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Multi-criteria supplier segmentation using a fuzzy preference relations based AHP

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ABSTRACT

One of the strategic activities of a firm is supplier segmentation, whereby a firm creates groups of suppliers to handle them differently. Existing literature provides several typologies of suppliers, each of which uses different dimensions/variables. In this paper, different typologies are combined by distinguishing two overarching dimensions, the capabilities and the willingness of suppliers to cooperate with a particular firm. These dimensions cover almost all the existing supplier segmentation criteria mentioned in existing literature. For each particular situation, these dimensions can be specified using a multi-criteria decision-making method. A methodology is proposed that includes a fuzzy Analytic Hierarchy Process (AHP) which uses fuzzy preference relations to incorporate the ambiguities and uncertainties that usually exist in human judgment. The proposed methodology is used to segment the suppliers of a broiler company. The result is a segmentation of suppliers based on two aggregated dimensions. Finally some strategies to handle different segments are discussed and concluding remarks and suggestions for future research are provided.

1. Introduction

Supplier segmentation logically takes place after supplier selection. It basically means that a firm classifies its suppliers in different segments, which is essential for a buying firm that wants to deal with different suppliers in a systematic way. Firms should adopt a more strategic approach to supplier relationship management and avoid a "one-size-fits-all" strategy for supplier relationship management (Dyer et al., 1998).

Traditionally, the segmentation of suppliers is based on two dimensions. By using a 2×2 matrix, suppliers are segmented to four segments. Parasuraman (1980) and Kraljic (1983) were among the first researchers to propose the concept of supplier segmentation. Kraljic (1983) explicitly presented a model to segment supplies (the goods supplied) into four segments, using two dimensions (profit impact and supply risk for items supplied) and considered two levels (low and high) for each of these dimensions. As a result, supplies are segmented into four categories: (1) Non-critical items (supply risk: low; profit impact: low); (2) Leverage items (supply risk: low; profit impact: high); (3) Bottleneck items (supply risk: high; profit impact: low); and (4) Strategic items (supply risk: high; profit impact: high). Different strategies are described to handle the suppliers in each segment. Adopting Kraljic's so-called portfolio approach, several two-dimensional supplier segmentation methods have been proposed. For example: difficulty of managing the purchase situation; and strategic importance of the purchase (Olsen and Ellram, 1997); the supplier's and buyer's specific investments (Bensaou, 1999); technology; and collaboration (Kaufman et al., 2000); supplier's commitment; and the importance of the commodity (Svensson, 2004); supplier and buyer dependency risk (Hallikas et al., 2005). For a discussion of supplier segmentation approaches, see Rezaei and Ortt (2012) and Day et al. (2010). The fact that different researchers use different criteria to identify supplier segments implies that more than two criteria have to be considered when segmenting suppliers. In other words, the problem of segmentation is in fact a multi-criteria problem. Recently, Rezaei and Ortt (2012), in their literature review regarding supplier segmentation, proposed a framework for classifying the criteria in different supplier segmentation approaches using two overarching dimensions: supplier capabilities and supplier willingness. The proposed framework, which takes both the supplier segmentation variables and the criteria used in supplier selection into account, has the following benefits.

1. It makes it possible to consider multiple criteria, while most existing supplier segmentation methods are based on just two criteria.
2. It provides a logical basis for aggregating different criteria.
3. It gives us an adequate basis for segmenting suppliers in accordance with the common 2×2 matrix. The resulting matrix, however, is much more inclusive than those used by other methods, because the dimensions are based on multiple criteria.

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In this section, the supplier segmentation approach used in this paper is described. According to Rezaei and Ortt (2012), supplier segmentation is defined as "the identification of the *capabilities* and *willingness* of suppliers by a particular buyer in order for the buyer to engage in a strategic and effective partnership with the suppliers with regard to a set of evolving business functions and activities in the supply chain". In this definition, there are two dimensions (capabilities and willingness) on the basis of which suppliers can be segmented. Suppliers can be segmented for each function separately, such as purchasing, production, R&D, finance, and marketing and sales. The dimensions, capabilities and willingness, are seen as multi-criteria concepts. For example, the capabilities of a supplier can be evaluated using different criteria such as the quality of the products (Dickson, 1966; Weber et al., 1991; Tan et al., 2002), the technical capability of the supplier in question (Dickson, 1966; Weber et al., 1991; Choi and Hartley, 1996; Swift, 1995), the design capability of the supplier (Choi and Hartley, 1996), etc. Willingness of the supplier can be evaluated using multiple criteria, such as communication openness (Kannan and Tan, 2002; Choi and Hartley, 1996; Smeltzer, 1997) and commitment to continuous improvement in product and process (Kannan and Tan, 2002; Svensson, 2004; Urgal-González and García-Vázquez, 2007).

Each buyer may consider different capabilities and willingness criteria to evaluate and segment its suppliers. For a comprehensive sample of the various possible criteria for capabilities and willingness, see Tables 1 and 2 respectively. As mentioned earlier, supplier segmentation is a step between supplier selection and supplier relationship management. Consequently, a firm should select the criteria in such a way that there is a consistency between the supplier-related strategic activities mentioned above. For instance, the drivers and objectives of engaging in partnership with suppliers (e.g. cost reduction, marketing advantages, customer satisfaction, etc. (Lambert, 2008)) can serve as a helpful guideline for selecting the segmentation criteria. For example, if cost reduction is one of the main drivers to engage in partnership, price may be considered one of the supplier capabilities criteria. In addition, the requirements of the methodology being applied should be taken into account as well. For example, when using a version of crisp or fuzzy AHP, some independent criteria have to be selected for each dimension (in Section 3, some statistical tests are used to ensure the independence of the criteria). Once the criteria have been selected, aggregating the capabilities and willingness criteria yields a two-dimensional matrix. This matrix will be an $X \times Y$ matrix, due to the possible number of levels for each of the two dimensions. Such a matrix yields XY segments. For example, if two levels (low and high) are chosen for each dimension, the result is a 2×2 matrix that can be used to divide the suppliers into four segments.

