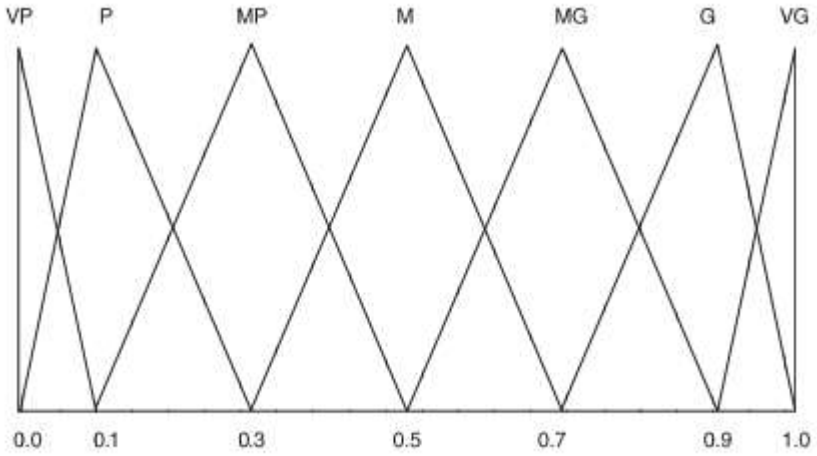


**Fig. 1.** Fuzzy linguistic assessment variables.

## 3. Results and Discussion

A medium-sized broiler (meat-type chicken) company that operates in the food industry, which is an important industry with a major share in all nations, was the target of the application of the methodology that was proposed. "Food supply systems function in a manner that is intricate, ever-changing, and describes a "time-critical environment" as one in which consumers have varying and growing requirements. They want that fresh products of excellent quality be sold at affordable prices. In addition, the fact that the food products contain perishable ingredients makes them extremely time-sensitive. The expectation that food companies will be able to fulfill these standards on their own is not even close to being realistic. As a result, food companies require the assistance of their suppliers in order to manufacture high-quality products at affordable rates and with dependable delivery. Within this framework, one of the most important activities is the management of the suppliers. In order to accomplish this goal successfully, food firms need to segment their suppliers in a manner that is both effective and dynamic[20].

The business that was chosen for our investigation is one that purchases newly hatched chicks from hatcheries and then raises them to reach market weight in approximately six weeks. Following this, the chickens are transported to a processing plant, where they are stunned and taken through additional processing steps[21]. Lastly, the products that have been packaged are brought to the market by trucks that are equipped with refrigeration. 42 different vendors provide the company with the newly hatched chicks, feed, pharmaceuticals, and other necessary supplies. Eleven of the

suppliers provide the company with newly hatched chicks, nine of the suppliers provide feed, six of the suppliers provide medications, and seventeen of the suppliers provide other goods and equipment. In order to categorize these suppliers, we conducted an interview with the manager of the company in order to collect the necessary information. The first thing that we did was ask the manager to go through the list of capabilities and willingness criteria and choose a few criterion for each dimension. Table 1 presents the results of the manager's meticulous assessment, which resulted in the selection of six criteria for capabilities and six criteria representing willingness[22].

After that, we requested that the manager give each of the criteria that were applied to the different suppliers a score that ranged from one (extremely low) to five (very high) for each of the criteria. The criterion is used to determine how each supplier is seen, and the score represents that perception. In Table 2, you can find the six scores that were obtained after considering all of the different criteria. it was possible to determine whether or not the criteria within each dimension were independent of one another, as well as whether or not the dimensions themselves were independent. There is not a single bivariate correlation that fulfills the capabilities requirements that is either high or very high. The same holds true for the criteria of willingness, albeit with considerably stronger correlations among the variables in this case. On average, the q values for the capacities and willingness criteria are 0.216 and 0.456, respectively. These values suggest that the correlations between the criteria are weak, which in turn suggests that they are highly independent of one another[23].

In addition to that, we requested that the manager carry out a pairwise comparison with reference to the various criteria. It is sufficient to have only comparisons elements for each matrix, as was said in the explanation of the fuzzy AHP methodology. This is the reason why the manager was asked to fill in n 1 cells of each matrix using the fuzzy AHP methodology. In addition to that, we requested that the manager carry out a pairwise comparison with reference to the various criteria. It is sufficient to have only n 1 comparisons elements for each matrix, as was said in the description of the fuzzy AHP approach. This is the reason why the manager was asked to fill in n 1 cells of each matrix using the fuzzy linguistic assessment variables (for more information on these variables, see Figure 1). The finished matrices for the necessary cells are displayed in Table 2 (capabilities) and Table 3 (willingness), respectively.

