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SUPPLIER SELECTION UNDER E-BUSINESS USING FIS

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ABSTRACT

In the present global markets which are speedily changing and dynamic under e-business, the success of firms rely on the appropriate suppliers. In this paper the supplier selection factors (criteria and sub-criteria) are derived through literature which supports the supplier selection process in an e-business environment. Then, a methodology is proposed onto evaluation and ranking of a given set of suppliers. In the evaluation process, decision makers' opinions on the importance of deciding the criteria and sub-criteria, in addition to their preference of the suppliers' performance with respect to sub-criteria are considered in linguistic values. To cope with the subjectivity of decision makers' assessments, fuzzy logic has been applied and a modular fuzzy inference system (FIS) approach is proposed for the supplier selection problem under e-business. Finally, a numerical example is applied to show the feasibility of the proposed method.

INTRODUCTION

With the rapid development of Internet, e-business has been attracted attentions of corporations and scholars, a corporation must be required to speed the rollout of new products within the shortest time to capture the market shares and meet the demand for consumers in the supply chain under e-business, so it is very important for corporations to select appropriate vendor (Li, Wang, & Chen, 2008).

In such circumstances, firms have more chances for selecting more effective suppliers due to the popularity of the Internet and globalization of trade. Researches carried out in the field of supplier selection have been applying multi-criteria decision making methods. Readers are referred to visit (Ho, Xu, & Dey, 2010) for a detailed account. Even though many publications exist on supplier selection, the research on supplier selection under e-business is not adequate.

To select the appropriate suppliers , two scenarios including the importance degree of the selection criteria, and the suppliers' performance with respect to these criteria are essential (Ordoobadi, 2009). These two scenarios need to be verified with the relevant decision makers. Decision makers normally prefer to answer the questions in linguistic terms instead of numerical form. Linguistic term is simple and tangible for them to express their perceptions. This might be a way of securing the company's information. But very often, they are obligated to answer the qualitative questions in quantitative form. Therefore, the subjectivity of human assessments is missed (Amindoust, 2012). To handle this issue and deal with the vagueness that is being existed in the supplier selection process, application of fuzzy logic is explored in this article. This paper puts importance on the weights of criteria and sub-criteria that are allocated in the modular FIS model for supplier selection decision under e-business.

SUPPLIER SELECTION FACTORS UNDER E-BUSINESS

The traditional approach to supplier selection was solely cost oriented for many years. But today, based on the influence of e-business, other factors have been taken into account. Li et al. (2008) introduced the appropriate indexes to rank the candidate suppliers under e-business. These indexes in the form of criteria and sub-criteria are including application level of IT index (investment of information system construction (IS), the percentage of computer professionals (CP), integration capability of information system (IC), and non-serious malfunction rate of the information system (MR)); service level index (flexibility(F), the satisfaction level of after-sale service(ASS)); and operation ability index (cost control(C), development potential and products supply ability(DP&PS)) (Li et al., 2008). The aforementioned criteria and sub-criteria are applied in this paper for supplier selection decision.

FUZZY SET THEORY

Zadeh (1965) introduced fuzzy set theory to cope with the imprecision and uncertainty which is inherent to the human judgments in decision making processes through the use of linguistic terms and degrees of membership. A fuzzy set is a class of objects with grades of membership. A normalized membership function is between zero and one (Zadeh, 1965). These grades present the degree of stability with which special element belongs to a fuzzy set. To express fuzzy sets on the mathematical point of view, consider a set of objects X . The set is explained as follows:

$$X = x_1, x_2, ..., x_n \qquad (1)$$

Where, x_i is an element in the set X . A membership value (μ) expresses the grade of membership related to each element x_i in a fuzzy set A , which shows a combination as below:

$$A = \mu_1(x_1), \mu_2(x_{2)}, ..., \mu_n(x_n) \qquad (2)$$

After Zadeh' work, Mamdani in 1974, investigated the feasibility of using the compositional rule of inference (Mamdani, 1974).The Mamdani FIS system has 4 parts as shown in **Error! Reference source not found.**.

