# Two Multi-criteria Approaches to Supplier Segmentation

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**Abstract.** Supplier segmentation is a strategic business activity whereby suppliers of a firm are categorized on the basis of their similarities. Instead of handling all suppliers separately, segmentation yields a manageable number of segments, each of which requires a similar strategy. Standard methods of supplier segmentation have serious shortcomings: they often use a limited number of criteria and do not capture the complicated interaction between different supplier aspects. There is often little by way of data that can be used to apply more advanced statistical segmentation approaches. In this paper, we use two overarching dimensions to capture all available segmentation criteria: supplier capabilities and supplier willingness. We propose two multi-criteria approaches to assess the position of suppliers with regard to these dimensions and subsequently that outcome to identify segments. These multi-criteria approaches, a fuzzy rule-based system and a DEA-like linear programming model are applied to a real-world case to demonstrate how the results can be used in practice. The results of the two approaches are compared and some strategies are suggested to handle different segments.

**Keywords:** supplier segmentation; supplier relationship management; buyer-supplier relationship, fuzzy rule-based system, linear programming, DEA.

## 1 Introduction and review of literature

Supplier relationship management (SRM) provides a structure for firms to develop and maintain relationships with their suppliers [1]. SRM does not refer to managing individual relationships with suppliers, but means that different groups of suppliers, each of which with different characteristics, can be handled in different ways [2]. A close relationship should be developed and maintained with key suppliers, whereas the traditional procurement strategies may be adopted for other suppliers. Supplier segmentation is a prerequisite for SRM, it provides a framework to identify different groups of suppliers.

Compared to customer segmentation [3], supplier segmentation has received relatively little attention. Customer segmentation is aimed at dealing with heterogeneity

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on the demand side of the market, while supplier segmentation focuses on the supply side of the market [4].

The term supplier segmentation originated in early 1980s, when Parasuraman [5] and Kraljic [6] proposed two different approaches to supplier segmentation. Parasuraman [5] proposed a four-step process for supplier segmentation: (1) Key features of customer segments are identified; (2) Key characteristics of suppliers are identified; (3) Relevant variables for supplier segmentation are selected; and (4) Suppliers are segmented based on these variables. Parasuraman [5] did not specify the variables to segment the suppliers. By contrast, Kraljic [6] pre-specified the segmentation variables when he proposed two dimensions, profit impact and supply risk, for segmenting suppliers, which are measured for different products supplied to a firm. Considering two levels (low and high) for each dimension a 2×2 matrix distinguishes four segments: (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). Kraljic [6] then suggested different strategies for handling these supplier segments. Kraljic's approach [6] is extended by several researchers. For example, Olsen and Ellram [7] proposed a supplier segmentation based on two dimensions: difficulty of managing the purchase situation, and strategic importance of the purchase. Bensaou [8] considered two other dimensions: the supplier's specific investments and the buyer's specific investments. Kaufman *et al.*' segmentation [9] was based on two dimensions: technology, and collaboration. Supplier commitment and commodity importance are the two dimensions of Svensson' approach [10]. Hallikas *et al.* [11] used supplier dependency risk and buyer dependency risk as the two dimensions of their proposed approach. For a discussion of supplier segmentation approaches, see Rezaei and Ortt [12].

Several two-dimensional approaches have been proposed for supplier segmentation, each of which includes some important segmentation variables, while neglecting some other important ones. The shortcoming of the approaches can lead to a lack of homogeneity within segments and a lack of heterogeneity between supplier segments. Recently, Rezaei and Ortt [12] have proposed a supplier segmentation framework that consists of two overarching dimensions: supplier capabilities and supplier willingness. They define supplier capabilities and supplier willingness as follows:

*"Supplier's capabilities are complex bundles of skills and accumulated knowledge, exercised through organisational processes that enable firms to co-ordinate activities and make use of their assets in different business functions that are important for a buyer."*

*"Supplier's willingness is confidence, commitment and motivation to engage in a (long-term) relationship with a buyer".*

These two dimensions encompass almost all of the variables previously proposed for supplier segmentation. Methods to measure and combine the variables in each of the dimensions are proposed to satisfy another general requirement of a segmentation approach: measurability. This approach also creates a connection between different supplier-related activities such as supplier relationship management and supplier development, in the supply chain management framework. Finally, this approach enables a buying firm to explicitly assess the combination of segmentation variables that best fit its specific company, supplier and market conditions.

In this paper, we adopt the supplier segmentation framework proposed by Rezaei and Ortt [12]. To measure and integrate the variables of the different dimensions, we apply a fuzzy rule-based system and a DEA-like linear programming model, which are briefly discussed in section 2 and 3 respectively. In section 4, the two approaches are illustrated for the suppliers of a broiler company. The managerial implications of the outcomes are discussed and future work is described in section 5.