According to Equations the completed comparison matrices can be acquired by converting the filled cells of Tables 3 and 4 to their corresponding fuzzy numbers. This allows for the completion of the comparison matrices, which are listed in Tables 4 and 5 accordingly. It is clear from looking at Tables 5 and 6 that there are some elements that do not fit inside the range of [1,0]. Because of this, were utilized in order to transfer the elements that were going to be included in the interval [0,1]. The outcomes of this process are displayed in Tables 5 and 6, respectively. It is important to keep in mind that the process of transformation has a relative impact on factors other than itself.

Through the utilization we are able to compute the ultimate weights of the numerous criteria that are defuzzified. This allows us to arrive at the defuzzified weights, which can be found in Table 8 and Figures 2 and 3. This is the conclusion that can be drawn from the fuzzy AHP. Through the utilization of the criteria weights, we are able to compute the aggregated scores for the capabilities and willingness of every provider by utilizing (1) and (2) (refer to Table 8. Now, in accordance with the fifth and last phase of the technique that has been proposed, we are able to separate the suppliers into four distinct groups, as shown in Figure 4 and Table 7. Every single calculation was carried out with the help of the Solver in Microsoft Excel (Microsoft, 2007). It is also possible to make use of other optimization applications, such as MATLAB.

Table 1
Capabilities and willingness measures of the suppliers.

| Supplier no. | $C_1^C$ | $C_2^C$ | $C_3^C$ | $C_4^C$ | $C_5^C$ | $C_6^C$ | $C_1^W$ | $C_2^W$ | $C_3^W$ | $C_4^W$ | $C_5^W$ | $C_6^W$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 4 | 3 | 3 | 1 | 4 | 4 | 3 | 4 | 4 | 4 | 5 |
| 2 | 4 | 4 | 5 | 3 | 4 | 2 | 5 | 5 | 3 | 5 | 4 | 4 |
| 3 | 4 | 4 | 5 | 3 | 3 | 3 | 4 | 4 | 3 | 5 | 3 | 4 |
| 4 | 4 | 5 | 5 | 3 | 3 | 3 | 5 | 4 | 4 | 4 | 5 | 4 |
| 5 | 4 | 4 | 4 | 4 | 2 | 2 | 3 | 4 | 3 | 4 | 5 | 4 |
| 6 | 3 | 5 | 3 | 3 | 2 | 3 | 4 | 3 | 3 | 4 | 5 | 4 |
| 7 | 3 | 5 | 3 | 4 | 5 | 3 | 4 | 4 | 3 | 4 | 5 | 2 |
| 8 | 4 | 5 | 3 | 4 | 5 | 4 | 2 | 2 | 2 | 2 | 3 | 2 |
| 9 | 3 | 2 | 4 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 2 |
| 10 | 3 | 2 | 4 | 1 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 2 |
| 11 | 3 | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 5 | 4 |
| 12 | 3 | 5 | 3 | 2 | 5 | 3 | 4 | 4 | 4 | 5 | 5 | 5 |
| 13 | 4 | 5 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 5 | 5 | 5 |
| 14 | 3 | 4 | 3 | 3 | 3 | 1 | 3 | 4 | 3 | 4 | 3 | 4 |
| 15 | 3 | 3 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 4 | 5 | 3 |
| 16 | 3 | 1 | 4 | 4 | 1 | 1 | 3 | 3 | 3 | 4 | 4 | 3 |
| 17 | 3 | 1 | 3 | 1 | 5 | 1 | 4 | 5 | 4 | 4 | 5 | 4 |
| 18 | 2 | 1 | 3 | 1 | 3 | 1 | 4 | 5 | 4 | 3 | 4 | 4 |
| 19 | 3 | 4 | 4 | 3 | 5 | 3 | 4 | 2 | 2 | 2 | 1 | 2 |
| 20 | 4 | 3 | 4 | 4 | 1 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 21 | 3 | 3 | 1 | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 3 | 2 |
| 22 | 3 | 5 | 4 | 2 | 4 | 3 | 3 | 4 | 4 | 4 | 5 | 4 |
| 23 | 3 | 4 | 3 | 4 | 5 | 3 | 4 | 4 | 4 | 5 | 4 | 4 |
| 24 | 2 | 1 | 3 | 5 | 1 | 1 | 3 | 4 | 4 | 4 | 4 | 3 |
| 25 | 3 | 3 | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 4 | 3 |
| 26 | 4 | 3 | 4 | 3 | 2 | 3 | 5 | 5 | 4 | 3 | 4 | 4 |
| 27 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 3 |
| 28 | 3 | 4 | 5 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 3 |
| 29 | 3 | 4 | 3 | 3 | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 3 |
| 30 | 1 | 4 | 3 | 1 | 1 | 2 | 4 | 3 | 3 | 3 | 5 | 3 |
| 31 | 3 | 4 | 4 | 3 | 2 | 3 | 5 | 4 | 3 | 4 | 3 | 3 |
| 32 | 1 | 5 | 5 | 3 | 4 | 3 | 4 | 5 | 4 | 4 | 4 | 3 |
| 33 | 3 | 4 | 3 | 2 | 4 | 3 | 5 | 4 | 4 | 4 | 4 | 4 |
| 34 | 4 | 5 | 4 | 4 | 3 | 2 | 2 | 2 | 3 | 2 | 1 | 3 |
| 35 | 3 | 4 | 5 | 3 | 2 | 3 | 4 | 4 | 4 | 5 | 4 | 4 |
| 36 | 3 | 3 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 3 |
| 37 | 4 | 5 | 5 | 3 | 4 | 3 | 4 | 5 | 4 | 4 | 4 | 4 |
| 38 | 3 | 5 | 4 | 4 | 2 | 2 | 3 | 3 | 4 | 3 | 4 | 4 |
| 39 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 3 |
| 40 | 4 | 5 | 4 | 3 | 2 | 3 | 4 | 5 | 4 | 4 | 4 | 3 |
| 41 | 3 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 3 | 3 |
| 42 | 4 | 3 | 5 | 3 | 3 | 4 | 3 | 4 | 3 | 4 | 5 | 4 |
| 43 | 2 | 2 | 5 | 1 | 1 | 2 | 4 | 5 | 5 | 5 | 3 | 4 |