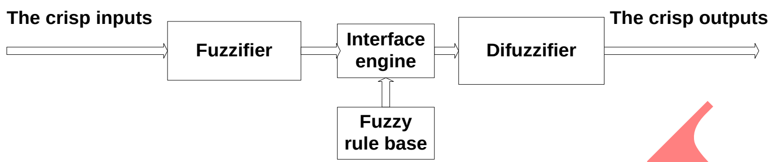

Fig. 1 The Mamdani's fuzzy inference system

- Fuzzifier: the fuzzy sets of inputs are represented by membership functions to transfer crisp inputs into fuzzy inputs. Several functional forms of the membership function are available to represent different situations of fuzziness; for example, linear shape, concave shape and exponential shape. Two commonly used types of membership function are linear triangular and linear trapezoid membership functions (Chen, 2009).

- Rules: the main part of the FIS model is "Rules". The fuzzy "if-then" rules are defined on the basis of experts' knowledge in each area. A fuzzy rule can be written as "if x_1 is a_1 and x_2 is b_1, then y is c_1" so that x_1 and x_2 are variables, y is a solution variable, and a_1, b_1, and c_1 are fuzzy linguistic terms.

- Interface engine: the fuzzy interface engine takes integrations of the identified fuzzy sets considering the fuzzy rule and allocates to integrate the related fuzzy area individually.

- Defuzzifier: transforms the fuzzy output to crisp output. Among 4 parts of FIS, defuzzification process has the most computational complexity. The defuzzifier finally identifies a numerical output value. Popular defuzzication approaches include the center of area method (COA), bisector of area method (BOA), mean of maximum method (MOM), smallest of maximum method (SOM), and the largest of maximum method (LOM) (Sivanandam, Sumathi, & Deepa, 2007).

THE PROPOSED SUPPLIER SELECTION MODEL FOR E-BUSINESS ENVIRONMENTS

To design our proposed fuzzy model, some basic concepts must be considered. So these concepts are discussed in the next sub-sections and finally the description of the proposed model is presented through three stages in **Error! Reference source not found.**.

A. Fuzzy Membership Functions

In this work the relative importance of the criteria and sub-criteria and also the supplier's performance with respect to the sub-criteria, are implemented on the basis of decision makers' opinion. Thus we set out two membership functions, one for estimation of the criteria and sub-criteria weights and the other for the supplier's performance with respect to sub-criteria. It is noted that the membership functions are applied in the trapezoidal and triangular forms in this paper. A trapezoidal fuzzy number can be shown as $\tilde{w} = (a, b, c, d)$ in **Error! Reference source not found.** and the trapezoidal membership function is defined as Eq. (3). According to Eq. (3), if $b = c$ then the number is called a triangular fuzzy number.

$$\mu_{\tilde{w}}(x) = \begin{cases} 0 \quad if \quad x < a \\ \frac{1}{b-a}(x-a) \quad if \quad a \le x \le b \\ 1 \quad if \quad b \le x \le c \\ \frac{1}{c-d}(x-d) \quad if \quad c \le x \le d \\ 0 \quad if \quad x > d \end{cases} \tag{3}$$

