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Sustainable supplier selection: A ranking model based on fuzzy inference system

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ABSTRACT

In these days, considering the growth of knowledge about sustainability in enterprise, the sustainable supplier selection would be the central component in the management of a sustainable supply chain. In this paper the sustainable supplier selection criteria and sub-criteria are determined and based on those criteria and sub-criteria 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 terms. To handle the subjectivity of decision makers' assessments, fuzzy logic has been applied and a new ranking method on the basis of fuzzy inference system (FIS) is proposed for supplier selection problem. Finally, an illustrative example is utilized to show the feasibility of the proposed method.

1. Introduction

Due to the recent agile improvement of network technology and economic globalization, purchasing management has come to play a critical role as a key to business success in supply chain management (SCM). One of the crucial challenges confronted by purchasing managers is the evaluation and selection of the right kind of suppliers compatible to agile systems. Researches carried out in the field of supplier selection have been applying multi-criteria decision making methods, such as analytic hierarchy process (AHP), analytic network process (ANP), data envelopment analysis (DEA), and mathematical programming [1–6]. Readers are referred to visit [7] for a detailed account.

Nowadays, sustainable development has become a buzzword that received a lot of attentions in many domains such as manufacturing [8], business development [9], tourism [10], and agriculture [11]. Also, in SCM both academics and practitioners consider the sustainable issues in their works. Sustainable SCM is the management of material, information and capital flows, as well as cooperation among companies along the supply chain, while taking into account the goals from all three dimensions, such as economic, environmental and social, of sustainable development derived from customer and stakeholder requirements [12].

To achieve a sustainable supply chain, all of the members in the chain from suppliers to top managers must have affinity with sustainability. Even though many publications exist on supplier selection, the research on sustainable supplier selection [13,14] is not adequate.

To select the appropriate suppliers, two subjects including importance degree of the selection criteria, and suppliers' performance with respect to these criteria are essential [15]. These two subjects 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. 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. Some researchers have used fuzzy concepts for supplier selection issue [16–20]. Also, Ordoobadi proposed a mathematical algorithm by applying fuzzy membership functions to rank the suppliers [15]. However, in case of large number of suppliers and criteria this method is quite time consuming and the final results of ranking are very close to each other. Therefore, the ranking results from this method may not be accurate. So, this paper focused on the said limitations and applies the FIS system to overcome the drawbacks of Ordoobadi's [15] model. Further, Carrera and Mayorga applied the FIS system for supplier selection. But, they did not assign the importance of weights for the selected indicators

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Table 1
The literature of selection indicators in supplier selection.

Criteria sub-criteria	References												
	[25]	[26]	[27]	[28]	[13]	[29]	[12]	[14]	[30]	[31]	[32]	[33]	[34]
Economic													
Cost/price					√			√	√		√	√	√
Quality			√				√	√	√	√	√	√	√
Technology capability					√		√		√			√	
Production facilities and capacity					√				√				
Financial capability					√		√		√				
Organization and management							√		√	√		√	
Delivery								√		√	√	√	√
Service								√	√	√			
Relationship									√	√		√	
Flexibility										√		√	
Environmental													
Environmental costs	√										√		√
Green design	√			√						√	√		√
Environmental management system	√	√	√	√		√		√		√	√	√	√
Environmental competencies	√	√	√				√		√				√
Green R&D				√						√			
Pollution control			√	√	√	√						√	
Green product			√							√		√	
Resource consumption						√						√	
ECO-design requirements for energy using product								√					
Ozone depleting chemicals								√					
Waste electrical and electronic equipment								√					
Recycling											√		
Green supply chain management										√	√		
Innovation										√			
Social													
The interests and rights of employee								√					
The rights of stakeholders								√					
Work safety and labor health					√								
Information disclosure								√					
Respect for the policy								√					

(criteria and sub-criteria). In their model, the fuzzy rules for each FIS system did not envelop all possible characteristics of suppliers [21]. So, this paper puts importance on weights of criteria and sub-criteria that are allocated in the proposed model considering sustainable issues. From the available literature it may be pointed that sustainable supplier selection issue was not yet considered in FIS system in earlier works.

This paper is organized to determine the sustainable supplier selection indicators through the literature survey. Then, a new ranking method for FIS is suggested using those criteria and sub-criteria onto selecting the best suppliers.

2. Determination of the sustainable supplier selection indicators

The traditional approach to supplier selection has solely considered economic aspects for many years. It is not enough because of globalization in business, competitive market situations, and the changing customers' demands in these days. Organizations must add the environmental/ecological and social aspects to the traditional supplier selection criteria such as quality, cost, delivery, and service to remain in the sustainable supply chain.

In our rigorous literature searches from reliable sources on supplier selection only 13 journal articles have been found which considered environmental and social aspects – separately or together – besides economic aspect to derive a set of appropriate sustainable (economic, environmental, and social) indicators. The sub-criteria applied by these researchers are combined in this work into three main sustainable criteria during the scanning of these sub-criteria by removing their duplications as shown in Table 1.

It is evident that choosing the indicators for supplier selection problem depends on the circumstances and situations and each organization may consider its individual indicators to select the best suppliers.

3. Fuzzy set theory

Zadeh 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 [22]. 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:

$$X = x_1, x_2, \ldots, x_n, \tag{1}$$

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:

$$A = \mu_1(x_1), \mu_2(x_2), \ldots, \mu_n(x_n) \tag{2}$$

After Zadeh' work, Mamdani in 1974, investigated the feasibility of using compositional rule of inference [23]. The Mamdani FIS system has 4 parts as shown in Fig. 1

- 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,