# 2 Fuzzy rule-based system

A fuzzy rule-based system [13] is a system that is used to govern the relationship between input and output variables. Here, supplier capabilities and willingness are considered as the output of two fuzzy rule-based systems, while the criteria used to evaluate the different dimensions serve as input. First of all, based on expert knowledge, these variables are fuzzified, which means that linguistic values (fuzzy subsets) are used (like low, medium and high) and fuzzy numbers are formed for each linguistic value. Secondly, a fuzzy rule base is provided based on the expert knowledge. These rules make a logic connection between different linguistic values that have been defined for input and output variables. A typical fuzzy rule has the form: IF antecedent THEN consequent. The number of rules is a function of the number of input variables and the number of linguistic values defined for inputs. If we have *n* inputs and *k* linguistic values for each input, then the total number of rules is $k^n$. Next, a fuzzy inference engine should be designed. The evaluation of a rule is based on computing the truth value of its premise part and applying it to its conclusion part. This results in assigning one fuzzy subset to each output variable of the rule. This inference engine performs mathematical computations based on the fuzzy numbers. As the final operation of a fuzzy inference system, the fuzzy output produced by the system is converted to a crisp number. More information about fuzzy rule-based systems can be found in [13, 14].

# 3 Data Envelopment Analysis (DEA)-like

Here, we describe a simple DEA-like linear programming model introduced by Rezaei *et al.* [15].

Suppose we have *N* suppliers. The level of willingness of supplier *i* (*Ei*) is seen as the sum product of its item measures $d_{ij}, j = 1, \ldots, J$ by their weights $w_{ij}, j = 1, \ldots, J$, $\left(\sum_{j=1}^{J} w_{ij} d_{ij}\right)$. We can measure the level of capabilities of the supplier in the same formulation. Now, if supplier $i$ is allowed to maximize its level of willingness/capabilities, providing the level of willingness/capabilities of other suppliers do not exceed 1, then the calculated maximum level of willingness/capabilities of this supplier denotes its relative willingness/capabilities. The mathematical programming model for supplier *i* is as follows.

$$\max(E_i) = \sum_{j=1}^{J} w_{ij} d_{ij} \tag{1}$$

*s.t.*

$\sum_{j=1}^{J} w_{ij} d_{nj} \le 1, n = 1, \ldots, i, \ldots, N$ (*N* is the number of suppliers)

$w_{ij} \geq 0, j = 1, \ldots, J.$ ($J$ is the number of items)

Solving $N$ models for supplier willingness, and $N$ models for supplier capabilities, the relative level of willingness and capabilities for each supplier are determined in the range of [0,1]. The results can then be used as a base to segment suppliers. For example if we consider the middle of the range of supplier willingness and supplier capabilities scores as two cut-off points, then we can form two levels for willingness and capability scores and combine them to segment the suppliers into four segments.

## 4 Implementation of the approaches, and discussion

In this section, we describe the implementation of the supplier segmentation using the two approaches discussed above: (1) A fuzzy rule-based system, and (2) a DEA-like linear programming model for a broiler company.

The broiler company receives newly hatched chicks, feed, medications and other equipment and materials from 43 suppliers. The company raises the chicks to market weight in about six weeks and the chickens are then delivered to a processing plant to be stunned and undergo further processing. To manage the relationship with a large number of suppliers, the broiler company needs to segment them. Interviewing the managers of the company yielded six criteria (price, delivery, quality, reserve capacity, geographical location and financial position) for measuring the supplier's capabilities, and another six criteria (commitment to quality, communication openness, reciprocal arrangement, willingness to share information, supplier's effort in promoting JIT principles, and long term relationship) for measuring the supplier's willingness (to see a comprehensive list of the relevant criteria and their selection procedure, see [12]). We then asked the manager to evaluate all the suppliers using scores between 1 (very low) to 5 (very high) for all criteria.

### 4.1 The rule-based systems

To measure the aggregated degree of supplier's capabilities and supplier's willingness, we designed two fuzzy rule-based systems each of which consists of six input variables and a single output. To fuzzify the variables we considered two fuzzy subsets (e.g., Low and High, or Bad and Good) and their equivalent triangular membership function based on the knowledge of the company manager and two experts. The intended fuzzy rule-based systems are shown in Fig. 1.

Considering the number of criteria and the number of fuzzy subsets, we had to make $2^6 = 64$ rules for each system. Below, an example rule of the second system is presented that is designed to measure a supplier's willingness.