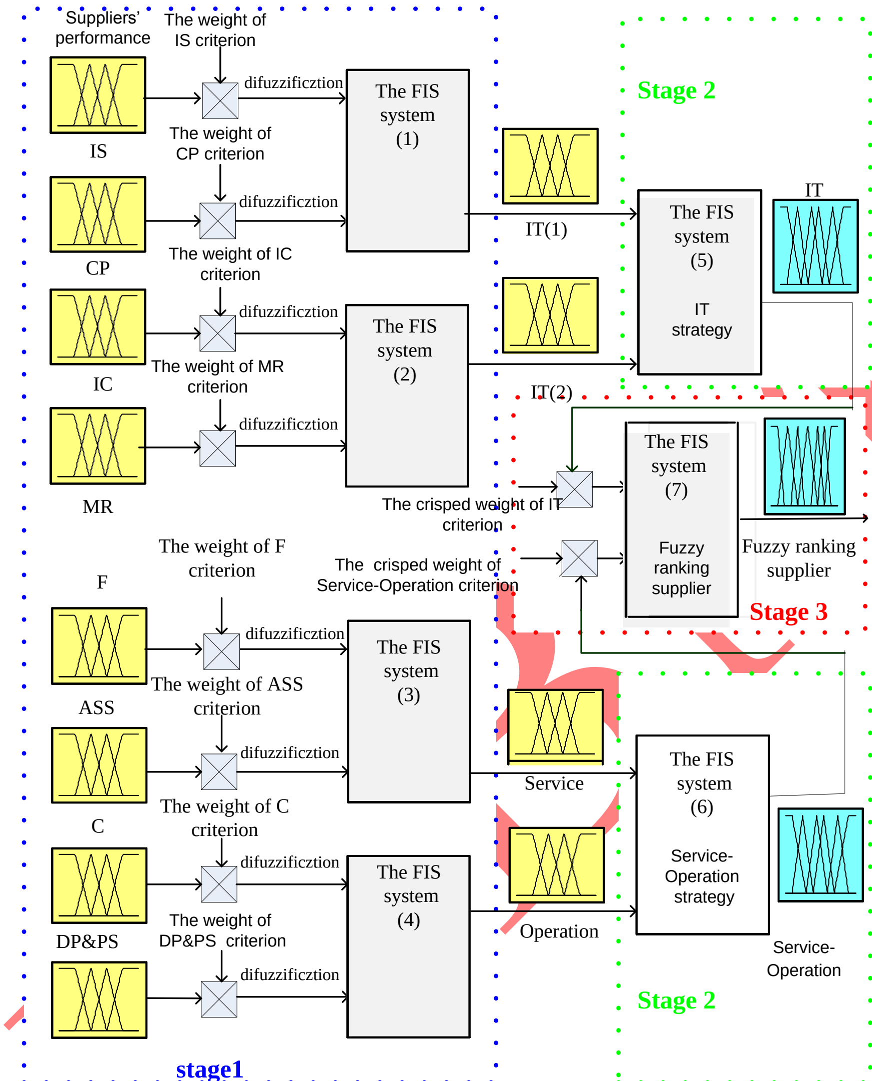

Fig. 2 The proposed fuzzy ranking model

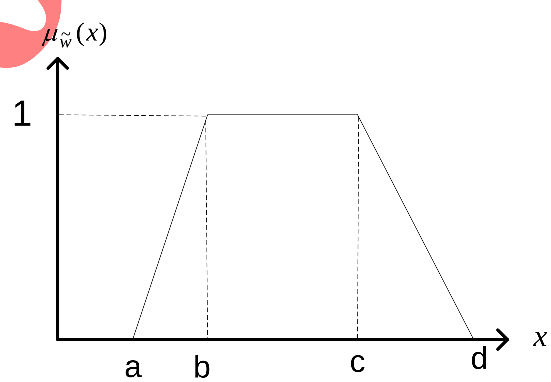

Fig. 3 The trapezoidal fuzzy membership function

Membership Functions for the Inputs and Outputs

In the first stage of the model four fuzzy sets of membership functions are applied for both inputs and outputs of the FIS systems. The fuzzy sets in the form of linguistic rating variables include "weakly preferred", "moderately preferred", "strongly preferred" and "extremely preferred" as shown in **Error! Reference source not found.**. These variables are equivalent to fuzzy numbers on the numeric scale 0-10. For example, moderately preferred (MP) is equivalent to (2, 4, 4, 6).

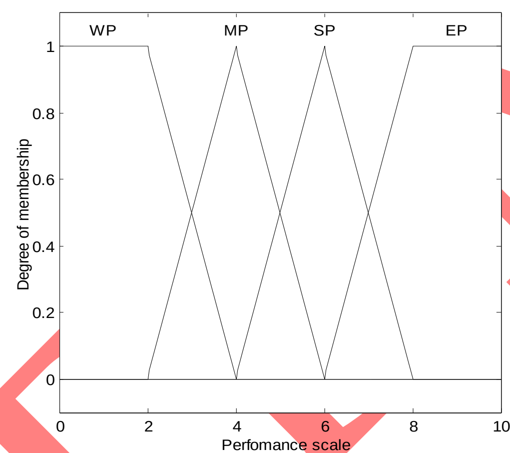

Fig. 4 The membership functions in stage 1 and stage 2 for the supplier's performance

Like the first stage, we considered four fuzzy sets of membership functions for inputs in the second stage and six fuzzy sets of membership functions for outputs of the FIS systems. The output fuzzy sets in the form of linguistic rating variables include "weakly preferred", "low moderately preferred", "high moderately preferred", "strongly preferred", "very strongly preferred" and "extremely preferred" as shown in **Error! Reference source not found.**. For example, the corresponding fuzzy number to strongly preferred (SP) is (4, 5.5, 5.5, 7).