Table 2
Fuzzy linguistic preference relation decision matrix of capabilities criteria.

| Capabilities | $C_1^C$ | $C_2^C$ | $C_3^C$ | $C_4^C$ | $C_5^C$ | $C_6^C$ |
|---|---|---|---|---|---|---|
| $C_1^C$ | (0.5,0.5,0.5) | (0.0,0.0,0.1) | (−0.5, −0.4, −0.1) | (−0.3,0.0,0.4) | (−0.5,0.0,0.6) | (−1.0, −0.4,0.4) |
| $C_2^C$ | (0.9,1.0,1.0) | (0.5,0.5,0.5) | (0.0,0.1,0.3) | (0.2,0.5,0.8) | (0.0,0.5,1.0) | (−0.5,0.1,0.8) |
| $C_3^C$ | (1.1,1.4,1.5) | (0.7,0.9,1.0) | (0.5,0.5,0.5) | (0.7,0.9,1.0) | (0.5,0.9,1.2) | (0.0,0.5,1.0) |
| $C_4^C$ | (0.6,1.0,1.3) | (0.2,0.5,0.8) | (0.0,0.1,0.3) | (0.5,0.5,0.5) | (0.3,0.5,0.7) | (−0.2,0.1,0.5) |
| $C_5^C$ | (0.4,1.0,1.5) | (0.0,0.5,1.0) | (−0.2,0.1,0.5) | (0.3,0.5,0.7) | (0.5,0.5,0.5) | (0.0,0.1,0.3) |
| $C_6^C$ | (0.6,1.4,2.0) | (0.2,0.9,1.5) | (0.0,0.5,1.0) | (0.5,0.9,1.2) | (0.7,0.9,1.0) | (0.5,0.5,0.5) |

Table 3

Fuzzy linguistic preference relation decision matrix of willingness criteria.

| Willingness | $C_1^W$ | $C_2^W$ | $C_3^W$ | $C_4^W$ | $C_5^W$ | $C_6^W$ |
|---|---|---|---|---|---|---|
| $C_1^W$ | (0.5, 0.5,0.5) | (0.7,0.9,1.0) | (0.5,0.9,1.2) | (0.3,0.9,1.4) | (−0.2,0.5,1.2) | (0.2,1.0,1.7) |
| $C_2^W$ | (0.0,0.1,0.3) | (0.5,0.5,0.5) | (0.3,0.5,0.7) | (0.1,0.5,0.9) | (−0.4,0.1,0.7) | (0.0,0.6,1.2) |
| $C_3^W$ | (−0.2,0.1,0.5) | (0.3,0.5,0.7) | (0.5,0.5,0.5) | (0.3,0.5,0.7) | (−0.2,0.1,0.5) | (0.2,0.6,1.0) |
| $C_4^W$ | (−0.4,0.1,0.7) | (0.1,0.5,0.9) | (0.3,0.5,0.7) | (0.5,0.5,0.5) | (0.0,0.1,0.3) | (0.4,0.6,0.8) |
| $C_5^W$ | (−0.2,0.5,1.2) | (0.3,0.9,1.4) | (0.5,0.9,1.2) | (0.7,0.9,1.0) | (0.5,0.5,0.5) | (0.9,1.0,1.0) |
| $C_6^W$ | (−0.7,0.0,0.8) | (−0.2,0.4,1.0) | (0.0,0.4,0.8) | (0.2,0.4,0.6) | (0.0,0.0,0.1) | (0.5,0.5,0.5) |