In this paper, a methodology is proposed to segment suppliers using multiple criteria. A Fuzzy Analytic Hierarchy Process (FAHP), a multi-criteria decision-making (MCDM) method, is applied to determine the weight of the criteria of each dimension. The paper is organized as follows. In Section 2, the methodology is presented.

Table 1
A list of capabilities criteria (Rezaei and Ortt, 2012).

Capabilities criteria	References
Price/cost	Dickson (1966), Weber et al. (1991), Kannan and Tan (2002), Day (1994), Choi and Hartley (1996), Swift (1995), and Rezaei and Davoodi (2011, 2012)
Profit impact of supplier	Choi and Hartley (1996), van Weele (2000), and Kraljic (1983)
Delivery	Dickson (1966), Weber et al. (1991), Kannan and Tan (2002), Day (1994), Choi and Hartley (1996), Swift (1995), Tan et al. (2002), and Rezaei and Davoodi (2011, 2012)
Quality	Dickson (1966), Weber et al. (1991), Tan et al. (2002); and Rezaei and Davoodi (2011, 2012)
Reserve capacity	Kannan and Tan (2002)
Industry knowledge	Kannan and Tan (2002)
Production, manufacturing/transformation facilities and capacity	Dickson (1966), Weber et al. (1991), and Day (1994)
Geographic location/proximity	Dickson (1966), Weber et al. (1991), Kannan and Tan (2002), and Swift (1995)
Design capability	Choi and Hartley (1996)
Technical capability	Dickson (1966), Weber et al. (1991), Choi and Hartley (1996), and Swift (1995)
Technology monitoring	Day (1994)
Management and organization	Dickson (1966) and Weber et al. (1991)
Supplier process capability	Kannan and Tan (2002)
Reputation and position in industry	Dickson (1966), Weber et al. (1991), Choi and Hartley (1996), and Swift (1995)
Financial position	Dickson (1966), Weber et al. (1991), Kannan and Tan (2002), Day (1994), Choi and Hartley (1996), and Swift (1995)
Performance awards	Choi and Hartley (1996)
Performance history	Dickson (1966) and Weber et al. (1991)
Cost control	Day (1994)
Technology development	Day (1994)
Repair service	Dickson (1966) and Weber et al. (1991)
After sales support	Choi and Hartley (1996)
Packaging ability	Dickson (1966) and Weber et al. (1991)
Reliability of product	Choi and Hartley (1996) and Swift (1995)
Operational controls	Dickson (1966) and Weber et al. (1991)
Training aids	Dickson (1966) and Weber et al. (1991)
Labor relations record	Dickson (1966) and Weber et al. (1991)
Impact on energy utilization	Swift (1995)
Ease of maintenance design	Swift (1995)
Communication system	Dickson (1966) and Weber et al. (1991)
Desire for business	Dickson (1966) and Weber et al. (1991)
Human resource management	Day (1994)
Amount of past business	Dickson (1966) and Weber et al. (1991)
Warranties and claims	Dickson (1966), Weber et al. (1991), and Swift (1995)
Market sensing	Day (1994)
Customer linking	Day (1994)
Environmental health and safety	Day (1994)
Innovation	Spina et al. (2002)
Supplier's order entry and invoicing system including EDI	Kannan and Tan (2002)

Table 2
A list of willingness criteria (Rezaei and Ortt, 2012).

Willingness criteria	References
Commitment to quality	Kannan and Tan (2002) and Svensson (2004)
Honest and frequent communications/communication openness	Kannan and Tan (2002), Choi and Hartley (1996), and Smeltzer (1997)
Commitment to continuous improvement in product and process	Kannan and Tan (2002), Svensson (2004), and Urgal-González and García-Vázquez (2007)
Relationship closeness	Choi and Hartley (1996) and Kaufman et al. (2000)
Open to site evaluation	Kannan and Tan (2002)
Attitude	Dickson (1966) and Weber et al. (1991)
Bidding procedural compliance	Dickson (1966) and Weber et al. (1991)
Reciprocal arrangements	Dickson (1966), Weber et al. (1991), and Kaufman et al. (2000)
Prior experience with supplier	Swift (1995)
Impression	Dickson (1966) and Weber et al. (1991)
Ethical standards	Kannan and Tan (2002)
Willingness to co-design and participate in new product development	Spina et al. (2002) and Tan et al. (2002)
Willingness to integrate supply chain management relationship	Kannan and Tan (2002)
Mutual respect and honesty	Smeltzer (1997)
Willingness to share information, ideas, technology, and cost savings	Kannan and Tan (2002), Smeltzer (1997), and Tan et al. (2002)
Consistency and follow-through	Smeltzer (1997)
Supplier's effort in eliminating waste	Kannan and Tan (2002)
Supplier's effort in promoting JIT principles	Kannan and Tan (2002)
Dependency	Hallikas et al. (2005) and Kaufman et al. (2000)
Willingness to invest in specific equipment	Urgal-González and García-Vázquez (2007)
Long term relationship	Choi and Hartley (1996)

In Section 3, the proposed methodology is applied to a real-world case. Finally, the conclusion and future work are presented in Section 4.