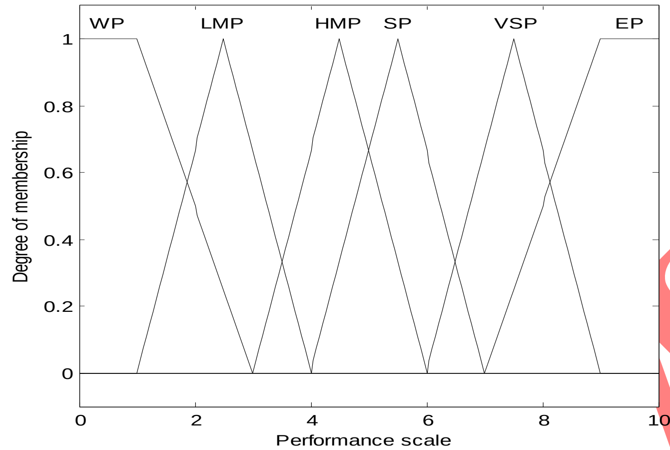

Fig. 5 The membership functions in stage 1 and stage 2 for the supplier's performance

In the third stage, we considered six fuzzy sets of membership functions for inputs which are same the outputs of second stage and seven fuzzy sets of membership functions for outputs of the FIS systems. The output fuzzy sets in the form of linguistic rating variables include "very weakly preferred", "weakly preferred", " low moderately preferred", "high moderately preferred", "strongly preferred", "very strongly preferred" and "extremely preferred" as shown in **Error! Reference source not found.**. The related fuzzy numbers are in the numeric scale 0-100. For example, high moderately preferred (HMP) is equivalent to (40, 55, 55, 70).

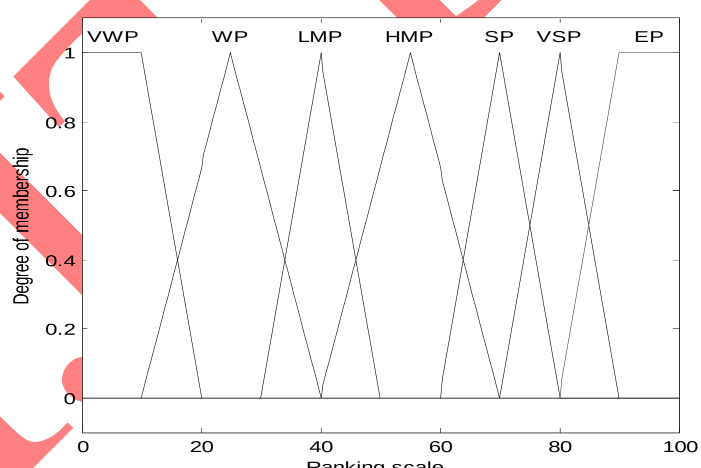

Fig. 6 The membership functions in stage 3 for ranking the suppliers

Membership Functions for the Importance of Criteria and Sub-criteria

In the first and third stages of the model, four fuzzy sets in the form of linguistic weighting variables which include "weak importance", "moderate importance", "strong importance", and "extreme importance" were utilized to evaluate the importance of sub-criteria and criteria. These variables are equivalent to fuzzy numbers on the numeric scale 0-1 as shown in **Error! Reference source not found.**. For example, strong importance (SI) is equivalent to (.4, .6, .6, .8).

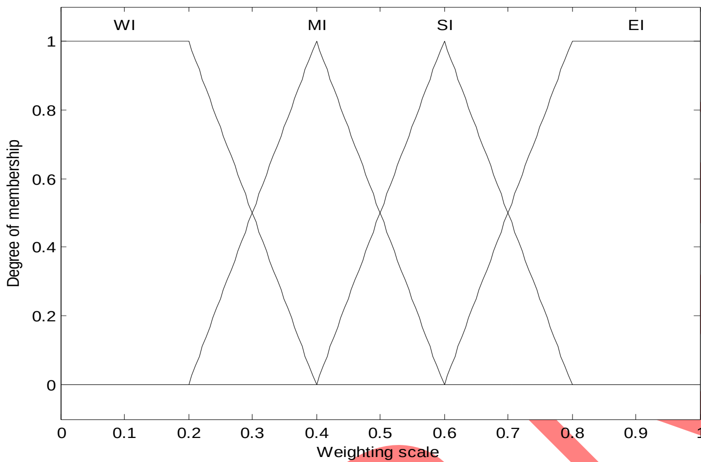

Fig. 7 Membership functions for the weights of criteria and sub-criteria

B. Fuzzy Operators

Addition and multiplication of fuzzy operations are utilized in our model. Suppose equations (4) and (5) be two trapezoidal fuzzy numbers as

$$R = (r1, r2, r3, r4) \tag{4}$$

$$S = (s1, s2, s3, s4) \tag{5}$$

So, addition and multiplication of them are as follows respectively.