Table 4

| Capabilities | $C_1^C$ | $C_2^C$ | $C_3^C$ | $C_4^C$ | $C_5^C$ | $C_6^C$ |
|---|---|---|---|---|---|---|
| $C_1^C$ | (0.5,0.5,0.5) | (0.33,0.33,0.37) | (0.17,0.2,0.3) | (0.23,0.33,0.47) | (0.17,0.33,0.53) | (0.0,0.2,0.47) |
| $C_2^C$ | (0.63,0.67,0.67) | (0.5,0.5,0.5) | (0.33,0.37,0.43) | (0.4,0.5,0.6) | (0.33,0.5,0.67) | (0.17,0.37,0.6) |
| $C_3^C$ | (0.7,0.8,0.83) | (0.57,0.63,0.67) | (0.5,0.5,0.5) | (0.57,0.63,0.67) | (0.5,0.63,0.73) | (0.33,0.5,0.67) |
| $C_4^C$ | (0.53,0.67,0.77) | (0.4,0.5,0.6) | (0.33,0.37,0.43) | (0.5,0.5,0.5) | (0.43,0.5,0.57) | (0.27,0.37,0.5) |
| $C_5^C$ | (0.47,0.67,0.83) | (0.33,0.5,0.67) | (0.27,0.37,0.5) | (0.43,0.5,0.57) | (0.5,0.5,0.5) | (0.33,0.37,0.43) |
| $C_6^C$ | (0.53,0.8,1.0) | (0.4,0.63,0.83) | (0.33,0.5,0.67) | (0.5,0.63,0.73) | (0.57,0.63,0.67) | (0.5,0.5,0.5) |

Table 5

| Willingness | $C_1^W$ | $C_2^W$ | $C_3^W$ | $C_4^W$ | $C_5^W$ | $C_6^W$ |
|---|---|---|---|---|---|---|
| $C_1^W$ | (0.5,0.5,0.5) | (0.58,0.67,0.71) | (0.5,0.67,0.79) | (0.42,0.67,0.88) | (0.21,0.5,0.79) | (0.38,0.71,1.0) |
| $C_2^W$ | (0.29,0.33,0.42) | (0.5,0.5,0.5) | (0.42,0.5,0.58) | (0.33,0.5,0.67) | (0.13,0.33,0.58) | (0.29,0.54,0.79) |
| $C_3^W$ | (0.21,0.33,0.5) | (0.42,0.5,0.58) | (0.5,0.5,0.5) | (0.42,0.5,0.58) | (0.21,0.33,0.5) | (0.38,0.54,0.71) |
| $C_4^W$ | (0.13,0.33,0.58) | (0.33,0.5,0.67) | (0.42,0.5,0.58) | (0.5,0.5,0.5) | (0.29,0.33,0.42) | (0.46,0.54,0.63) |
| $C_5^W$ | (0.21,0.5,0.79) | (0.42,0.67,0.88) | (0.5,0.67,0.79) | (0.58,0.67,0.71) | (0.5,0.5,0.5) | (0.67,0.71,0.71) |
| $C_6^W$ | (0.0,0.29,0.63) | (0.21,0.46,0.71) | (0.29,0.46,0.63) | (0.38,0.46,0.54) | (0.29,0.29,0.33) | (0.5,0.5,0.5) |

Table 6

| Capabilities criteria | Fuzzy weight | Defuzzified weight | Willingness criteria | Fuzzy weight | Defuzzified weight |
|---|---|---|---|---|---|
| $C_1^C$ | (0.065,0.106,0.181) | 0.1116 | $C_1^W$ | (0.114,0.206,0.35) | 0.2038 |
| $C_2^C$ | (0.11,0.161,0.238) | 0.1617 | $C_2^W$ | (0.086,0.15,0.266) | 0.1528 |
| $C_3^C$ | (0.148,0.206,0.279) | 0.2007 | $C_3^W$ | (0.094,0.15,0.253) | 0.1512 |
| $C_4^C$ | (0.115,0.161,0.231) | 0.1610 | $C_4^W$ | (0.094,0.15,0.253) | 0.1512 |
| $C_5^C$ | (0.109,0.161,0.24) | 0.1619 | $C_5^W$ | (0.127,0.206,0.328) | 0.2010 |
| $C_6^C$ | (0.132,0.206,0.302) | 0.2030 | $C_6^W$ | (0.074,0.137,0.25) | 0.1399 |

As can be seen, three suppliers are assigned to Type 1 (low capabilities and low willingness), six suppliers are assigned to Type 2 (low capabilities and high willingness), three suppliers are assigned to Type 3 (high capabilities and low willingness), and the highest number of suppliers, thirty-one, are assigned to Type 4 (high capabilities and high willingness). a high level of willingness and talents). It can be deduced from this that the broiler company has 31 reliable suppliers. There are twelve providers who need to improve their competence, their willingness, or both. All of the suppliers are located in or close to the upper right quadrant, as seen in Figure 4, which may be seen upon closer study.