2. Proposed methodology

In this section, a five-step methodology to supplier segmentation is described.

1. Determine a number of capabilities and willingness criteria, or select them from Tables 1 and 2 respectively $(C_1^C, C_2^C, \ldots, C_K^C$ and $C_1^W, C_2^W, \ldots, C_J^W)$ through screening by the decision-maker.
2. Determine the weights of the respective capabilities and willingness criteria respectively $(w_1^C, w_2^C, \ldots, w_K^C$ and $w_1^W, w_2^W, \ldots, w_J^W)$ using an MCDM method (in this paper a fuzzy AHP).
3. Assign a score to each supplier considering each capabilities criterion $(a_{i1}^C, a_{i2}^C, \ldots, a_{ik}^C, \ldots, a_{iK}^C)$ and willingness criterion $\left(a_{i1}^W, a_{i2}^W, \ldots, a_{ij}^W, \ldots a_{iJ}^W\right)$ by the decision-maker, where a_{ik}^C is evaluation of supplier i with respect to kth capabilities criterion and a_{ij}^W is evaluation of supplier i with respect to jth willingness criterion, and K and J are the number of capabilities criteria and the number of willingness criteria respectively.
4. Determine the final aggregated scores of capabilities and willingness of each supplier as follows:

$$S_i^C = \sum_{k=1}^{K} w_k^C a_{ik}^C, \forall i \tag{1}$$

$$S_i^W = \sum_{j=1}^{J} w_j^W a_{ij}^W, \forall i \tag{2}$$

5. Divide the suppliers based on their final aggregated scores into XY segments, where X and Y are the number of levels considered for capabilities and willingness respectively. For example for a common 2×2 segmentation there would be four segments (types) as follows.

Type 1: all suppliers with $S_i^C < \frac{\alpha}{2}$ and $S_i^W < \frac{\beta}{2}$

Type 2: all suppliers with $S_i^C < \frac{\alpha}{2}$ and $\frac{\beta}{2} \leqslant S_i^W \leqslant \beta$

Type 3: all suppliers with $\frac{\alpha}{2} \leqslant S_i^C \leqslant \alpha$ and $S_i^W < \frac{\beta}{2}$

Type 4: all suppliers with $\frac{\alpha}{2} \leqslant S_i^C \leqslant \alpha$ and $\frac{\beta}{2} \leqslant S_i^W \leqslant \beta$

where α and β are the maximum potential values of the supplier's aggregated capabilities and willingness scores respectively. $\frac{\alpha}{2}$ and $\frac{\beta}{2}$ are the cut-off points (dividing the dimensions to two equal parts Low and High) for the dimensions of supplier capabilities and willingness respectively for a common 2×2 segmentation.

It is clear that, depending on the decision-maker's requirements, it is possible to assign suppliers to more segments than four. For example, when considering three levels (low, medium and high) for the capabilities dimension and two levels (low and high) for the willingness dimension, the resulting number of segments is six. In this case, there will be two cut-off points for capabilities dimension $\left(\frac{\alpha}{3}\right.$ and $\left.\frac{2\alpha}{3}\right)$ and one cut-off point for willingness dimension $\left(\frac{\beta}{2}\right)$.

To carry out step 2 of the above-mentioned methodology, i.e. to calculate the weights of capabilities and willingness criteria, a multi-criteria decision-making method should be applied. AHP, which was first introduced by Saaty (1980), is one of the most commonly used methodologies in this kind of a situation. However, although it is a simple and convenient judgment-based methodology, it is unable to handle the ambiguities that commonly exist in human judgments. Fuzzy set theory introduced by Zadeh (1965) has enriched classic models in its ability to handle impreciseness in human thinking, judgment and decision-making. Applying fuzzy AHP is preferred because it is conceptually closer to human thinking. Fuzzy AHP has been used to solve various problems in different areas of study, from evaluating the knowledge portal development tools (Kreng and Wu, 2007), matchmaking (Joshi and Kumar, 2012), behavior-based safety management (Dağdeviren and Yüksel, 2008) and inventory management (Rezaei, 2007) to organizational capital measurement (Bozbura and Beskese, 2007). It has also been used in some areas of supply chain management, such as supplier selection (Kahraman et al., 2003), global supplier development (Chan and Kumar, 2007) and the evaluation of buyer–supplier relationships (Lee, 2009).

In the next subsections, some preliminaries materials are introduced and then the fuzzy AHP is discussed as used in step 2 of the proposed methodology. The other steps are relatively straightforward.

2.1. Preliminaries

Here the definitions of some materials used in the proposed fuzzy AHP are presented.

Definition 1. (van Laarhoven and Pedrycz, 1983) Triangular fuzzy number (TFN): A fuzzy number N on $\Re$ is defined to be a TFN if its membership function $\mu_N(x) : \Re \to [0,1]$ be:

$$\mu_N(x) = \begin{cases} \frac{x-l}{m-l}, & l \leqslant x \leqslant m, \\ \frac{u-x}{u-m}, & m \leqslant x \leqslant u, \\ 0, & \text{otherwise}, \end{cases} \tag{3}$$

where l, and u are the lower and upper bounds of the support N respectively, m is the modal value and $l < m < u$. This triangular fuzzy number can be noted by the triple (l,m,u). The operational laws of two TFNs $N_1 = (l_1,m_1,u_1)$ and $N_2 = (l_2,m_2,u_2)$ are as follows:

