Weighting Suppliers Using Fuzzy Inference System and Gradual Covering in a Supply Chain Network

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Abstract

Extensive research has been done on supplier evaluation and selection as a strategic and crucial component of supply chain management (SCM) in recent years. However, a few articles in the previous literature have been dedicated to the use of Fuzzy Inference Systems (FIS) as an aid in decision making. Therefore, here is be attempted to demonstrate the application of this method in evaluating suppliers based on a comprehensive framework of qualitative and quantitative factors besides the effect of gradual coverage distance. The purpose of this study is investigating the applicability of the numerous measures and metrics in a supply chain network design with the aim of selecting the most qualified suppliers. In this paper, the effectiveness of the configured network would be illustrated using a sample and then the results will be discussed.

Keywords
Supplier selection, fuzzy inference system, coverage distance, supply chain management

1. Introduction
In the last two decades, several studies have been conducted on the issue that most of them have used of MCDM methods such as analytic hierarchy process (AHP), data envelopment analysis (DEA) and statistic method (Sreekumar and Mahapatra 2009). Anyone have usually considered same factors like quality, delivery, capacity and price in the evaluation of supplier (Weber et al. 1991). Here is attempted to provide a new classification of a more comprehensive framework than presented in the past.
As the traditional MCDM approach, it faces the obstacle in handling uncertainties of real world. In addition, human preference is uncertain and decision makers might be reluctant or unable to assign exact numerical values (Chan and Kumar 2007). This is why some papers have investigated use of fuzzy sets in the supplier selection.
This study presents a framework for assessing the competence of suppliers that was followed by the application of non-conventional technique, a method for handling both qualitative and quantitative factors to appraise providers in SCM practices beside a new approach that can evaluate them basis of their distance from the manufacturers.
This study suggests and develops an integrated procedure that will aid decision makers for appraising performance of suppliers in a supply network with numerous measures and metrics. In this paper, decision makers evaluate suppliers with qualitative criteria like safely and quantitative criteria like part price appraised by MATLAB FIS editor. The present work uses the editor to define rules and determine the weights. All the features of this approach such as applying various and occasionally different rules and simultaneous use of a wide range of multiple conflicting factors in a comprehensive system can be the reasons for using this method as a methodology in provider evaluation.
The remainder of this paper is organized as follows. After brief review the relevant literature in Section 2, in Section 3 we define the problem and introduce the fuzzy rule-based system and cover distance equation in detail. Also a numerical example of its occurrence is used to show the applicability of the approach. Finally, concluding remarks and directions for further development are provided in the last Section.

2. Literature review

Performance evaluation of the supplying firms is being recognized as one of the critical indicators (Sharma 2010). The literature on supplier evaluation exist some surveys (i) focused on problem criteria, and (ii) proposed methods for selection process. In identification of the qualitative and quantitative criteria after Dickson (1966), Dempsey (1978) described 18 criteria. Weber et al. (1991) extensively reviewed, annotated and classified 74 related articles, which have appeared since 1966, and specific attention is given to the criteria and analytical methods. They concluded that quality, cost and on-time delivery are the three most important supplier selection criteria commonly used.

De Boer et al. (2001) offer a lecture review of supplier selection in all phases including the initial problem definition, formulation of the criteria, determine the eligibility of potential suppliers and ultimately choice the qualified suppliers, in which cover various methods of supplier selection. Some of these methods used a single model, such as linear programming, AHP, fuzzy set theory (Zadeh 1973), etc. and others used combined model, such as integrated AHP and DEA, fuzzy and multi-objective programming, etc.

According to Wang and Yang (2009), the quantitative decision methods for solving the supplier selection problem can be classified into three categories: (1) multi attribute decision making includes the linear weighting method and the AHP, (2) mathematical programming models include the linear programming models, mixed integer programming, multi-objective programming and data envelopment analysis and (3) intelligent approaches include neural network based methods, expert systems, fuzzy decision making, hybrid approaches.

In the last two decades, various decision-making approaches have been proposed to tackle the problem of supplier evaluation and selection; please refer to recent reviews by Ho et al. (2010) and Mafakheri et al. (2011). Based on the applications of AHP and fuzzy AHP have been very popular. This methodology has been used to rank potential suppliers in a hierarchical manner. For instance, Barbarosoglu and Yazgac (1997) applied a five-level AHP structure to the supplier selection problem.

