Supplier Performance Evaluation Based On Fuzzy Logic

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Abstract

Purpose *– This paper describe the development of the fuzzy logic model approach to supply chain and its value for managers by illustrating its application to supplier performance appraisals.*

Design/methodology/approach *– Measuring supplier performance possesses the properties of multi-dimension and multi-scale, it increases the complexity of the aggregation and assessment process. A focal company must develop an effective procedure for overcoming the complexity of performance measurement. Performance evaluations of supplier are not easy; many criteria and standards that are involved should be considered. In reality, supplier selection is the essence of supply chain management; mean while, assessment of supply performance becomes the main activity of supplier selection. An extensive literature review provided the framework for the model development in this research. Supplier performance evaluations represent a critically important decision that often involves subjective information. Models and heuristic techniques that focus on the use of different types of information are available; however, with few exceptions, the models are not robust enough to be applied in a practical, managerially useful manner. Fuzzy logic models provide a reasonable solution to these common decision situations.*

Findings *– The results demonstrate that the Fuzzy logic can be a powerful tool for managers to evaluating the suppliers' performance. The flexibility of the model allows the decision maker to introduce vagueness, uncertainty, and subjectivity into the supplier performance evaluation system.*

Research limitations/implications *– Limitations that could lead to future research include primary issue, Future research in this area is needed to develop a method for relating supplier performance values to linguistic variables in supplier performance evaluation, as well as testing the sensitivity of supplier performance values and their impact on the outcome*

Practical implications *– In addition, This research calls attention to an alternative method of the supplier performance evaluation system.*

Originality/value *– This paper provides a simple-to-use fuzzy logic model for establishing a more meaningful supplier performance evaluation system, and to help uncover ways to improve the success of supplier selection.*

Article Type – Research paper

Keywords – Performance Evaluation, Fuzzy Logic, Supply Chain

Introduction

Competitive advantage of a focal company heavily relies upon the performance of his suppliers. The effectiveness of selecting, and evaluating procedures of suppliers becomes an important factor in achieving business goals (Wang et al, 2009). In general, supply performance, which depends on supply behavior, has the properties of multi dimension And multi-scales, relating to different attributes. So, the performance assessment of a supplier is not only comprehensive, but is also difficult under a uniform scale (Wang et al, 2009). Appraisal methods provide a output defining the suppliers' performance, but, some of the supply behaviors can be measured explicitly according to its definition (such as unit price and defect). Some cannot be represented with a precise numeric value (such as ability on R&D and quality), However, much of the information related to supplier performance appraisal is not quantifiable and precise with crisp boundaries. Rather, this information is presented in expressions or words in natural language and without precision. Fuzzy logic models provide a reasonable solution to these common situations, though may be easily converted into human linguistic form constructed from semantics.

Fuzzy logic is a problem solving methodology that provides a simple way of definite conclusions from vague and imprecise information. Fuzzy set theory was first introduced by Zadeh in 1965. He was motivated by observing that human reasoning can utilize concepts and knowledge that don't have well-defined boundaries (Yen, Langari, 1999). Fuzzy set theory is a generalization of the ordinary set theory. A useful approach for examining many real-world problems is fuzzy approximate reasoning or fuzzy logic. This technique is based on the fuzzy set theory (Zadeh, 1965) that allows the elements of a set to have varying degrees of membership, from a non-membership grade of 0 to a full membership of 100 per cent or grade 1. This smooth gradation of values is what makes fuzzy logic match well with the vagueness and uncertainty typical of many real world problems.

Fuzzy set theory (Zadeh, 1965) was developed to address contexts in which decision Makers need to accurately analyze and process information that is imprecise in nature. Fuzzy sets provide a conceptual framework, as well as an analytical tool to solve real World problems where there is a lack of specific facts and precision (Baldwin, 1996; Klir and Yuan, 1995). However, the application of fuzzy set theory and logic to management decisions has been generally lacking despite its potential value in many common situations (Dorsey and Coovert, 2003). Nevertheless, human semantics are embedded in the meaning of fuzziness and comparison (Zadeh,1983). On the other hand, the usage of multi granularity linguistic information can eliminate the difference from evaluators (Herrera et.al, 2000). The purpose of this paper is to develop a framework for the application of fuzzy logic to supplier performance appraisal. This study attempts to develop an assessment approach on supply performance to improve the previous techniques.