***"IF 'supplier's commitment to quality' is Low AND 'communication openness' is Low AND 'reciprocal arrangement' is Low AND 'willingness to share information' is Low AND 'supplier's effort in promoting JIT principles' is High AND 'length of relationship is Short, THEN supplier's willingness is Low"***

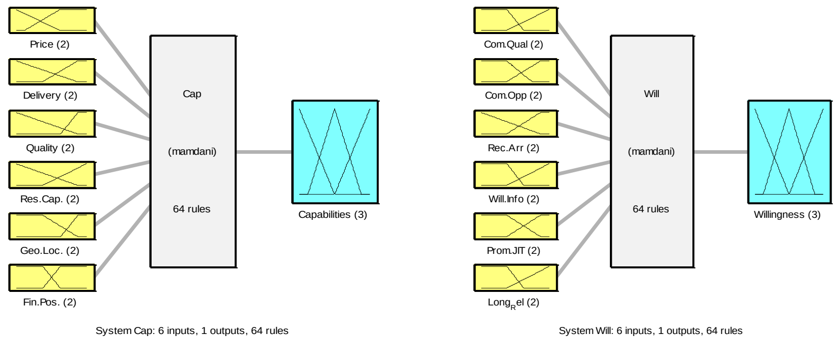


**Fig. 1. Fuzzy rule-based systems (FS). Left: FS1 (capabilities); Right: FS2 (willingness).**

This rule shows how particular values (i.e., high or low) of the criteria are combined into an overall value for supplier willingness. We then use the inference engine developed by Mamdani and Assilian [16] by applying a compositional minimum operator, which represents a conservative attitude towards measuring the supplier's capabilities and willingness. At a minimum inferencing, the entire strength of the rule is considered as the minimum membership value of the input variables' membership values.

$$\mu_{output} = \min\{\mu_{input1}, \mu_{input2}, \dots, \mu_{inputN}\}$$

The output of the fuzzy inference engine is a fuzzy number that needs to be defuzzified. We applied the Center of Gravity (COG) defuzzification method, one of the most commonly used defuzzification methods, as follows:

$$y_c = \frac{\int_i \ \mu_F(y_i) y_i dy_i}{\int_i \ \mu_F(y_i) dy_i} \qquad (2)$$

where $y_i$ is the representative value of the fuzzy subset member $i$ of the output, and $\mu_F(y_i)$ is the confidence in that member (membership value) and $y_c$ is the crisp value of the output.

To calculate the final aggregated scores, we used MATLAB's Fuzzy Logic Toolbox. Based on the two final scores for each supplier, the suppliers are assigned to four segments (see the left side of Fig. 2) (it is, however, clear that more segments can be formed). Of the 43 suppliers, three are segmented as Type 1 (low capabilities and low willingness), nine as Type 2 (low capabilities and high willingness), three as Type 3 (high capabilities, and low willingness) and, finally, 28 as Type 4 (high capabilities, and high willingness).

### 4.2 DEA-like linear programming model

To measure the aggregated degree of a supplier's willingness and capabilities, we formulate 86 linear programming problems of type (1). That is to say, two linear programming problems for each supplier are formulated and solved: one to determine the relative willingness and one to determine the relative capabilities of the supplier. As such, two aggregated scores are obtained for each supplier in the range of [0, 1]. Considering the actual minimum and maximum aggregated scores for supplier willingness and capabilities, two cut-off points are determined to divide the suppliers into four segments. In our case, the minimum and maximum aggregated scores for supplier willingness are 0.6 and 1.0 respectively. The minimum and maximum aggregated scores for supplier capabilities are 0.8 and 1.0 respectively. Therefore, we determined 0.8 and 0.9 as the cut-off points for supplier willingness and supplier capabilities, respectively, as a base to segment the suppliers to four segments (see Fig. 2). Of the

43 suppliers, four are identified as being Type 1 (low capabilities and low willingness), nine as Type 2 (low capabilities and high willingness), two as Type 3 (high capabilities and low willingness) and, finally, 28 as Type 4 (high capabilities and high willingness).

As can be seen from the right side of Fig. 2, the number of suppliers assigned to each segment is almost the same in the two approaches, but there are some differences. For example, both approaches assign 28 suppliers to segment Type 4. However, only 22 of these 28 suppliers are assigned to this segment in both cases, which has to with weight of the various criteria.