$$R + S = (r1 + s1, r2 + s2, r3 + s3, r4 + s4) \tag{6}$$

$$R * S = (r1 * s1, r2 * s2, r3 * s3, r4 * s4) \tag{7}$$

C. Fuzzy rules in the Proposed Model

A set of the fuzzy linguistic rules based on expert knowledge are utilized to implement our fuzzy ranking model. The rules are adjusted on the preference of decision makers to have the appropriate ranking for suppliers. Also, the rules are designed on the basis of averaging concept for each FIS systems. For instance, when the supplier's performance with respect to flexibility is "strongly preferred" and the supplier's performance with respect to after-sale service is "strongly preferred" then the FIS output is "strongly preferred" (see Ttable I) or when the supplier's performance with respect to flexibility is "weakly preferred" and the supplier's performance with respect to after-sale service is "strongly preferred" then the FIS output is "moderately preferred" (see Ttable I). Moreover, the designed rules cover the changes of suppliers' performance completely and map their numeric scale of inputs to their numeric scale in outputs.

The rules for the related FIS engines are the same at each stage of the proposed model. The rules for first, second, and third stages are shown in **Error! Reference source not found.**, **Error! Reference source not found.**, and **Error! Reference source not found.**, respectively.

D. *Defuzzification Approach*

To rank the fuzzy numbers for comparing the mentioned alternatives, the fuzzy numbers must be difuzzified to crisp numbers. In this paper, the COA method is used for difuzzification as shown in (8).

$$x_{COA} = \frac{\sum_{i=1}^{n} x_i . \mu_i(x_i)}{\sum_{i=1}^{n} \mu_i(x_i)} \tag{8}$$

Where, x_i is an element in the set X as mentioned in (1) and (2).

E. *Proposed Supplier Selection Model*

Our proposed model explicitly shows a mathematical function in which the image of 8 elements (sub-criteria) is the final result of the model.

TABLE I THE FUZZY RULE BASE MATRIX IN STAGE1

THE FIRST INPUT / THE SECOND INPUT	WP	MP	SP	EP
WP	WP	WP	MP	MP
MP	WP	MP	MP	SP
SP	MP	MP	SP	SP
EP	MP	SP	SP	EP

TABLE II THE FUZZY RULE BASE MATRIX IN STAGE2

THE FIRST INPUT / THE SECOND	WP	MP	SP	EP

INPUT				
WP	WP	WP	LMP	HMP
MP	WP	LMP	HMP	SP
SP	LMP	HMP	SP	VSP
EP	HMP	SP	VSP	EP

TABLE III THE FUZZY RULE BASE MATRIX IN STAGE3

THE FIRST INPUT / THE SECOND INPUT	WP	LMP	HMP	SP	VSP	EP
WP	VWP	WP	LMP	LMP	HMP	SP
LMP	WP	LMP	LMP	HMP	HMP	SP
HMP	LMP	HMP	HMP	SP	SP	VSP
SP	LMP	HMP	HMP	SP	SP	VSP
VSP	HMP	HMP	SP	SP	VSP	VSP
EP	SP	SP	SP	VSP	VSP	EP

Usually, in FIS models, the maximum number for fuzzy inputs are not considered more than two elements in order to decrease the number of fuzzy rules and design the rules more simply. Hence, we have taken this into account in the proposed model. The proposed model is done through three stages as presented in **Error! Reference source not found.**. First, the supplier's performance with respect to each sub-criterion is multiplied by the weight of the sub-criterion. Then, the obtained fuzzy numbers are defuzzified to the desired crisp numbers for using as input variables ($x_{1,} x_2, \ldots, x8$) for the FIS systems in the first stage. To begin the second stage, four inputs including two outputs of IT-level group, one output of service-level group, and one output of operation-level group are considered for two FIS systems in the second stage.