Background of Supplier selection and assessment of supply performance

Performance evaluations of supplier are not easy; many criteria and standards that are involved should be considered. In reality, supplier selection is the essence of supply chain management [1]; mean while, assessment of supply performance becomes the main activity of supplier selection(Lau et.al,2002). Choi and Hartley evaluated suppliers based on consistency, reliability, relationship, flexibility, price, service, technological capability and finances, and also addressed 26 supplier-selection criteria (Choi , Hartley,1996) . Verma and Pullman ranked the importance of the supplier attributes of quality, on-time delivery, cost, lead-time and flexibility (Verma , Pullman,1998). Vonderembse and Tracey described that supplier and manufacturing performance were determined by supplier selection criteria and supplier involvement (Vonderembse , Tracey,1999). It was concluded that the supplier selection criteria could be evaluated by quality, availability, reliability and performance. Supplier involvement could be evaluated by product R&D and improvement, and supplier performance could be evaluated by stoppage, delivery, damage and quality. Additionally, manufacturing performance could be evaluated by cost, quality, inventory and delivery. Tracey and Tan developed supplier selection criteria, including quality, delivery, reliability, performance and price (Tracey, Tan, 2001).

The criteria are also used to assess customer satisfaction based on price, quality, variety and delivery. Moreover, Kannan and Tan determined supplier selection based on commitment, needs, capability, fit and honesty, and developed a system for supplier evaluation based on delivery, quality, responsiveness and information sharing(Kannan , Tan,2002). Kannan and Tan also evaluated supplier selection and performance based on the weights of evaluation attributes or criteria with crisp values that depend on subjective individual judgments. Muralidharan et .al compared the advantages and limitations of nine previously developed methods of supplier rating, and combined multiple criteria decision making and applied analytic hierarchy processes to construct multi-criteria group decision making model for supplier rating(Muralidharan et .al,2002) The attributes of quality, delivery, price, technique capability, finances, attitude, facility, flexibility and service were used for supplier evaluation, and the attributes of knowledge, skill, attitude and experience were used for individual assessments. However multiple factors have been considered in supplier selection and evaluation, including operational, culture, technology, relationship, cost, quality, time and flexibility. In this paper different criteria are classified in six categories as shown in table 1 and are used in the presented model.

Fuzzy sets structure and analysis

The most fundamental form of a fuzzy set A in a universe X is:

$$A = \{X, \mu_A(X) \mid X \varepsilon X\}$$

Where $\mu_A(x)$ represents the grade of membership or compatibility function of element x

Of X in fuzzy set A. Element x may show a full membership in A (i.e. $\mu_A(x)$ = 1), as well as partial membership (0< $\mu_A(x)$ <1) or non-membership ($\mu_A(x)$ = 0).

For example, the fuzzy linguistic variable performance can be characterized by terms: very strong, strong, average, weak, poor, and very poor. Each term is called a linguistic modifier. Therefore, a fuzzy set is formed when a linguistic variable is combined with a linguistic modifier (i.e. strong performance). In our example, each linguistic modifier is linked to a numerical value on a scale of 1 to 7 that represents the level of performance. Thus, the performance set A and its modifiers can be represented by a fuzzy set as:

$$A = \{1.0|0, 2.0|0.10, 3.0|0.30, 4.0|0.40, 5.0|0.60, 6.0|0.80, 7.0|1.0\}$$

In this fuzzy set, each element represents a corresponding value in the universe of discourse and a degree of membership. That is, 7 has a full membership grade of 1 corresponding to very strong performance, and 1 with a non-membership grade of zero indicating no performance as well as 5 with a partial membership grade of 0.60 representing average performance.