Fuzzy number addition $\oplus$

$$N_1 \oplus N_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{4}$$

Fuzzy number multiplication $\otimes$

$$N_1 \otimes N_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) \cong (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$$
$$\text{where } l_i, m_i, u_i \text{ are all positive real numbers.} \tag{5}$$

Fuzzy number division$(/)$

$$N_1 (/) N_2 = (l_1, m_1, u_1)(/)(l_2, m_2, u_2) \cong (l_1/u_2, m_1/m_2, u_1/l_2) \text{ where } l_i, m_i, u_i \text{ are all positive real numbers.} \tag{6}$$

Definition 2. (Herrera-Viedma et al., 2004; Wang and Chen, 2008) Fuzzy preference relations: a fuzzy preference relation P on a set of alternatives $A = \{a_1,a_2,\ldots,a_n\}$ is a fuzzy set on the product set $A \times A$ with membership function $P{:}A \times A \to [0,1]$.

The preference relation is represented by the $n \times n$ matrix $P = (p_{ij})$, where $p_{ij} = P(a_i,a_j)$, for all i, $j \in \{1,2,\ldots,n\}$. Herein, p_{ij} is the preference ratio of alternative a_i to a_j:$p_{ij} = 1/2$ means that there is no difference between a_i and a_j, $p_{ij} = 1$ indicates that a_i is absolutely better than a_j, and $p_{ij} > 1/2$ indicates that a_i is better than a_j. In this case, the preference matrix P is generally assumed to be an additive reciprocal of $p_{ij} + p_{ji} = 1$ for all $i, j \in \{1,2,\ldots,n\}$.

Proposition 1. *(Wang and Chen, 2008) For a fuzzy reciprocal linguistic preference relation, $\widetilde{P} = (\tilde{p}_{ij})$ with $\tilde{p}_{ij} \in [0,1]$, verifies the additive reciprocal, then, the following statements are equivalent.*

$$p^L_{ij} + p^R_{ji} = 1, \tag{7}$$

$$p^M_{ij} + p^M_{ji} = 1, \tag{8}$$

$$p^R_{ij} + p^L_{ji} = 1. \tag{9}$$

Proposition 2. *(Wang and Chen, 2008) For a reciprocal fuzzy linguistic preference relation $\widetilde{P} = (\tilde{p}_{ij}) = \left(p^L_{ij}, p^M_{ij}, p^R_{ij}\right)$ to be consistent, verifies the additive consistency, then, the following statements must be equivalent:*

$$p^L_{ij} + p^L_{jk} + p^R_{ki} = \frac{3}{2} \forall i < j < k, \tag{10}$$

$$p^M_{ij} + p^M_{jk} + p^M_{ki} = \frac{3}{2} \forall i < j < k, \tag{11}$$

$$p^R_{ij} + p^R_{jk} + p^L_{ki} = \frac{3}{2} \forall i < j < k, \tag{12}$$

$$p^L_{i(i+1)} + p^L_{(i+1)(i+2)} + \cdots + p^L_{(j-1)j} + p^R_{ji} = \frac{j-i+1}{2} \forall i < j, \tag{13}$$

$$p^M_{i(i+1)} + p^M_{(i+1)(i+2)} + \cdots + p^M_{(j-1)j} + p^M_{ji} = \frac{j-i+1}{2} \forall i < j, \tag{14}$$

$$p^R_{i(i+1)} + p^R_{(i+1)(i+2)} + \cdots + p^R_{(j-1)j} + p^L_{ji} = \frac{j-i+1}{2} \forall i < j. \tag{15}$$

2.2. Preference relations-based fuzzy AHP

In existing literature, there are several types of fuzzy AHP. van Laarhoven and Pedrycz (1983) used triangular fuzzy numbers and Lootsma's logarithmic least square method to derive local fuzzy priorities and, in doing so, presented a fuzzy AHP for the first time. Buckley (1985) used trapezoidal fuzzy numbers and a geometric mean method in his proposed fuzzy AHP. Boender et al. (1989) improved the original work by van Laarhoven and Pedrycz (1983) to obtain more robust results. Chang (1996) used triangular fuzzy numbers for pairwise comparison and the extent analysis method to arrive at a fuzzy AHP. His method is much simpler and has relatively lower computational requirements. The fuzzy AHP proposed by Chang (1996) was then improved by Zhu et al. (1999) and, due to its computational simplicity, has become a popular fuzzy AHP. Recently, however, Wang et al. (2008) have found that the extent analysis method used in the fuzzy AHP proposed by Chang (1996) cannot derive the priorities from a fuzzy or crisp comparison matrix and therefore has resulted in a huge number of misapplications. Mikhailov (2003) derived priorities from fuzzy pairwise comparison judgments based on an α-cut decomposition of the fuzzy judgments into a series of interval comparisons.

Apart from advantages and disadvantages of the afore-mentioned works, the most important criticism regarding most of them is their failure to handle inconsistency (Leung and Cao, 2000). Having consistency is crucial because inconsistent comparisons lead to misleading solutions. There are a few articles in the literature that study the inconsistency in fuzzy AHP (see, for example Salo, 1996; Leung and Cao, 2000; Ramik and Korviny, 2010).

The topic of fuzzy preference relations has received increasing attention in priority-ranking problems (see, for example, Chiclana et al., 1998, 2001, 2003;Xu, 2004; Xu and Da, 2005). For a robust ranking, it is crucial to have consistent fuzzy preference relations. Herrara-Viedma et al. (2004) presented a characterization of the consistency property based on the additive transitivity property of the fuzzy preference relations. Wang and Chen (2008) incorporated the characterization of the consistency property proposed by Herrara-Viedma et al. (2004) into AHP and proposed a method that leads to consistent priority-ranking from only $n-1$ pairwise comparisons. Their method has two very important features: (1) it yields consistent priority ranking and (2) it requires fewer pairwise comparisons.