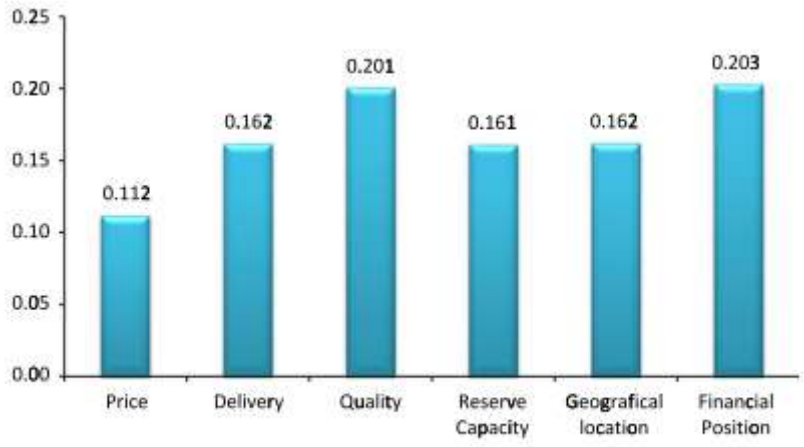


**Fig. 2.** Defuzzified weight of capabilities criteria.

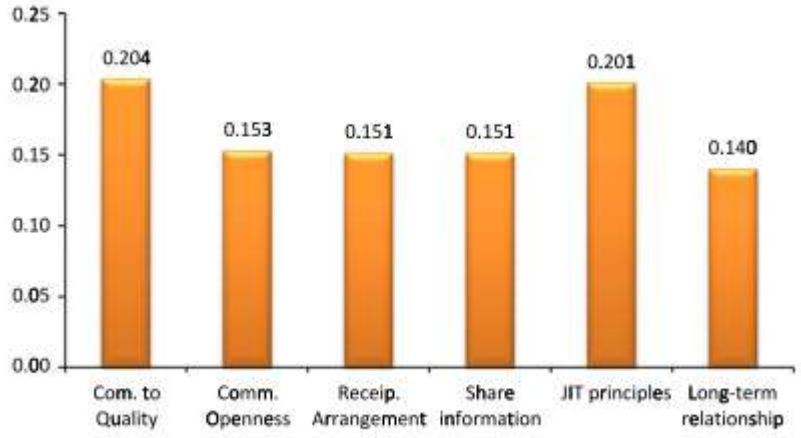


**Fig. 3.** Defuzzified weight of willingness criteria.

These suppliers are the worst possible suppliers since they have limited capabilities and, at the same time, a low willingness to deal with the buyer. Type 1 suppliers are the worst providers. There is a possibility that purchasers will be recommended to replace these. The providers. We were able to identify these suppliers through the interview that we had with the management of the broiler company. The providers included two companies that produced newly hatched chicks and one company that supplied medication. After determining that they lacked both the capabilities and the willingness to participate, we talked about the reasons why they became suppliers and what the management ought to do. It was noted by the management that it would not be sensible to replace the two producers of freshly hatched chicks because the company only works with them when there is a strong demand for their products, and it is difficult to locate better suppliers during the high-demand season. On the other hand, the provider of medication can usually be replaced.

Two types. Not only do these suppliers have limited capabilities, but they are also quite willing to collaborate with the buyer. It is possible that these providers will take advantage of the relationship more than the buyer will. It is possible for the buyer to assist these providers in improving their capabilities. In the course of the interview, we were able to identify these vendors. Again, the majority of them were producers of freshly hatched chicks (three out of six); two of them were suppliers of feed, and one of them supplied materials and equipment. The fact that these suppliers have a high level of willingness to work together with the company is a fortunate circumstance that makes it desirable to invest in their growth. Through the formation of cross-functional teams to identify and solve problems, which is in fact a component of a total quality management (TQM) system the company could assist these suppliers in improving their skills. Additionally, because the primary issue with newly hatched chicks is to ensure that the chicks are sold on time, the company has the ability to minimize its supply base. Supply base reduction is described as the process of and actions linked to lowering the number of suppliers. By way of illustration, the company has the ability to terminate its partnership with the newly hatched chick's manufacturer of Type 1 and boost its purchasing volume with Type 2 suppliers. This will not only address the company's concern regarding the shortage during high demand seasons, but it will also address the issue of the shortage.

The third type. Although they have a high level of capabilities, these suppliers have a low degree of willingness to engage with the buyer. In this scenario, it is more likely that the suppliers do not gain from the relationship, or that the relationship is not significant enough for them to enter into a close relationship with the customer. In situations like these, the buyer should investigate the reasons behind the behavior of the suppliers and work to strengthen the connection with them, since it is beneficial to continue working with these suppliers. During the course of the interview, the suppliers were identified as one producer of freshly hatched chicks, one supplier of feed, and one supplier of material and other pieces of equipment. The establishment of a partnership is one way to increase the willingness of these suppliers: "A partnership is a tailored business relationship that is based on mutual trust, openness, shared risk, and shared rewards that results in business performance that is greater than what would be achieved by the two firms working together together in the absence of partnership. It is possible that this will bring these suppliers into the best quadrant, which is Type 4.