To begin the third stage, the fuzzy weight of IT level criterion is defuzzified to crisp number and multiplied by its related output value in the second stage**.** Also, the average between the weights of service-level and operation-level criteria is defuzzified to crisp number and multiplied by its related output value in second stage (see **Error! Reference source not found.**).

It is worthwhile to say that after multiplication of criteria and sub-criteria weights by suppliers' performance in the first and third stages, the range of supplier's performance ([0 10]) is reduced. So, the obtained results do not satisfy the aims of designed rules and causes inadequate precision for the FIS outputs. To tackle this problem, the FIS inputs are normalized for remaining in the previous scale of inputs.

This methodology must be repeated for each candidate supplier to obtain its ranking.

NUMERICAL EXAMPLE

The proposed supplier selection model under e-business environment can be executed for any number of suppliers and there is no limitation. However, here a supposed illustration is utilized to show the application of the proposed model. Suppose *Aco*. is a company which has five candidate suppliers. We want to rank the five suppliers and find the best ones. The suppliers are named supplier A, supplier B, supplier C, supplier D, and supplier E. There are three purchasing managers as decision makers in the company, hereafter referred to them as DMU1, DMU2, and DMU3. The decision makers' perceptions about the importance weights of the e-business criteria and sub-criteria as mentioned in section 2 must be deducted. This process is presented in table IV and the results of it are illustrated in table V and

table **VI**. The mean values of fuzzy weightings for criteria and sub-criteria are also calculated. It is noted that the fuzzy numbers mean of service-level and operation-level criteria is considered for weighted criterion of the second inputs in the third stage. It is worthwhile to mention that decision makers' perceptions of the suppliers' performance with respect to the sub-criteria are same and they agreed with each other.

TABLE IV DECISION MAKERS' OPINIONS FOR CRITERIA WEIGHTS

Decision makers / Criteria	DM1	DM2	DM3
IT level	EI(.6, .8, 1, 1)	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)
Service level	SI(.4, .6, .6, .8)	SI(.4, .6, .6, .8)	EI(.6, .8, 1, 1)
Operation level	SI(.4, .6, .6, .8)	SI(.4, .6, .6, .8)	SI(.4,.6, . 6, .8)

TABLE V DECISION MAKERS' OPINIONS FOR SUB-CRITERIA WEIGHTS

Sub-Criteria	Decision Makers		
	DM1	DM2	DM3
IS	EI(.6, .8, 1, 1)	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)
CP	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)	EI(.6, .8, 1, 1)
IC	SI(.4, .6, .6, .8)	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)

MR	SI(.4, .6, .6, .8)	MI(.2, .4, .4, .6)	WI(0, 0, .2, .4)
F	SI(.4, .6, .6, .8)	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)
ASS	EI(.6, .8, 1, 1)	SI(.4, .6, .6, .8)	WI(0, 0, .2, .4)
C	SI(.4, .6, .6, .8)	WI(0, 0, .2, .4)	EI(.6 .8, 1, 1)
DP&PS	MI(.2, .4, .4, .6)	SI(.4, .6, .6, .8)	MI(.2, .4, .4, .6)

TABLE VI DECISION MAKERS' OPINIONS FOR SUPPLIER RATINGS

Sub-Criteria	Decision Makers						
	A	B	C	D	E	Ideal	Anti-Ideal
IS	SP	EP	MP	EP	WP	EP	WP
CP	SP	EP	MP	EP	WP	EP	WP
IC	MP	EP	MP	WP	EP	EP	WP
MR	MP	EP	MP	WP	EP	EP	WP
F	SP	MP	EP	WP	EP	EP	WP
ASS	SP	MP	EP	WP	EP	EP	WP
C	MP	MP	EP	WP	EP	EP	WP
DP&PS	MP	MP	EP	WP	EP	EP	WP

The illustrative example has been exerted for five suppliers in addition to virtual suppliers as shown in

table **VI**. The two virtual suppliers are defined as the best supplier (Ideal) and the worst supplier (anti-Ideal).

Finally, the performance score of each supplier is computed and ranking results for all suppliers are shown in table VII. Except for two virtual suppliers including Ideal and anti-Ideal, the order of five suppliers is B, E, C, D, and A.