This robust method is applied to obtain the weights of capabilities and willingness criteria in this paper as follows:

Step 1. Establish the hierarchy
Here, a hierarchy is constructed, including the goal and criteria.

Step 2. Determine the pair-wise comparison matrices
This step includes the construction of comparison matrix $\widetilde{P}$ for the criteria.

$$\widetilde{P} = \begin{bmatrix} \tilde{p}_{11} & \tilde{p}_{12} & \cdots & \tilde{p}_{1n} \\ \tilde{p}_{21} & \tilde{p}_{22} & \cdots & \tilde{p}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{p}_{n1} & \tilde{p}_{n2} & \cdots & \tilde{p}_{nn} \end{bmatrix} \tag{16}$$

where $\tilde{p}_{ij}$ is a fuzzy linguistic variable or its equivalent triangular fuzzy number to show the decision-maker's preference of i over j, as indicated in Fig. 1 and Table 3.

In this step, following Wang and Chen (2008), it is necessary only to fill in $n-1$ cells of the matrix. The other cells can be obtained using the equations that are derived based on the reciprocity (Eqs. (7)–(9)) and consistency (Eqs. (10)–(15)) properties of a positive additive matrix:

Step 3. Construct the fuzzy linguistic preference relation decision matrices for the criteria.

If, after calculating the pairwise comparisons, the value of some elements of the aggregated matrices do not have a value between zero and one ($\tilde{p}_{ij} \notin [0,1]$) the following transformations should be applied to transform the elements to the interval [0,1], i.e. f:[$-c$, 1 + c] → [0,1] where c is the maximum amount of violation from interval [0,1] among elements of $\widetilde{P}$.

$$f(x^L) = \frac{x^L + c}{1 + 2c}, \tag{17}$$

$$f(x^M) = \frac{x^M + c}{1 + 2c}, \tag{18}$$

$$f(x^R) = \frac{x^R + c}{1 + 2c}. \tag{19}$$

Step 4. Calculate the weights of the criteria as follows:

$$\tilde{w}_i = \frac{\tilde{g}_i}{\tilde{g}_1 \oplus \ldots \oplus \tilde{g}_n}, \tag{20}$$

where $\tilde{g}_i$ is the mean of the comparison values of row i and is calculated as follows.

$$\tilde{g}_i = \frac{1}{n}[\tilde{p}_{i1} \oplus \tilde{p}_{i2} \oplus \ldots \oplus \tilde{p}_{in}], \quad i = 1, \ldots, n. \tag{21}$$

Using a defuzzification method, like fuzzy mean (FM), the final defuzzied weights are calculated as follows:

$$w_i = \frac{w_i^L + w_i^M + w_i^R}{3} \tag{22}$$

It has to be mentioned that, to calculate the weight of the criteria and to defuzzify them, other operators and methods can be used as well (for other operators, see Chen and Hwang (1992), and for the defuzzification methods, see Leekwijck and Kerre (1999)).

3. Case study

The proposed methodology was applied to a medium-sized broiler (meat-type chicken) company operating in the food industry, which is an important industry with a considerable share in all countries. "Food supply chains operate in a complex, dynamic and time-critical environment" (Bourlakis and Weightman, 2004), where customers have different increasing needs. They demand high quality fresh products at low prices. In addition, the perishability of the food products renders them very time-critical. It is far from realistic to expect food companies to meet these requirements on their own, which is why they need the help of their suppliers to produce good products with low prices and reliable delivery. Within this framework, managing the suppliers is a critical activity. To do so effectively, food companies need to segment their suppliers in an effective and dynamic way.

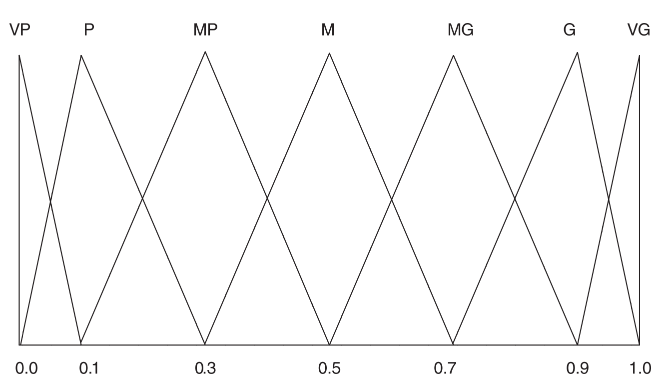

Fig. 1. Fuzzy linguistic assessment variables.

Table 3
Fuzzy linguistic assessment variables.

Linguistic variables	Triangular fuzzy numbers
Very poor (VP)	(0,0,0.1)
Poor (P)	(0,0.1,0.3)
Medium poor (MP)	(0.1,0.3,0.5)
Medium (M)	(0.3,0.5,0.7)
Medium good (MG)	(0.5,0.7,0.9)
Good (G)	(0.7,0.9,1)
Very good (VG)	(0.9,1,1)

The company selected for our study buys newly hatched chicks from hatcheries and raises them to market weight in about 6 weeks. The chickens are then delivered to a processing plant to be stunned and undergo further processing. Finally, the packaged products are transported by refrigerated trucks to the market. The company receives the newly hatched chicks, feed, medications and other required materials from 43 suppliers (newly hatched chicks: 11 suppliers, feed: 9 suppliers, medications: 6 suppliers, and other materials and equipment: 17 suppliers). To segment these suppliers, we gathered the relevant data by interviewing the manager of the company. We first asked the manager to screen the list of capabilities and willingness criteria to select a handful of criteria for each dimension. After careful consideration, the manager selected six criteria for capabilities and six criteria for willingness, as shown in Table 4.