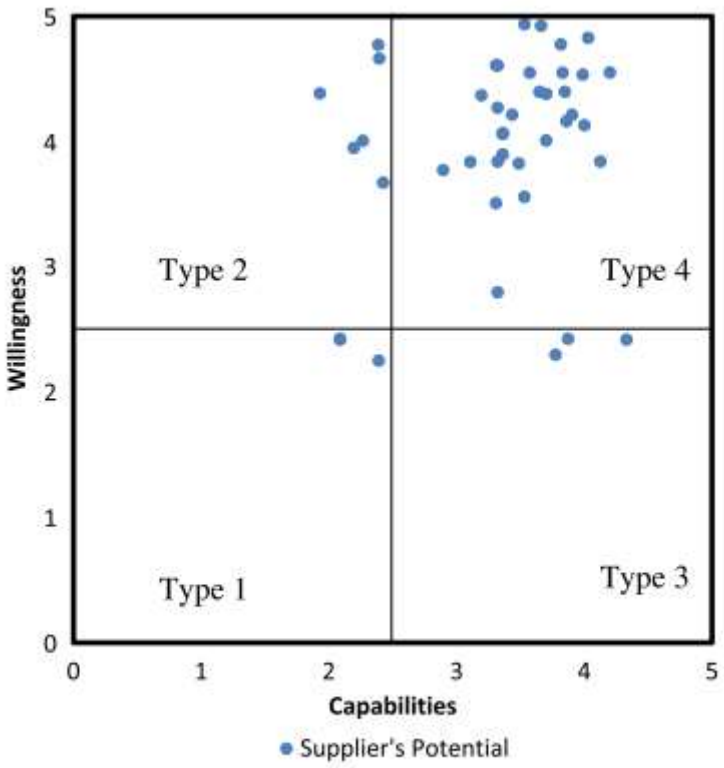


**Fig. 4.** Segments of the suppliers.

In the fourth category, the suppliers are considered to be the best since they possess strong capabilities and a high level of willingness. Working with these providers gives the customer the opportunity to reap benefits. For instance, in our situation, the purchaser can reap the benefits. when considering the capability of the providers in terms of low prices, good delivery, high quality, and other factors. Additionally, the relationship between the buyer and the supplier is beneficial to both parties, which indicates that the relationship is more likely to be a partnership-based arrangement. There are 31 vendors in this market segment, five of which are producers of freshly hatched chicks, five of which are suppliers of medication, six of which are suppliers of feed, and fifteen of which are suppliers of material and equipment. The company ought to make an effort to preserve its relationship with these suppliers, for instance by achieving a significant level of operational integration and by enhancing inter-organizational communication. This sort of communication is essential for the dissemination and exchange of information and knowledge that is mutually beneficial. This, in turn, will result in the creation of synergy through the combination of resources and capabilities, which will ultimately lead to the development of a long-term strategic advantage.

Table 7
segments of the suppliers.

| Segments | No. of suppliers | Supplier no. |
|---|---|---|
| Type 1 | 3 | 9, 10, 21 |
| Type 2 | 6 | 16, 17, 18, 24, 30, 43 |
| Type 3 | 3 | 8, 19, 34 |
| Type 4 | 31 | 1, 2, 3, 4, 5, 6, 7, 11, 12, 13, 14, 15, 20, 22, 23, 25, 26, 27, 28, 29, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42 |

## 4. Conclusion

partitioning of the population. Using fuzzy-based AHP to solve problems of this nature is extremely relevant from a scientific point of view. The intrinsic complexity and fuzziness of notions

in the management sciences, where "boundaries are not sharply defined," appears to be an ideal fit for methodologies that are based on fuzzy sets theory. In general, this seems to be the case. A great number of concepts are evaluated in management sciences for the purpose of assisting managers in making decisions. One prominent example of such constructs is the evaluation and segmentation of service providers. In order to evaluate and categorize suppliers, a prospective purchaser needs to take into account a multitude of criteria, which are then integrated in a manner that is both complicated and ambiguous. Therefore, the AHP technique captures the complexity of the phenomena of supplier evaluation by employing a rigid hierarchy to evaluate and classify alternatives (in our instance, suppliers). However, it does not take into account the natural fuzziness that is present in human evaluations when dealing with situations of this nature. The intricacy and fuzziness of this phenomenon are both captured by the fuzzy analysis of probabilities (AHP). One of the first formulations of the supplier segmentation problem as a multi-criteria problem, as far as we are aware, is presented here. We have examined two overarching factors, namely the competence of providers and their desire to provide their services. The relevant parameters that each individual buyer may take into consideration will be covered by these two dimensions. After determining the relative weights of the criterion, the fuzzy AHP that was proposed was utilized. Finally, two aggregated scores were computed for each provider, one for their capability and one for their willingness. To illustrate the position of each supplier in relation to its capabilities and willingness, a scatter plot was utilized. The horizontal and vertical axes of the plot, respectively, represent the capabilities and willingness dimensions of the market.