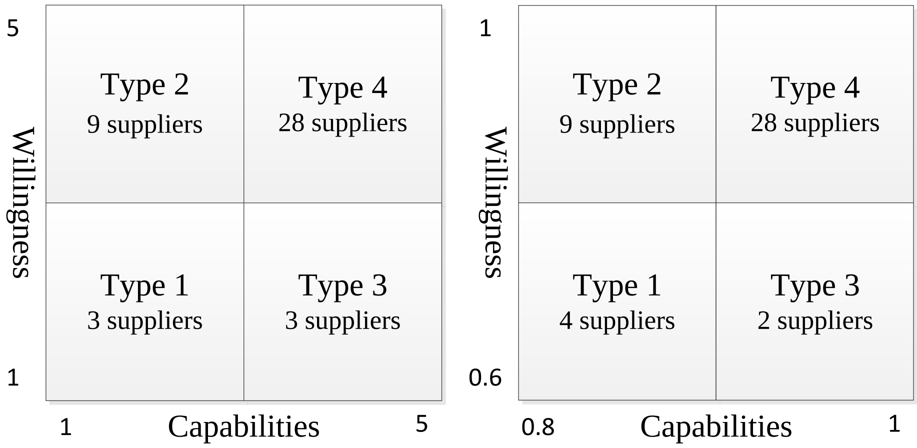


**Fig. 2. The final supplier segmentation results; Left: fuzzy rule-based, Right: DEA-like.**

### 4.3 Managerial implications

Generally speaking, firms can use our approach to formulate different strategies for handling different segments. Our approach condenses a comprehensive set of segmentation criteria into two overarching dimensions: supplier willingness and supplier capabilities. The values that specific suppliers assign to on these dimensions are subsequently used to segment the suppliers. In this article, we created 2×2 = 4 segments. Each of these segments requires a different strategy from the buying company. Type 4 suppliers, for example, are the most capable suppliers who are also highly willing to cooperate with the buying firm. However, because of their capabilities, they are likely to be attractive to other firms as well. Therefore, the firm in question should try to maintain strong relationships with those suppliers. Type 3 suppliers are also highly capable, but they are less willing to cooperate with the firm. The firm should try and become more attractive to these suppliers and show greater loyalty, for example by increasing communication and purchase volume. Type 2 suppliers are very willing to cooperate, but less able to meet the buyer’s requirements. A general suggestion is to help these suppliers improve their capabilities and performance. Finally, Type 1 suppliers are less capable and less willing to cooperate with the firm. In all likelihood, it is best to maintain an arm’s length relationship to manage the relationship with these suppliers.

In addition, strategies can be formulated to improve the (capabilities or willingness of) suppliers and thereby upgrade them to other segments. The main supplier development strategies mentioned by Krause et al. [17] are: supplier assessment, providing suppliers with incentives for improved performance, instigating competition among suppliers, and direct involvement of the buying firm's personnel with suppliers. These strategies to a large extent focus on improving capabilities. Although, as a result of these strategies, supplier willingness may also increase; specific strategies can be used that focus specifically on this aspect. We believe that the key concept here is trust. Trust is a crucial component in the dimension of supplier willingness. As has been argued in various studies (e.g. [18]), a buyer's trust in a supplier can enhance that supplier's willingness to share information, make investments specifically with regard to the buying firm and maintain a long-term relationship.

These strategies can be implemented to promote suppliers in segment Type 1 to segment Type 3, for example. Type 4 suppliers are key suppliers with whom a firm should try to maintain a close long-term relationship.

Specifically, the analysis yielded interesting insights into some of the broiler company's suppliers. Some suppliers with low scores on both dimensions were nevertheless allowed to continue as suppliers to meet seasonal peaks in demand. The company has already started implementing strategies to manage the relationship with its suppliers, and to develop those who are segmented as Type 1 to 3, especially Type 2 and 3.

## 5 Conclusion

In this paper, we proposed two multi-criteria methodologies to measure supplier capabilities and willingness: A fuzzy rule-based system and a DEA-like linear programming model. The final scores of these two dimensions are used to divide suppliers into four segments. Supplier segmentation allows firms to maximize its efforts to formulate suitable strategies for handling different suppliers. The approaches to assess the suppliers' positions on the dimensions of capability and willingness help connect the related activities of supplier selection, supplier relationship management and supplier development. The rule-based approach proved a very flexible approach that can be designed by interviewing a limited number of knowledgeable managers or experts within the company. It has some advantages over other methods, such as the ability to handle the inherent interdependencies, vagueness and contingencies of segmentation variables. The DEA-like methodology, on the other hand, is a data-based methodology that requires a minimum number of data [15]. However, it is more flexible in terms of weighting the criteria. Both approaches are suitable when a high data volume is not available and advanced statistical methodologies are not possible.

As pointed out by several researchers (e.g. [19]), matching certain characteristics between buyers and suppliers is an important factor in the success of their partnerships. Therefore, as a future research direction, we suggest studying the relationship between symmetry in capabilities and willingness between various buyer and supplier segments and partnership success. It is interesting to compare the proportion of different segments for different industries and situations. We also suggest integrating supplier segmentation into other supplier-related activities, such as 'lot-sizing with supplier selection' [20]. Finally, we suggest studying the relationship between partnership with suppliers from different segments and firm performance.

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