We then asked the manager to assign a score between 1 (very low) and 5 (very high) for each criterion as applied to the various suppliers. The score reflects how each supplier is perceived based on the criterion. The resulting six scores for the various criteria are presented in Table 5.

To check the independence of the criteria within each dimension, as well as the independence of the dimensions, the non-parametric correlation (Spearman's ρ)[2] (Spearman, 1910) was calculated. None of the bivariate correlations for the capabilities criteria is high or very high. The same applies to the willingness criteria, although here the correlations are somewhat higher. The average ρ for capabilities and willingness criteria are 0.216 and 0.456 respectively, which on average indicate that the correlations between the criteria are weak, which in turn implies that they are highly independent.

To check the independence of the two aggregated dimensions, the discriminant validity was tested. Spearman's correlation was calculated and corrected for attenuation effects due to measurement error. Schmidt and Hunter (1996) formula $\hat{\rho}_{xy} = r_{xy}/\sqrt{r_{xx}r_{yy}}$ was used, where r_{xy} is the correlation between the two scales (here

[2] Spearman's correlation or Spearman's rank correlation ρ, is a non-parametric measure of statistical dependence between two variables. It takes a value in range [−1,1]. The greater the absolute value of ρ, the more dependence between the two variables and vice versa ($|\rho| < 0.3$: little; $0.3 \leqslant |\rho| < 0.5$: low; $0.5 \leqslant |\rho| < 0.7$: moderate; $0.7 \leqslant |\rho| < 0.9$: high; $0.9 \leqslant |\rho| \leqslant 1$: very high). For further information, see Spearman (1910).

Table 4
Selected capabilities and willingness criteria.

Selected capabilities criteria	Selected willingness criteria
Price $\left(C_1^C\right)$	Commitment to quality $\left(C_1^W\right)$
Delivery $\left(C_2^C\right)$	Communication openness $\left(C_2^W\right)$
Quality $\left(C_3^C\right)$	Reciprocal arrangement $\left(C_3^W\right)$
Reserve capacity $\left(C_4^C\right)$	Willingness to share information $\left(C_4^W\right)$
Geographical location $\left(C_5^C\right)$	Supplier's effort in promoting JIT principles $\left(C_5^W\right)$
Financial position $\left(C_6^C\right)$	Long term relationship $\left(C_6^W\right)$

two dimensions capabilities and willingness), and r_{xx} and r_{yy} are the reliability of the two scales. r_{xy}, r_{xx} and r_{yy} found as 0.220, 0.657, and 0.866 respectively. Hence, $\hat{\rho}_{xy}$ or the corrected correlation between capabilities and willingness is 0.292, which shows a high discriminant validity.

We also asked the manager to conduct a pairwise comparison with regard to the different criteria. As mentioned in the explanation of the fuzzy AHP methodology, it is enough to have only $n-1$ comparisons elements for each matrix, which is why the manager was asked to fill in $n-1$ cells of each matrix using the fuzzy linguistic assessment variables (see Table 3 and Fig. 1 for these variables). The completed matrices for the required cells are shown in Table 6 (capabilities) and Table 7 (willingness).

Table 5
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 6
Fuzzy pairwise comparison 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		VP	×	×	×	×
C_2^C			P	×	×	×
C_3^C				G	×	×
C_4^C					M	×
C_5^C						P
C_6^C						

Table 7
Fuzzy pairwise comparison 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		G	×	×	×	×
C_2^W			M	×	×	×
C_3^W				M	×	×
C_4^W					P	×
C_5^W						VG
C_6^W						

Converting the filled cells of Tables 6 and 7 to their corresponding fuzzy numbers and according to Eqs. (7)–(15), the completed comparison matrices can be obtained as indicated in Tables 8 and 9 respectively.

As it can be seen from Tables 8 and 9, some elements fall outside the interval [0,1]. Therefore, Eqs. (17)–(19) were used to transfer the elements to be included in interval [0,1], the results of which are shown in Tables 10 and 11, respectively. Please note that the transforming process has a relative effect on other elements.

Applying (20) and (21) we are able to calculate the final weights of the various criteria that are defuzzified using (22) to arrive at the defuzzified weights (see Table 12 and Figs. 2 and 3). This is the final result of the fuzzy AHP.

Using the criteria weights, we can calculate the aggregated scores for the capabilities and willingness of each supplier using (1) and (2) (see Table 13).

Now, in line with the final step of the proposed methodology (step 5), we are able to divide the suppliers into four segments, which can be seen in Fig. 4 and Table 14.

All the computations were done using Microsoft Excel's Solver (Microsoft, 2007). Other optimization software can be used as well, for instance MATLAB (MathWorks, 2010), LINGO (LINDO, 2012), etc.

Table 8
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 9
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 10
Transforming results of the six capabilities criteria matrix from Table 8.

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 11
Transforming results of the six willingness criteria matrix from Table 9.

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 12
Capabilities and willingness criteria weights.

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); while the highest number of suppliers (31) are assigned to Type 4 (high capabilities and high willingness). This means that the broiler company has 31 *good* suppliers. Twelve suppliers are lacking in capabilities, willingness or both. Upon closer inspection, Fig. 4 indicates that all suppliers are in or around the upper right quadrant.