In recent years, a number of researchers have taken advantage of FIS in their articles. However, these uses have been quite limited. For example, Liu and Wang (2009) developed an integrated fuzzy approach for the problem of provider selection that applies the fuzzy set theory, fuzzy Delphi, fuzzy inference and fuzzy linear assignment, in order to deal with this problem. Güneri et al. (2011) proposed an analytical technique, based on Adaptive Neuro-Fuzzy Inference System (ANFIS) model, for supplier selection decision-making which consists of two main stages: first selecting inputs by ANFIS, and second building the final model using selected inputs. Amindoust et al. (2012) introduced a fuzzy ranking model basis of FIS that considers sustainable criteria in the supplier selection problem.

In another study, Carrera and Mayorga (2008) applied the FIS to a supplier selection problem for new product development. Their model includes 16 variables categorized in four groups and each group has an individual output. They did not assign the importance of weights for the selected indicators (criteria and sub-criteria). In their model, the fuzzy rules for each FIS did not envelop all possible characteristics of suppliers.

As a result, most of the discussed studies took two to three variables at a time, which are not sufficient practically. Moreover, a proper design and management requires planning and decision-making with respect to a more comprehensive consideration which involving linguistic variables makes it more difficult.

3 Problem definition

Determining appropriate strategy for supplying raw materials is known as one of the basic principles to achieve an integrated configuration of SC network. In this section, a supply and production procedure is investigated. Representing of network is illustrated in Figure 1. We describe a structure for aiding decision makers in the performance assessment of potential suppliers based on an evaluation framework as is shown in Figure 2. The results of this phase make the suppliers importance by a fuzzy rule-based system and a new equation for considering the distance effect.

3.1 Fuzzy inference system

Method adopted to obtain relevant conclusion of some rules involves the use of Mamdani's fuzzy inference method (proposed by Mamdani and Assilian (1975)) which is the most commonly seen fuzzy methodology and was among the first control systems built using fuzzy set theory. This method attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's

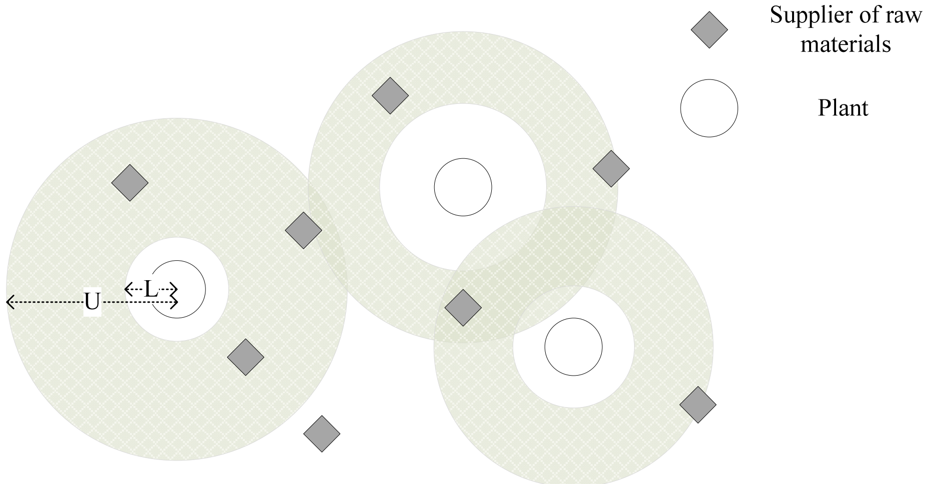

Figure 1: Suppliers evaluation by FIS and distance

effort was based on Zadeh (1973) on fuzzy set theory as a methodology, which incorporates imprecision and subjectively into the model formulation and solution process in complex systems and decision processes. Although the inference process described in this section differs somewhat from the methods described in the original paper, the basic idea is much same.

Fuzzy inference process comprises of five parts: fuzzification of the input variables, application of the fuzzy operator (AND or OR) in the antecedent, implication from the antecedent to the consequent, aggregation of the consequents across the rules, and defuzzification. These odd names have very specific meanings that are defined in the following.

Here we have used two membership functions with different fuzzy linguistic sets that are built on the *Gaussian* distribution curve and *Triangular* for inputs and conclusions, respectively (see Figure 3). In this manner, each input is fuzzified over all the qualifying membership functions required by the rules. The basic structure of an example with the two-input, one-output and three-rule is shown in Figure 4.

Note that each rule can have different weights that generally are considered one and thus has no effect at all on the implication process. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule. *Min* (minimum) is applied as built-in method, which truncates the output fuzzy set, and are used by the AND method.

Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable. The input of the aggregation process is the list of truncated output functions returned by the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable that eventually will be defuzzification.

There are various built-in methods for the aggregation such as *max* (maximum), *probor* (probabilistic OR value) and *sum* (simply the sum of each rule's output set) to combine the output of each rule into a single fuzzy set whose membership function assigns a weighting for every output value. We used of the centroid calculation for defuzzification, which is the most popular method. This method returns the center of area under the curve. There are other methods such as bisector, middle of maximum, largest of maximum, and smallest of maximum.

Figure 5 shows fuzzy inference diagram for an example with the two-input, one-output and three-rule. In this figure, the flow shows everything at once, from linguistic variable fuzzification all the way through defuzzification of the aggregate output. Decision makers use a crisp number between 0 and 10 for showing importance of the criterion.

When the values for each class are obtained by FIS, the next step is establishing final weight for overall performance of the suppliers. The decision-makers make use of the linguistic weighting variables with triangular fuzzy numbers to show how well each class qualify (seven classes include time, cost, quality, etc.). These weight are considered same for all suppliers where has been defined a sample of that in Table 1.

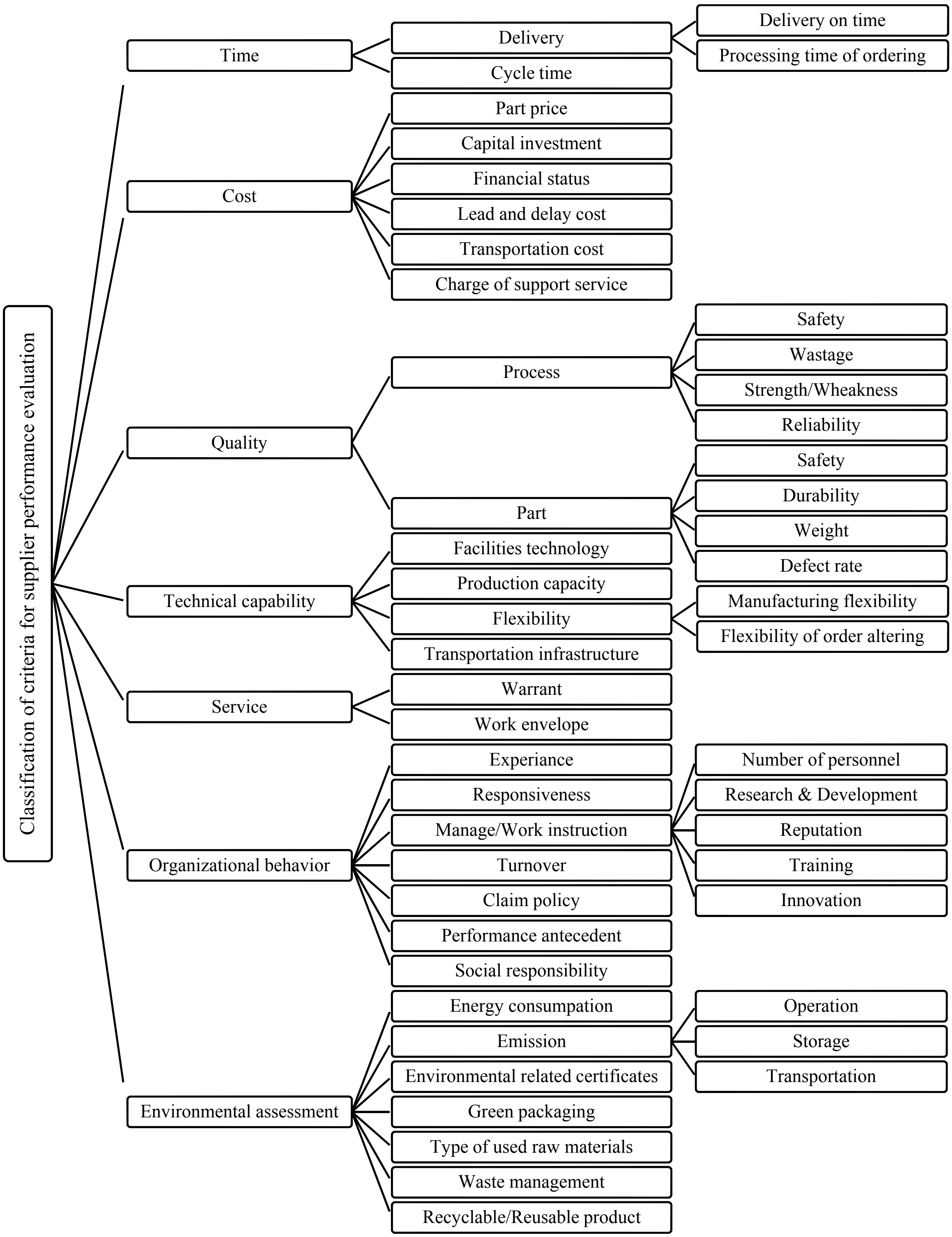

Figure 2: Some of the most important factors that influence supplier performance evaluation