Another example of constructing fuzzy sets for linguistic variables is presented in Figure 1, where three fuzzy sets are used to characterize a supplier's performance. The Fuzzy linguistic variable performance can be defined by terms or linguistic modifiers

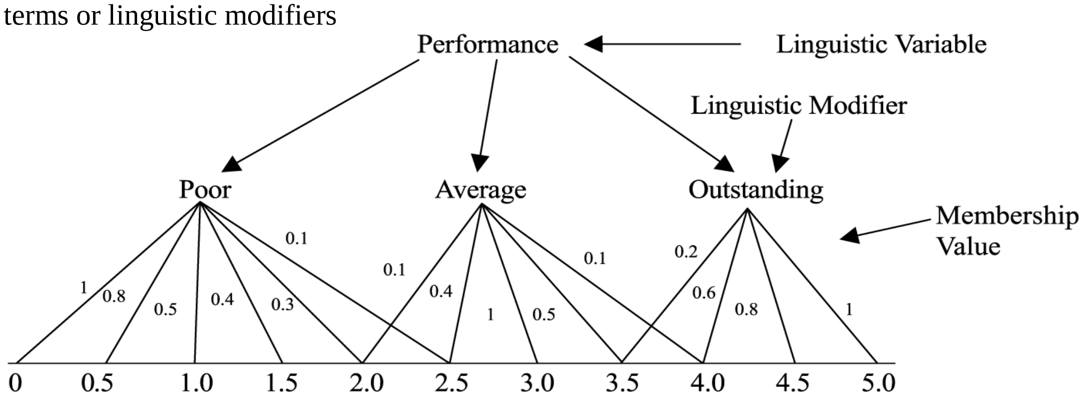

Figure 1: **Fuzzy set structure of performance**

Poor, average, outstanding, with the membership value from 0 to 1 describing the level Of performance on a scale from 0 to 5.In Figure 1, if the norm for performance is average, number 3 represents the highest level of the term average with a membership grade of 1 and number 4 defines average with a grade of 0.10 or outstanding with a grade of 0.60. Therefore, number 4 describes the performance of a supplier whose performance is 60 per cent outstanding and 10 percent average. Figure 1 represents three fuzzy sets:

$$Poorperformance = \{0|1.0, 0.50|0.80, 1.0|0.50, 1.50|0.40, 2.0|0.30, 3.0$$

$$|0.0, 3.50|0.0, 4.0|0.0, 4.50|0.0, 5.0|0.0\}$$

$$Averageperformance = \{0|0.0, 0.50|0.0, 1.0|0.0, 1.50|0.0, 2.0|0.10, 2.50|0.40, 3.0|1.0,$$

$$3.50|0.50, 4.0|0.10, 4.50|0.0, 5.0|0.0\}$$

$$Outs\tan dingperformance = \{0|0.0, 1.0|0.0, 1.50|0.0, 2.0|0.0, 2.50|0.0, 3.0|0.0, 3.50|0.20|$$

$$1.0|0.60, 4.50|0.80, 5.0|1.0\}$$

These sets represent the decision maker's intuitive understanding of the linguistic variable performance and its modifiers: poor, average, and outstanding.

Fuzzy set operations

Fuzzy sets can be manipulated by one of the four standard fuzzy set operations: union,
Intersection, complementation, and implication operations (Mendel,2001). to illustrate, assume A and B are fuzzy sets with membership functions

$\mu_A(x) = \{0,3,5,7,8\}$, with unit interval X→ [0 1], $\mu B(y) = \{1,2,4,6,9\}$

And Y $\rightarrow$ [0 10] respectively. The union of A and B is a fuzzy set $C = A \cup B$ where: $\mu_A \vee_B (z) = \mu_A(x) \vee \mu_B(y)$

A union operation is identical to a logical OR operation and a fuzzy set union is
Performed by applying the max function to the elements of two sets; that is, taking the
Higher value of the first, second . . . element in each set in order to form the union of the
Two sets, thus:

$\mu_{A \vee B}(z) = \{1,3,5,7,9\}$

A logical AND can be used to determine a fuzzy set $D = A \cap B$ with:

$\mu_{A \wedge B}(\omega) = \mu_A(x) \wedge \mu_B(y)$

Fuzzy set intersections are done by applying the min function; therefore:

$\mu_{A \wedge B}(\omega) = \{0,2,4,6,8\}$.