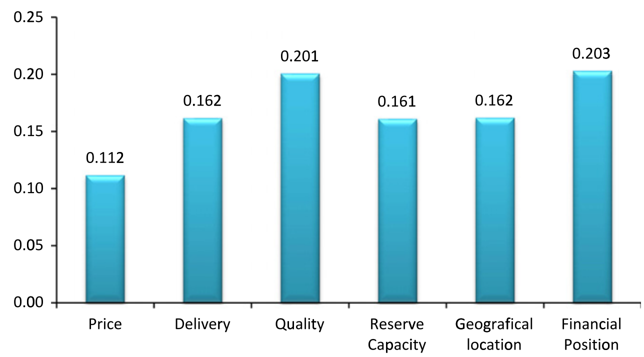

Fig. 2. Defuzzified weight of capabilities criteria.

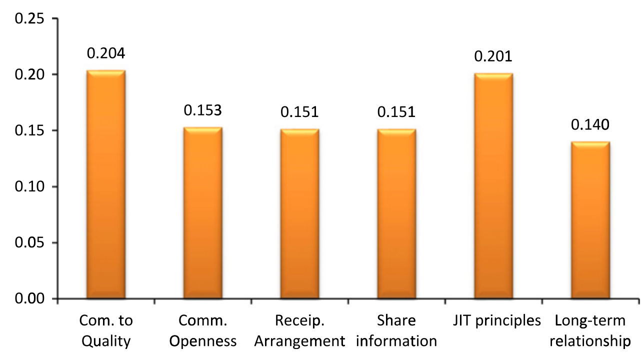

Fig. 3. Defuzzified weight of willingness criteria.

Type 1. These suppliers are the worst suppliers as they have low capabilities and at the same time a low willingness to work with the buyer. In general, buyers may be advised to replace these suppliers. In the interview with the manager of the broiler company, we identified these suppliers. The suppliers were two newly hatched chicks producers and one medication provider. We discussed why they became suppliers and what the manager should do after identifying their lack of capabilities and willingness. The manager indicated that replacing the two newly hatched chicks producers is not rational, as the firm is working with them only when demand is high and finding better suppliers in the high-demand season is not easy. However, the medication provider is replaceable.

Type 2. These suppliers have low capabilities but a high willingness to work with the buyer. These suppliers may benefit more from the relationship than the buyer. The buyer may help these suppliers improve their capabilities. In the interview, we identified these suppliers. Again, most of them newly hatched chicks producers (three out of six); two of them were feed suppliers and one of them supplied materials and equipment. Fortunately, there is a high level of willingness among these suppliers to cooperate with the firm, which makes it worthwhile to invest in their development. The firm could help these suppliers improve their capabilities by forming cross-functional teams to identify and solve problems, which is in fact part of a total quality management (TQM) system (Hackman and Wageman, 1995). In addition, as the main concern regarding newly hatched chicks is making sure about selling the chicks on time, the firm can also reduce its supply base, which is defined as the process of and activities related to reducing the number of suppliers (Ogden, 2006). For example, the firm can terminate its relationship with the newly hatched chick's producer of Type 1 and increase its purchasing volume with Type 2 suppliers, which will also address its concern regarding the shortage during high demand seasons.

Table 13
Aggregated scores for suppliers' capabilities and willingness.

Supplier no.	Aggregated capabilities	Aggregated willingness
1	3.194	4.37
2	3.817	4.775
3	3.86	4.164
4	4.03	4.828
5	3.435	4.216
6	3.321	4.271
7	4	4.132
8	4.33	2.412
9	2.087	2.415
10	2.087	2.415
11	3.532	4.936
12	3.662	4.924
13	3.988	4.535
14	2.894	3.775
15	3.531	3.561
16	2.425	3.674
17	2.387	4.772
18	1.929	4.386
19	3.872	2.418
20	3.308	3.512
21	2.39	2.245
22	3.703	4.381
23	3.83	4.55
24	2.266	4.008
25	3.361	3.899
26	3.309	4.609
27	3.701	4.011
28	4.125	3.843
29	3.108	3.84
30	2.195	3.952
31	3.362	4.068
32	3.848	4.398
33	3.322	4.608
34	3.775	2.291
35	3.572	4.55
36	3.362	4.063
37	4.2	4.552
38	3.487	3.828
39	3.321	2.789
40	3.649	4.398
41	3.321	3.843
42	3.903	4.216
43	2.394	4.663

Type 3. These suppliers have high capabilities but a low level willingness to cooperate with the buyer. Here, it is more likely that the suppliers do not benefit, or that the relationship is not important enough for them to enter into a close relationship with the buyer. In these cases, the buyer should find the causes behind the behavior of the suppliers and tighten the relationship, as these suppliers are worth keeping on board. In the interview, the suppliers were identified as one newly hatched chicks' producer, one feed supplier and one material and equipment supplier. The willingness of these suppliers can be improved by establishing a partnership: "A partnership is a tailored business relationship based on mutual trust, openness, shared risk and shared rewards that results in business performance greater than would be achieved by the two firms working together in the absence of partnership" (Lambert, 2008). This could move these suppliers to the best quadrant (Type 4).