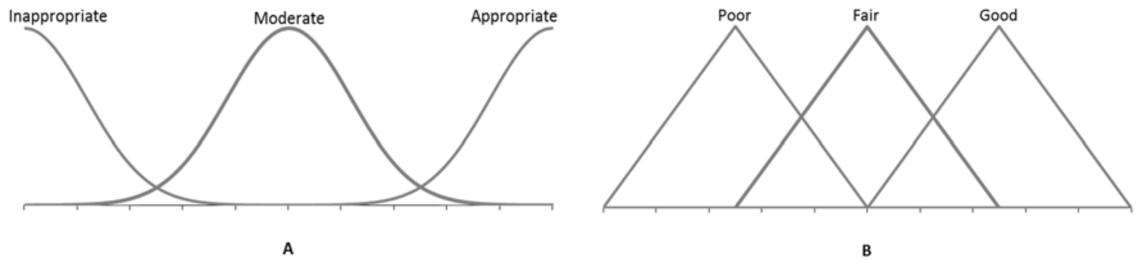

Figure 3: The membership function for A: the input variable, B: the output variable

According to this table the linguistic variables used in the rating of each class were limited to seven scales inclusive {extremely unimportant, strongly unimportant, unimportant, moderately, important, strongly important, extremely important} to be the linguistic set used to express opinions on the classes for the final performance evaluation of the supplier.

Table 1: Linguistic variable values for weighting of each class

Linguistic data	Triangular fuzzy number
Extremely unimportant	(0.0, 0.0, 0.1)
Strongly unimportant	(0.0, 0.1, 0.3)
Unimportant	(0.1, 0.3, 0.5)
Moderately	(0.3, 0.5, 0.7)
Important	(0.5, 0.7, 0.9)
Strongly important	(0.7, 0.9, 1.0)
Extremely important	(0.9, 1.0, 1.0)

This methodology is used in weighting importance of all classes; next final weight of the supplier is calculated by the following equation.

$$\widetilde{W}_{it} = \sum_{c=1}^{n} (\tilde{I}_{ct} \times P_{cit}) \, / \sum_{c=1}^{n} \tilde{I}_{ct} \tag{1}$$

Where $\widetilde{W}_{it}$ is the final weight of supplier *i* at time *t*, $\tilde{I}_{ct}$ and P_{cit} are the fuzzy importance number and the value calculated by FIS for each class, respectively, and *n* is the number of classes.

Now, this weight must be defuzzified. In this paper, a linear ranking function is applied for convert the calculated fuzzy weight into the crisp equivalent number, with the first index of Ronald (1978) and Ronald (1981). Thus by applying the first index of Ronald and by considering triangular fuzzy numbers, a defuzzified number of $\widetilde{W}_{it} = (w_{it}^{L}, w_{it}^{C}, w_{it}^{R})$ is calculated by Eq. (2).

$$W_{it} = w_{it}^{C} + \frac{d_{it}^{R} - d_{it}^{L}}{3} \qquad \forall i \in I, t \in T, \tag{2}$$

Where, d_{it}^{R} and d_{it}^{L} are the lateral margins (right and left, respectively) of the central point w_{it}^{C}.

3.2 Coverage distance

One of the assumptions in the cover location problem is the ‘‘abrupt’’ termination of coverage; points in a distance critical are fully covered and outside of that distance do not receive any coverage. This approach seems to be unrealistic in practice. Berman et al. (2003) developed a generalization of the cover location problem where two coverage radii have been replaced instead this distance.

Based on the above content the supplier selection decisions could be modeled by using the notion of gradual covering. The percent of the final importance calculated for the supplier *i* when the distance to the nearest manufacture is letter than of *u*, maximum distance that the decision maker is willing to purchase its needed materials.