TABLE VII VALIDATION AND RANKING OF THE MODEL

Suppliers	**Ranking Results**				
	COA	**MOM**	**SOM**	**LOM**	**BOA**
A	41.9175	33.6549	36.6868	30.9957	42.1126
Ranking of A	(6)	(6)	(6)	(6)	(6)
B	80.6922	77.7295	68.8258	80.5212	80.2445
Ranking of B	(2)	(2)	(2)	(2)	(2)
C	63.6929	55.2646	55.2686	55.4935	60.9659
Ranking of C	(4)	(4)	(4)	(4)	(4)
D	53.4466	53.4466	53.4466	53.4466	53.4466
Ranking of D	(5)	(5)	(5)	(5)	(5)
E	73.5763	68.6889	66.6121	73.8325	72.2455
Ranking of E	(3)	(3)	(3)	(3)	(3)
Ideal	100.0000	97.6695	83.8293	99.8726	99.6644
Ranking of Ideal	(1)	(1)	(1)	(1)	(1)
Anti-Ideal	11.4863	11.4863	11.4863	11.4863	11.4863
Ranking of Anti-Ideal	(7)	(7)	(7)	(7)	(7)

To show the structure of rule viewers in the model which present the roadmaps of FIS systems, we choose one of the FIS systems as an example. Fig. 8 illustrates the rule viewer of the related FIS to the second stage of IT-level group for supplier E. Each rule is a row of plots and each column is a variable (IT1, IT2, and IT Strategy) in **Error! Reference source not found.**. The input values can be varied by moving the red line and the FIS system gives the output value. As four membership functions are considered for inputs, the number of rules will be 16 (4^2) to have the output value. After verifying the rules, it is clear that the output value (IT index) increases similar to results obtained from the input values (IT-level1 and IT-level2).

We have proved the robustness of the proposed model in two ways. First, the ranking results of five suppliers are between the Ideal and anti-Ideal ranking as shown in table VII **Validation and ranking of the model**

and this shows the validity of our model. In addition, we applied some difuzzification methods to show the validity of the model (Ordoobadi, 2009) such as COA, BOA, MOM, SOM, and LOM. As can be seen from table VII **Validation and ranking of the model**

, the obtained ranking results for all of the suppliers are the same in different defuzzification methods and this also show the validity of our model.

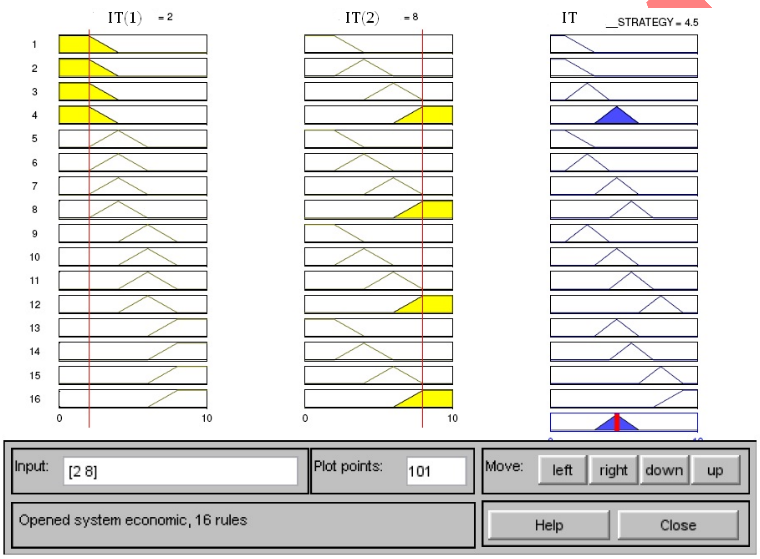

Fig. 8 Rule viewer of the FIS in the case example

CONCLUDING REMARKS

Due to the speedy improvement of Internet, e-business has been receiving a lot of attention in business activities. Hence, in supply chain management (SCM), e-business must be considered as a main component of the tasks. Since supplier selection is one the main decisions in SCM, so this selection is involved with the e - business scenario. In this paper, a modular FIS model is proposed for supplier selection problem under e-business environments. The proposed model can handle the fuzzy data. Also, the relative importance of criteria and sub-criteria weights depends on the decision makers' preference are considered in the proposed model. Although many attempts have been made for the supplier selection, considering the e-business concept for this problem remains a challenge and this is a fertile area for future research.

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