Type 4. These are the best suppliers: they have high capabilities and a high level of willingness. The buyer can benefit from working with these suppliers. In our case, for example, the buyer can benefit from the suppliers' capabilities in terms of low prices, good delivery, high quality, etc. In addition, the suppliers also benefit from the relationship with the buyer, which means the relationship is more likely to be a partnership. Of the 31 suppliers in this segment, five are newly hatched chicks producers, five are medication suppliers, six are feed suppliers and 15 are material and equipment

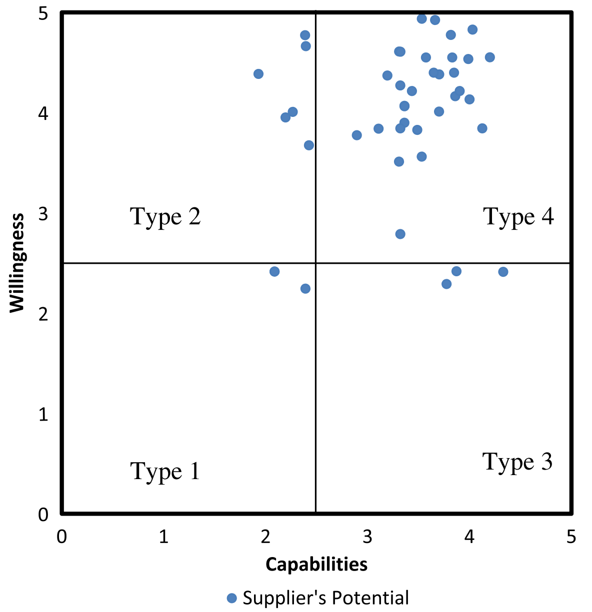

Fig. 4. Segments of the suppliers.

Table 14
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

suppliers. The firm should try to maintain the relationship with these suppliers, for example by realizing a significant level of operational integration (Lambert, 2008) and improving inter-organizational communication, which is necessary for circulating and sharing mutually beneficial information and knowledge, which in turn will create synergy by combining resources and capabilities to develop a lasting strategic advantage (Paulraj et al., 2008).

4. Conclusion

In this paper, a fuzzy relations-based AHP was applied to supplier segmentation. Scientifically, the application of fuzzy-based AHP to these types of problems is highly relevant. In general, methods based on fuzzy sets theory seem to be a perfect fit to the inherent complexity and fuzziness of constructs in the management sciences where "boundaries are not sharply defined" (Bellman and Zadeh, 1970). In management sciences, many constructs are assessed for managers to help them in their decision-making. Supplier evaluation and segmentation represent a typical example of such constructs. The assessment and segmentation of suppliers by a potential buyer requires many criteria that are combined in a *complex* and *fuzzy* way. The AHP method uses a strict hierarchy to evaluate and classify alternatives (in our case suppliers), and thereby captures the complexity of the phenomenon of supplier evaluation, while neglecting the inherent fuzziness of human evaluations in these type of problems. Fuzzy AHP captures both the complexity and fuzziness of this phenomenon.

To our knowledge, this is one of the first formulations of the supplier segmentation problem as a multi-criteria problem. We have looked at two overarching dimensions: capabilities and willingness of suppliers. These two dimensions cover the relevant criteria each specific buyer may consider for its own purposes. The proposed fuzzy AHP was used to determine the relative weights of the criteria and, finally, two aggregated scores were calculated for capabilities and willingness for each supplier. A scatter plot was used to display the position of each supplier in terms of its capabilities and willingness, where the horizontal and vertical axes indicate the capabilities and willingness dimensions respectively. By dividing each axis into two equal parts, four segments of suppliers are formed. The buyer should devise different strategies to handle suppliers in each segment. The proposed methodology was applied to segment the suppliers of a broiler company considering six criteria for capabilities and six criteria for willingness. The result is the positioning of each supplier into a segment. In contrast to almost all the previous supplier segmentation approaches that place a supplier into a segment, applying the proposed methodology the buyer is also able to see the position of each supplier *within* a segment. Furthermore, as the final aggregated capabilities and willingness scores for each supplier are obtained in a continuous spectrum, the proposed methodology is able to segment the suppliers to more than four segments. This decision mainly depends on the number of suppliers and the ability and desire of the firm to implement different strategies for different suppliers.

The relevance of our analysis for managers is considerable. The analysis revealed that some suppliers lacked in capabilities and or willingness. Due to the complexity of the supplier assessment (six criteria for two dimensions, capabilities and willingness, were proposed by the manager of the broiler company to assess his suppliers), a completely intuitive evaluation is almost certainly bound to be inadequate for handling the problem. The fuzziness of evaluating the criteria could be addressed using fuzzy AHP rather than standard AHP. It was interesting to see how the results of our analysis in a qualitative evaluation during an interview helped the manager clarify, adapt and specify his implicit strategy of supplier evaluation and segmentation.

An advantage of fuzzy methodologies is that they are easy to apply when limited data (number of cases) are available. Furthermore, the evaluation task in fuzzy approaches seems to match the type of evaluation that managers use in practice more closely and the results are easier to interpret and use in practice by these managers.

While multi-criteria decision-making (MCDM) methods have been applied to a variety of supply chain management (SCM) problems, such as supplier selection, supplier improvement and buyer–supplier relationship, it is surprising to note that supplier segmentation literature has not benefitted from these decision-making methodologies. We therefore suggest applying other MCDM methods (e.g. ANP (Saaty, 1996), TOPSIS (Hwang and Yoon, 1981), fuzzy TOPSIS (Chen, 2000), PROMETHEE (Brans et al., 1986)) to handle this strategic decision-making problem that faces almost all firms operating in SCM frameworks. The clustering techniques are also suggested for future research (to see a comprehensive list of clustering techniques one may refer to Jain et al., 1999), 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. We also suggest applying the proposed framework and methodology to segment other partners in SCM framework, such as Research and Development (R&D) partners.

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