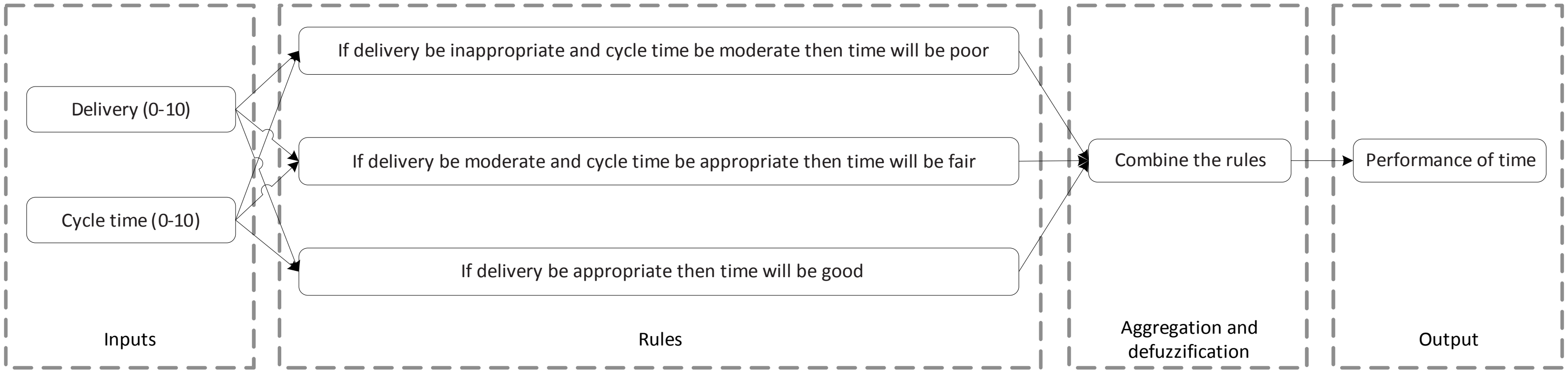

Figure 4: The basic structure of fuzzy inference process

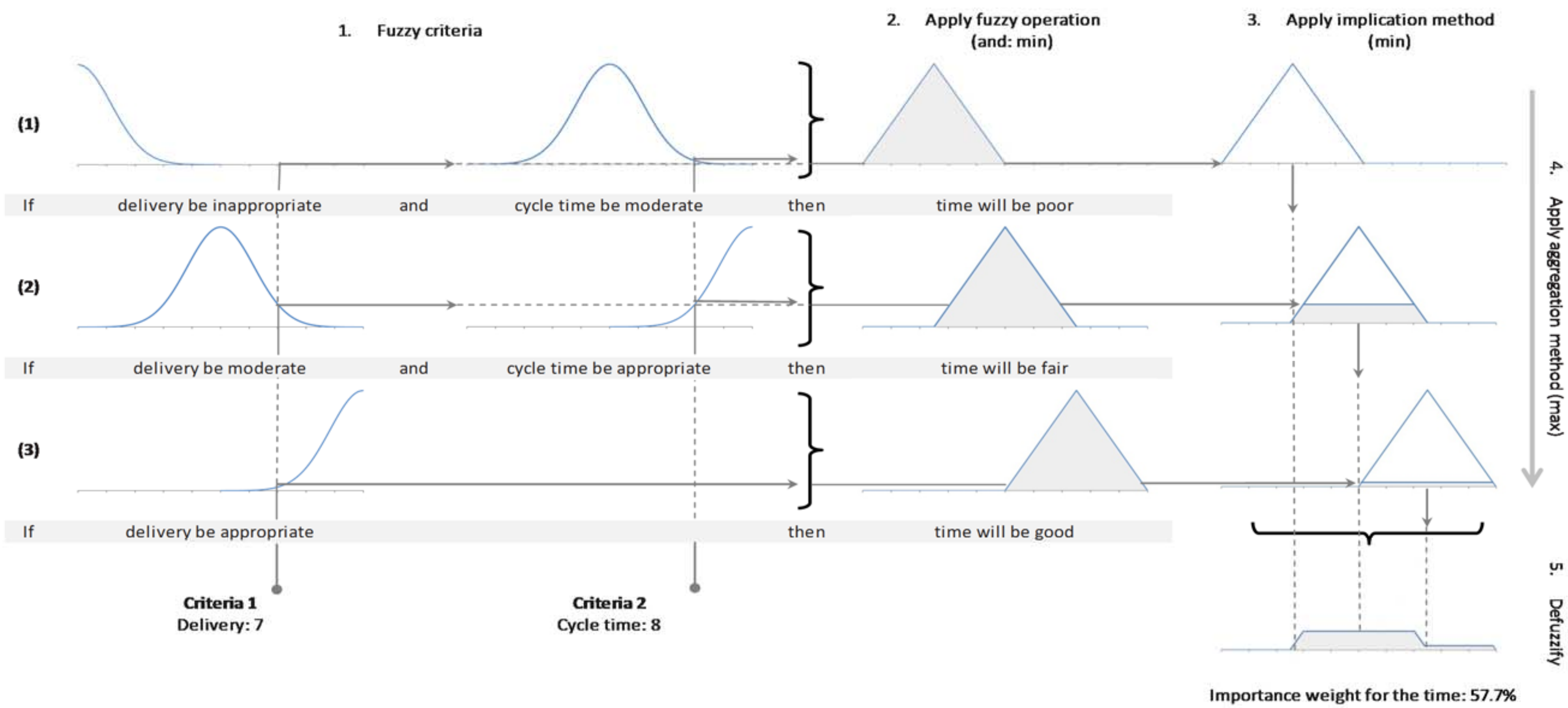

Figure 5: The actual full-size fuzzy inference diagram

If we assume that there is a same pair of radii (l,u) for all manufactures; to provide raw materials for factory j, supplier i is evaluated by the calculated importance if be fully covered by it ($ds_{ij} \leq l$). Eventually, if have not covered by any manufacture, none of them are considered ($ds_{ij} \geq u$).
Finally, the percent of the final importance calculated for supplier i is placed in the model for selecting the most qualified if the supplier is partially covered (l < dsij < u). In this case, the coverage percent can be expressed as follows:

$$p(c_{ij}) = \begin{cases} 1 & ; \; if \;\; ds_{ij} \leq l \\ \dfrac{u - ds_{ij}}{u - l} \;\; , & ; \; if \;\; l < ds_{ij} < u \\ 0 & ; \; if \;\; ds_{ij} \geq u \end{cases} \qquad (3)$$

It is noted that the producers could be assumed to have different coverage intervals and as illustrated in Figure 1. Figure 6 shows the weight percent of supplier i who is be evaluated to provide raw materials for manufacture j when located in distance d_{ij} of it.

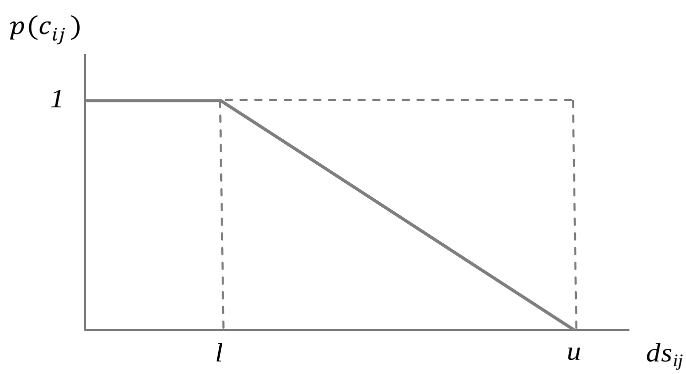

Figure 6: The covered percent of supplier weight

4. Conclusion

In this paper, we have investigated an approach for appraising potential providers based on FIS and the effect of gradual covering distance that these two factors along with other effective parameters could be used to configure a mathematical programming model for supplier selection, order allocation and determining the production strategy in an integrated supply network.
Some features of the proposed approach can be summarized as following:

(a) Decision makers use the linguistic terms to define rules that can be contained different importance from one to another.
(b) As there are not many articles that discuss sustainability issues in supplier evaluation. In this paper has been attempted to provide review capability of the sustainable criteria in the assessment by FIS.
(c) The proposed approach is applicable to any number of suppliers, and criteria that are commonly used in large companies.

In addition to strong point of FIS method is extensive use of different criteria in assessing suppliers by a comprehensive system as well as considering the effect of cover distance in the decay form that has not been seen in supplier evaluation papers.

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Biography

Mohammad Asghari completed the curriculum of University of Science and Technology on Sep. 2010 and a BSc in the field of Industrial Engineering- Industrial Production is conferred upon him which is followed by a MSc in same major from Ferdowsi University of Mashhad in 2012.His master's research was about returns of used or end-of-life products in the collection and recycling network. In addition to the items noted briefly, he has worked as an assistant manager in a local company, Solico group of food Industries, for approximately 8 months where has recently become one of the largest dairy and processed food producers and exporters in Iran.

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