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An approach based on ANFIS input selection and modeling for supplier selection problem

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ABSTRACT

Supplier selection is a key task for firms, enabling them to achieve the objectives of a supply chain. Selecting a supplier is based on multiple conflicting factors, such as quality and cost, which are represented by a multi-criteria description of the problem. In this article, a new approach based on Adaptive Neuro-Fuzzy Inference System (ANFIS) is presented to overcome the supplier selection problem. First, criteria that are determined for the problem are reduced by applying ANFIS input selection method. Then, the ANFIS structure is built using data related to selected criteria and the output of the problem. The proposed method is illustrated by a case study in a textile firm. Finally, results obtained from the ANFIS approach we developed are compared with the results of the multiple regression method, demonstrating that the ANFIS method performed well.

1. Introduction

Supplier selection plays an important role in the success of a company's strategic goals. Changing customer preferences, public procurement regulations, and new organizational forms with more decision-makers make the purchasing function more complex and important for companies in today's environment (De Boer, Labro, & Morlacchi, 2001). In addition, performing the purchasing function effectively and building strong and reliable partnerships with suppliers ensures that the company is more competitive in the market. An adequate method with appropriate selection criteria is necessary for a company to achieve a competitive advantage.

In practice, supplier selection includes several tangible and intangible factors. Weber et al. reviewed and classified 74 articles which have appeared in the literature since 1966 (Weber, Current, & Benton, 1991). The study categorized these articles with respect to the 23 criteria of Dickson's study. These criteria were originally based on a questionnaire sent to purchasing agents and managers from the United States and Canada. Dickson concluded that quality, delivery, and performance history are the three most important criteria. On the other hand, Weber and his colleagues noted that 47 of the 74 articles (64%) discussed more than one criterion. The two main articles that address the supplier selection criteria structure describe a multi-criteria view of the problem. The review of selection criteria based on various articles is shown in Table 1.

Several methods for supplier selection have appeared in literature, including approaches based on fuzzy logic. The main reason for a fuzzy logic approach is the need to handle vagueness and ambiguity in the problem. Researchers try to build effective models that not only consider quantitative aspects but also convert human judgments about qualitative criteria into meaningful results.

For the first time in a fuzzy supplier selection problem, Amid et al. present an asymmetric approach that enables decision makers to assign different weight for each criterion (Amid, Ghodsypour, & OBrien, 2006). Their fuzzy multi-objective linear model has the capability to capture the fuzziness of the problem and order quantities can easily be assigned to each supplier under various constraints. Chen et al. presented a fuzzy TOPSIS approach by applying trapezoidal fuzzy numbers to assess the importance level of each criterion and ratings of alternative suppliers with regard to selected criteria (Chen, Lin, & Huang, 2006). In this model, a closeness coefficient is defined to determine the ranking order of all alternative suppliers by calculating the distances to fuzzy positive and negative ideal solutions (Chen, 2000). Chan and Kumar implemented a Fuzzy Extended Analytic Hierarchy Process (FEAHP) model that includes four hierarchies for a global supplier selection problem (Chan & Kumar, 2007). The study also discusses the risk factors related to a global view of the problem. Bevilacqua et al. integrated the fuzzy logic approach with a Quality Function Deployment method for a supplier selection problem in a medium to large industry that manufactures complete clutch couplings (Bevilacqua, Ciarapica, & Giacchetta, 2006). In this model, alternative suppliers are ranked according to their fuzzy suitable index values. Kwong et al. introduced a combined scoring method with

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Table 1
Supplier selection criteria research.

Selection criteria	A	B	C	D	E	F	G	H	I
After sales service	X		X				X		
Amount of past business	X		X	X					
Attitude	X								
Communication system	X		X						
Conflict resolution					X				
Delivery	X	X	X			X	X	X	
Desire for business	X								
Ease of communication		X		X				X	
Economy				X					
Financial position	X	X	X	X	X	X			X
Flexibility and response to changes		X		X		X		X	X
Geographical location	X			X					
Impression and skill	X								X
Labor relations record	X								
Management and organization	X					X			X
Operating controls	X								
Packaging ability	X								
Performance history	X			X					
Political stability				X					
Price	X	X		X			X	X	
Procedural compliance and discipline	X					X			
Production facilities and capacity	X	X	X	X		X	X		X
Quality	X	X	X	X	X	X		X	X
Reciprocal arrangements	X		X						
Relationship closeness		X			X				
Reputation and position in industry	X	X							
Technical capability and technology	X	X	X	X	X	X	X		X
Terrorism				X					
Training aids	X								
Warranties and claim policies	X						X		

A. Dickson (1966); B. Lee (2009); C. Haq and Kannan (2006); D. Chan and Kumar (2007); E. Chen et al. (2006); F. Liu and Hai (2005); G. Xia and Wu (2007); H. Ghodsypour and O'Brien (1998); I. Yahya and Kingsman (1999).