The complement of a set is computed by subtracting each element of the set from its maximum possible value, in our example 10. So:

$\mu_{\bar{A}}(x) = 10 - \mu_A(x) = \{10,7,5,3,2\}$

And

$\mu_{\bar{B}}(y) = 10 - \mu_B(y) = \{9,8,6,4,1\}$.

The implication function is used to decide if A is true, to what extent that implies

That B is true? The implication operation is done by computing $\bar{A} \cup B$, known as Kleene-Dienes implication (Whalen and Schott, 1992), where:

$\mu_{\bar{A} \vee B}(u) = \mu_{\bar{A}}(x) \vee \mu_B(y)$

$\mu_{\bar{A} \vee B}(u) = \{10,7,5,6,9\}$.

It should be noted that fuzzy set operations are not limited to those used here; for other Fuzzy operations see (Mendel, 2001).

Supplier performance appraisal with fuzzy logic (numerical example)

Performance evaluations of supplier are not easy. Many criteria and standards that are involved should be considered. In reality, supplier selection is the essence of supply chain management; meanwhile, assessment of supply performance becomes the main activity of supplier selection.

However, for illustration purposes and to keep matters relatively simple to follow, the example used in this paper includes seven suppliers and six categories of performance evaluations for each supplier. These categories as shown in Table I .form a fuzzy set C in a universe U with the unit interval [0, 1], where:

$C = \{u | \mu_C(u), u \varepsilon U\}$

$\mu_C(u) = \{1.0,0.60,0.40,0.80,0.90,0.70\}$.

Each element of the set is given a score between 0 and 1; a high score signifies the relative importance of that category (fuzzy element) to the decision maker. Equal membership means equal importance. For each of the six categories, a qualitative judgment is used to determine the degree of supplier performance for that category These qualitative judgments could be: “not acceptable”, “poor”, “below average”, “slightly below average”, “average”, “slightly above average”, “above average”, and “outstanding”, thus forming a fuzzy set P in universe V with unit interval [0, 1] and a fuzzy membership function:

$P = \{v | \mu_P(v), v \varepsilon V\}$

$\mu_P(v) = \{0.10,0.20,0.30,0.40,0.60,0.70,0.80,1.0\}$

As shown in Table II.

To illustrate how the manipulation of fuzzy sets can result in a decision making system for supplier performance evaluation, several steps must be taken. The first step is to assess the performance of each supplier by each category that is based on the fuzzy opinion of the evaluator, as depicted in Table III.

The next step is to use Tables II and III to generate Table IV representing grades of supplier for all categories .Table IV contains seven fuzzy sets, p_1,. . .,p_7, with membership functions $\mu p_1(v)$,. . ., $\mu p_7(v)$. For example, the fuzzy set and membership function for supplier 1 is:

$P_1 = \{1.0|0.30, 2.0|0.10, 3.0|0.70, 4.0|0.80, 5.0|0.60, 6.0|0.60\}$

$\mu_{P_1}(v) = \{0.30,0.10,0.70,0.80,0.60,0.60\}$.