The formation of four distinct groups of providers is accomplished by dividing each axis into two proportional halves. When dealing with suppliers in each market category, the buyer have to come up with a variety of alternative techniques. Taking into consideration six criteria for capabilities and six criteria for willingness, the proposed methodology was utilized in order to segment the suppliers of a broiler producer. As a consequence, each provider is currently positioned within a particular market niche. By implementing the proposed methodology, the buyer is also able to view the location of each supplier inside a segment, which is significant in contrast to practically all of the prior approaches to supplier segmentation, which place a supplier into a segment. To add insult to injury, the suggested methodology is able to divide the suppliers into more than four distinct categories because the final aggregated capabilities and willingness scores for each source are derived in a continuous spectrum. This decision is mostly determined by the number of suppliers, as well as the company's capacity and desire to implement various strategies for each of the suppliers of the company.

There is a significant amount of significance that our findings may have for managers. According to the findings of the investigation, certain vendors lacked either the capabilities or the motivation to provide the service. Because of the intricacy of the supplier evaluation (the manager of the broiler firm suggested six criteria for two dimensions, capabilities and willingness, in order to evaluate his suppliers), an evaluation that is entirely based on intuition is probably likely going to be insufficient for dealing with the issue under consideration. As an alternative to the regular AHP, fuzzy AHP could be utilized to solve the fuzziness that is associated with the evaluation of the criteria. The manager was able to clarify, adapt, and specify his implicit strategy of supplier evaluation and segmentation with the help of the results of our study within a qualitative evaluation that took place during an interview. This was an amazing thing to observe.

In situations where there is a limited amount of data (in the form of a limited number of examples), fuzzy techniques are advantageous since they are simple to implement. Furthermore, the evaluation task in fuzzy techniques appears to be more closely aligned with the sort of evaluation that managers perform in practice, and the outcomes are simpler for these managers to grasp and use in practice using fuzzy approaches.

In spite of the fact that multi-criteria decision-making (MCDM) techniques have been utilized to address a wide range of supply chain management (SCM) issues, including supplier selection, supplier improvement, and buyer–supplier relationship, it is surprising to learn that the literature on supplier segmentation has not benefited from these decision-making systems. Other multi-criteria decision making (MCDM) approaches, such as ANP, TOPSIS, fuzzy TOPSIS, and PROMETHEE, are recommended by us as a means of addressing the strategic decision-making challenge that practically all companies that operate within SCM frameworks are grappling with. The clustering techniques are also suggested for future research (to see a comprehensive list of clustering

techniques, making it possible to compare the performance of different methods, and it is to be expected that the suitability of each particular method for different situations can be identified. Other partners in the supply chain management framework, such as those involved in research and development (R&D), might also be segmented using the methods and framework that we provide.

## References

[1] A. Saha, D. Pamucar, O. F. Gorcun, and A. R. Mishra, "Warehouse site selection for the automotive industry using a fermatean fuzzy-based decision-making approach," *Expert Syst. Appl.*, vol. 211, Jan. 2023, doi: 10.1016/j.eswa.2022.118497.

[2] Y. Yang, X. Wang, and Z. Xu, "The multiplicative consistency threshold of intuitionistic fuzzy preference relation," *Inf. Sci.*, vol. 477, pp. 349–368, Mar. 2019, doi: 10.1016/j.ins.2018.10.044.

[3] J. Aguarón and J. M. Moreno-Jiménez, "The geometric consistency index: Approximated thresholds," *Eur. J. Oper. Res.*, vol. 147, no. 1, pp. 137–145, May 2003, doi: 10.1016/S0377-2217(02)00255-2.

[4] M. Serda *et al.*, "Synteza i aktywność biologiczna nowych analogów tiosemikarbazonowych chelatorów żelaza," *Uniw. Śląski*, vol. 7, no. 1, pp. 343–354, 2013, doi: 10.2/JQUERY.MIN.JS.

[5] Y. Xu, X. Shang, J. Wang, W. Wu, and H. Huang, "Some q-rung dual hesitant fuzzy Heronian mean operators with their application to multiple attribute group decision-making," *Symmetry*, vol. 10, no. 10, 2018, doi: 10.3390/SYM10100472.

[6] E. Herrera-Viedma, F. Herrera, F. Chiclana, and M. Luque, "Some issues on consistency of fuzzy preference relations," *Eur. J. Oper. Res.*, vol. 154, no. 1, pp. 98–109, Apr. 2004, doi: 10.1016/S0377-2217(02)00725-7.

[7] M. Zhou, Z. Wang, and Y. Shen, "Simultaneous fault estimation and fault-tolerant tracking control for uncertain nonlinear discrete-time systems," *Int. J. Syst. Sci.*, vol. 48, no. 7, pp. 1367–1379, May 2017, doi: 10.1080/00207721.2016.1258596.