a fuzzy expert systems approach to perform supplier assessment (Kwong, Ip, & Chan, 2002). In the case study, existing supplier assessment forms are used to assign the score of each individual supplier. Then obtained scores are used as inputs to build fuzzy if-then rules. Finally, the designed fuzzy expert system is implemented in the C programming language. In another study, Carrea and Mayorga applied a Fuzzy Inference System (FIS) approach to a supplier selection problem for new product development (Carrera & Mayorga, 2008). Their model includes 16 variables categorized in four groups and each group has an individual output. MATLAB FIS Editor is used to define rules and solve the problem. The proposed FIS system uses Gaussian and Bell membership functions to define the shape of both input and output variables. Ohdar et al. and Famuyiwa et al. also applied a Fuzzy Inference System approach to the supplier selection problem using the MATLAB FIS editor (Famuyiwa, Monplaisir, & Nepal, 2008; Ohdar & Ray, 2004). The main point of the Fuzzy Inference System approach is to determine fuzzy if-then rules from experts' opinions. ANFIS, unlike FIS, automatically produces adequate rules with respect to input and output data, and takes advantage of the learning capability of neural networks.

Many researchers and academicians concentrate on a fuzzy logic approach for the supplier selection problem, but not much attention is given to fuzzy logic with neural networks. Nassimbeni and Battain applied the ANFIS approach to evaluate the contribution that suppliers have on product development (Nassimbeni & Battain, 2003). The three inputs of model are product concept and functional design, product structural design and engineering, and process design and engineering. These inputs are used to evaluate suppliers and the sum of the weighted score of experts' ratings corresponding to 15 selected criteria taken as output for the model. The data for 12 suppliers were used to instruct the neuro-fuzzy system, and data from the other four was used to test the results. In this article, output depends on subjective judgment of experts and focuses on supplier evaluation in a New Product Development (NPD) environment. We also discuss the topic of selecting a membership function type.

There have been no prior applications of the neuro-fuzzy approach to the supplier selection problem and with respect to this fact a new model based on ANFIS is developed. For the first time in a supplier selection problem, ANFIS is used for both selection of criteria and developing the model of the problem. The model output is defined to be the share of each supplier's sales. We also discuss selection of the number and type of membership functions. After the construction of the database, the model has two main stages: ANFIS input selection is executed first, and then the ANFIS model is built with respect to the related input/output data pattern.

The paper is organized as follows: the next section introduces the basics of ANFIS. Section 3 includes a literature review of ANFIS. In Section 4, we present the algorithm for the model we developed. Section 5 includes a case study of the model. Finally, we present our conclusions in the last section.

2. Adaptive Neuro-Fuzzy Inference System (ANFIS)

Jang first introduced the ANFIS method by embedding the Fuzzy Inference System (FIS) into the framework of adaptive networks (Jang, 1993). An adaptive network is a network structure consisting of a number of nodes connected through directional links. The outputs of these adaptive nodes depend on modifiable parameters pertaining to these nodes. The learning rule specifies how these parameters should be updated to minimize error. On the other hand, FIS is a framework based on fuzzy set theory and fuzzy if-then rules. The structure of FIS has three main components: a rule base, a database, and a reasoning mechanism. The rule base contains fuzzy if-then rules. For example, one rule might be "if price is low, then supplier's rating is high," where low and high are linguistic variables. The database defines the membership functions applied in fuzzy rules and the reasoning mechanism performs the inference procedure (Jang, Sun, & Mizutani, 1997).

Assume that the FIS has two inputs, x and y, and one output, z. In addition, the rule base of the FIS contains two fuzzy if-then rules, similar to the rule types described by Takagi and Sugeno (1983):

Rule 1: If X is A_1 and Y is B_1 then $f_1 = p_1x + q_1y + r_1$.
Rule 2: If X is A_2 and Y is B_2 then $f_2 = p_2x + q_2y + r_2$.

When $f(x,y)$ is a first-order polynomial as shown above, then the model is called a first-order Sugeno fuzzy model.

ANFIS architecture is shown in Fig. 1 where each node within the same layer performs functions of the same type. If a node's parameter set is not empty, then its node function depends on the parameter values; a square is used to represent this kind of adaptive node. On the other hand, if a node has an empty parameter set, then its function is fixed; a circle is used to denote this type of fixed node. The architecture is composed of five layers:

Layer 1: Every node i in this layer is a square node with a node function.

$$O_i^1 = \mu_{A_i}(x) \tag{1}$$

where x is the input to node i, A_i is the linguistic label, and O_i^1 is the membership function of A_i. Parameters in this layer are defined as premise parameters.

Layer 2: Circle nodes in this layer multiply the incoming signals and send the product out. This represents the firing strength of a rule.

$$\omega_i = \mu_{A_i}(x) \times \mu_{B_i}(y), \quad i = 1, 2 \tag{2}$$