The principal step in the decision making process is to establish a fuzzy implication relation between a specific category and each supplier's performance for that category. That is to say, given the relative importance of a category, does that imply a good performance by the supplier for that category? Assuming that the importance assigned to each category is the maximum value for that category the implication relationship is established by taking the complement of the category importance. This complementation creates a minimum performance value assigned to all suppliers given the category. The max function is applied to each supplier's performance set, i.e. μp_1 (v),. . . μp_7(v) and the complement of set μc(u). So:

$$\mu_{\overline{C}} \vee_{P1} (r) = \mu_{\overline{C}}(u) \vee \mu_{P1}(v)$$

$$\mu_{\overline{C}} \vee_{P1} (r) = \{0,0.40,0.60,0.20,0.10,0.30\} \vee \{0.30,0.10,0.70,0.80,0.60,0.60\}$$

$$= \{0.30,0.40,0.70,0.80,0.60,0.60\}.$$

The final step is to combine various performances of the supplier across all categories in order to obtain an overall evaluation. This is done by applying the min function to the set derived from the previous step. Table V shows the overall rating of the suppliers once the process is completed. It is not surprising that supplier 7 has been ranked top performer in this example since the proposed system favors the supplier with a high rating in the most important category. So, the higher the relative importance the category is, the more influence that category has in the final output.

Conclusions

This study develops an evaluation approach to measure supply performance .Many factors used in the supplier evaluation process are subjective and difficult to quantify. Fuzzy logic enables the reviewer or the decision maker to incorporate information in the supplier evaluation system which is vague and subjective. There are several advantages in using the model presented in this paper as opposed to a previous technique. The mathematics is extremely simple and can be easily computerized by software, as such as MATLAB. It is also extremely flexible, allowing the decision maker to use a broad range of linguistic variables and modifiers for finer discrimination or to make changes to membership values and/or supplier performance categories. Finally, it is an ideal system when the decision maker is faced with a series of sub-decisions where available data is based on vagueness, uncertainty, and opinion. These sub-decisions are then combined into an overall system for supplier performance evaluation. Fuzzy logic can be a powerful tool for managers to evaluate the suppliers' performance. The flexibility of the model allows the decision maker to introduce vagueness, uncertainty, and subjectivity into the supplier performance evaluation system. This research calls attention to an alternative method of the supplier performance evaluation system. Future research in this area is needed to develop a method for relating supplier performance values to linguistic variables in supplier performance evaluation, as well as testing the sensitivity of supplier performance values and their impact on the outcome. This paper provides a simple-to-use fuzzy logic model for establishing a more meaningful supplier performance evaluation system.

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Appendix of Tables

Table I: importance of criteria

Criteria		Relative Importance
Quality	C_1	1
On time delivery	C_2	0.6
Technological ability	C_3	0.4
Competitive cost & Financial situation	C_4	0.8
Product design Ability	C_5	0.9
After sale servises	C_6	0.7

Table II: importance of linguistics variables

Relative Importance		linguistics variables
0.1	na	not acceptable
0.2	p	poor
0.3	ba	below average
0.4	sba	slightly below average
0.6	ave	average
0.7	saa	slightly above average
0.8	aa	above average
1	o	outstanding

Table III: supplier performance by category (supplier performance rating)

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
C_1	ba	ave	aa	saa	ave	saa	aa
C_2	p	ave	saa	ave	ba	ave	aa
C_3	saa	aa	saa	aa	sba	sba	aa
C_4	aa	ave	aa	sba	aa	ave	o
C_5	ave	saa	saa	ave	sba	aa	aa
C_6	ave	aa	aa	p	saa	o	o

Table IV: Membership grades of supplier performance by category

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
C_1	0.3	0.4	0.8	0.7	0.6	0.7	0.8
C_2	0.1	0.6	0.7	0.6	0.8	0.6	0.8
C_3	0.7	0.8	0.4	0.8	0.4	0.4	0.8
C_4	0.8	0.6	0.8	0.4	0.8	0.6	1
C_5	0.6	0.7	0.7	0.6	0.4	0.8	0.8
C_6	0.6	0.8	0.8	0.2	0.7	1	1

Table V: suppliers overall rating

supplier	score
S_1	0.3
S_2	0.6
S_3	0.7
S_4	0.3
S_5	0.4
S_6	0.6
S_7	0.8