[8] H. Wu, I. Yuji, and H. Ban, "Reverse Radial Bias: Temporal Orientation Bias Compensation in Early Visual Areas Revealed by MEG," *J. Vis.*, vol. 18, no. 10, p. 716, Sep. 2018, doi: 10.1167/18.10.716.

[9] R. M. Rodríguez, Á. Labella, M. Sesma-Sara, H. Bustince, and L. Martínez, "A cohesion-driven consensus reaching process for large scale group decision making under a hesitant fuzzy linguistic term sets environment," *Comput. Ind. Eng.*, vol. 155, May 2021, doi: 10.1016/j.cie.2021.107158.

[10] Y. Xu, F. J. Cabrerizo, and E. Herrera-Viedma, "A consensus model for hesitant fuzzy preference relations and its application in water allocation management," *Appl. Soft Comput. J.*, vol. 58, pp. 265–284, Sep. 2017, doi: 10.1016/j.asoc.2017.04.068.

[11] Y. Zhang, Z. Xu, and H. Liao, "A consensus process for group decision making with probabilistic linguistic preference relations," *Inf. Sci.*, vol. 414, pp. 260–275, Nov. 2017, doi: 10.1016/j.ins.2017.06.006.

[12] Á. Labella, H. Liu, R. M. Rodríguez, and L. Martínez, "A Cost Consensus Metric for Consensus Reaching Processes based on a comprehensive minimum cost model," *Eur. J. Oper. Res.*, vol. 281, no. 2, pp. 316–331, Mar. 2020, doi: 10.1016/j.ejor.2019.08.030.

[13] P. K. Biswas and S. Liu, "A hybrid recommender system for recommending smartphones to prospective customers," *Expert Syst. Appl.*, vol. 208, Dec. 2022, doi: 10.1016/j.eswa.2022.118058.

[14] Z. Zhang and C. Wu, "A decision support model for group decision making with hesitant multiplicative preference relations," *Inf. Sci.*, vol. 282, pp. 136–166, Oct. 2014, doi: 10.1016/j.ins.2014.05.057.

[15] G. Crawford and C. Williams, "A note on the analysis of subjective judgment matrices," *J. Math. Psychol.*, vol. 29, no. 4, pp. 387–405, 1985, doi: 10.1016/0022-2496(85)90002-1.

[16] J. J. Buckley, "Fuzzy hierarchical analysis," *Fuzzy Sets Syst.*, vol. 17, no. 3, pp. 233–247, 1985, doi: 10.1016/0165-0114(85)90090-9.

[17] P. Grošelj and G. Dolinar, "Group AHP framework based on geometric standard deviation and interval group pairwise comparisons," *Inf. Sci.*, vol. 626, pp. 370–389, May 2023, doi: 10.1016/j.ins.2023.01.034.

[18] Z. Zhang and W. Pedrycz, "Goal Programming Approaches to Managing Consistency and Consensus for Intuitionistic Multiplicative Preference Relations in Group Decision Making," *IEEE Trans. Fuzzy Syst.*, vol. 26, no. 6, pp. 3261–3275, 2018, doi: 10.1109/TFUZZ.2018.2818074.

[19] P. F. Lee, W. S. Lam, W. H. Lam, and W. K. Muck, "Multi-Criteria Decision Analysis on the Preference of Courier Service roviders with Analytic Hierarchy Process Model," *J. Adv. Res. Appl. Sci. Eng. Technol.*, vol. 35, no. 2, pp. 94–103, May 2024, doi: 10.37934/ARASET.35.2.94103.

[20] Z. Xu, "Intuitionistic preference relations and their application in group decision making," *Inf. Sci.*, vol. 177, no. 11, pp. 2363–2379, Jun. 2007, doi: 10.1016/j.ins.2006.12.019.

[21] H. N. Ting, Y. M. Choo, and A. A. Kamar, "Classification of asphyxia infant cry using hybrid speech features and deep learning models," *Expert Syst. Appl.*, vol. 208, Dec. 2022, doi: 10.1016/j.eswa.2022.118064.
[22] E. Ilbahar, A. Karaşan, S. Cebi, and C. Kahraman, "A novel approach to risk assessment for occupational health and safety using Pythagorean fuzzy AHP & fuzzy inference system," *Saf. Sci.*, vol. 103, pp. 124–136, Mar. 2018, doi: 10.1016/j.ssci.2017.10.025.
[23] B. G. Gebregiorgis, G. M. Takele, K. D. Ayenew, and Y. E. Amare, "Prevalence of hospital-acquired infections (HAIs) and associated factors in Ethiopia: A systematic review and meta-analysis protocol," *BMJ Open*, vol. 10, no. 12, Dec. 2020, doi: 10.1136/BMJOPEN-2020-042111.