

## SUPPLIER SELECTION FOR A GREEN SUPPLY CHAIN USING MATHEMATICAL MODEL

Atefeh Amindoust<sup>1</sup>, Shamsuddin Ahmed<sup>2</sup>, Ali Saghafinia<sup>3</sup>

<sup>1&2</sup> Department of Engineering Design and Manufacture, University of Malaya,

<sup>3</sup> Faculty of Engineering, University of Malaya,

50603 Kuala Lumpur, Malaysia

Atefeh\_Amindoust@yahoo.com<sup>\*</sup>, ahmed@um.edu.my, Saghafi\_Ali@yahoo.com

***Abstract-** In today's manufacturing outsourcing of resources has significant importance. Efficient supplier selection process is a central part in supply chain management for enterprises for outsourcing. On the other hand, with the growing of awareness about environmental protection, the green issue has become more important than earlier in supply chain network. This paper intends to present a green supplier selection model based on mathematical programming. Since, the nature of supplier selection is a multi-criteria decision making problem, data envelopments analysis (DEA) is applied to deal with this problem with consideration of some inputs and outputs. A case study is done to present the application of the method.*

**Keywords:** Green Supplier Selection, Supply Chain Management, DEA

### 1. INTRODUCTION

Supply chain management (SCM) has been an important topic in business and manufacturing for about two decades and consists of activities like procuring materials, transforming them into the final products, and delivering the products to customers [1]. In recent years, due to the growth of knowledge about environmental protection, green supply chain management (GSCM) should receive due academic and practical attentions. The GSCM should be able to reduce environmental pollution from upstream to downstream when purchasing raw materials, manufacturing, distribution, selling products and obsolescing products [2]. Suppliers are the key partners of supply chains and selection of the suppliers must be done carefully, because they can have a very positive or adverse impact on the overall performance of an organization. In supplier selection decision process, two fundamental questions must be addressed. Firstly, what criterion should be used, and secondly, what methods can be applied to compare the potential suppliers.

Literature in supplier selection criteria is available since 1960's, when Dickson (1966) identified the importance of 23 supplier selection criteria for industrial purchasing, which deeply influenced later researches in this area. The basic attributes in Dickson's criteria were quality, delivery, performance history, warranty & claim policies, production facilities and capacity, and price [3]. Weber (1991) provided an explicit overview on the issues of supplier selection in 1991. His basic attributes were price, delivery, quality, production facilities and capacity, geographical location, and technical capability [4]. Zhiming et al (2003) summarized the literature on supplier selection issues from 49 articles published

during 1992 to 2003. In their paper the most important criteria identified were price, quality, delivery, production facilities and capacity, technical capability, and financial position [5]. Recently, Ho *et al* (2010) worked on published articles about supplier selection between 2000 and 2008 and discovered the most popular criterion considered by the decision makers is quality, followed by delivery, price/cost, manufacturing capability, service, and management[6].

Several techniques for supplier selection have been proposed in the literature. The first group is Mathematical programming models. Data envelopment analysis [7], a fuzzy mixed integer goal programming [8], and a mixed integer non-linear programming [9] are a few of them. The second group is the linear weighting models that include Analytic hierarchy process [10], and interpretive structural modeling [11]. The third group, statistical approaches used in some articles for conjoint analysis [12], and discrete choice analysis [13]. There are also some other methods employed in supplier selection such as total cost of ownership (TCO) [14], activity based cost (ABC) (Zhiming 1996), fuzzy logic approach [15], and visual interactive goal programming [16].

Only a few papers shed some lights on green suppliers. Lu et al. [17] applied multi-objective decision analysis for green supplier evaluation. Tsai and Hung [18] implemented a fuzzy goal programming for green supplier selection. Tuzkaya et al.[19] used hybrid fuzzy multi criteria decision approach and Lee et al. [20] also introduced a green supplier selection model for high-tech industry.

In this article Ho's criteria-group is considered, and environmental criteria on the basis of purchasing managers' opinions are added to the criteria for green

evaluating of the suppliers. Since, supplier selection is a multi-criteria decision making in nature, DEA is an appropriate tool for evaluation and selection of suppliers

## 2. EVALUATION AND SELECTION METHOD

Data Envelopment Analysis (DEA) proposed by Charnes, Cooper, and Rhodes (CCR) (1978) is a mathematical programming method for assessing the relative efficiency of homogenous decision making units (DMU) with multiple inputs and outputs. DEA is a non-parametric method that lets efficiency be measured without having specific weights for inputs and outputs or specify the form of the production function.

In supplier selection, the performance of a supplier is calculated using the ratio of weighted outputs to weighted inputs. The goal of the firm is to choose one or more suppliers from  $n$  candidates. In order to calculate the set of efficiencies for  $n$  suppliers,  $n$  fractional programming models are solved. The problem can be changed into linear programming. The model for supplier  $k$  could be defined as follows equation (1).

$$\text{Max} Z_k = \sum_{r=1}^s u_r y_{rk} \quad (1)$$

st :

$$\sum_{i=1}^m v_i x_{ik} = 1$$

$$\sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0 \quad (j = 1, 2, \dots, n)$$

$$u_r, v_i \geq \varepsilon$$

Where:  $k$  is the under evaluation unit;  $s$  represents the number of outputs;  $m$  represents the number of inputs;

$y_{rj}$  is the amount of output  $r$  provided by unit  $j$ ;  $x_{ij}$  is the amount of input  $i$  used by unit  $j$ ;  $u_r$  and  $v_i$  are the weights given to output  $r$  and input  $i$  respectively.

## 3. CASE STUDY

The case study presented in this paper stands for one of the electronic company in Iran which assembles some digital board. The company's goals in supply chain management included improving the quality of purchased products, lead-time reduction, securing global competitive pricing, and reduce environmental pollution. To identify the supplier selection criteria based on achieving these goals, we arranged some meetings and carried out interviews with managers and staffs and discussed about the appropriate criteria. After verifying a group of criteria, it appeared that Ho's criteria group was the best and closest criteria group for achieving the goals. So in this study Ho's criteria include quality, delivery, and price/cost. For environmental aspect, on the basis of

purchasing managers' preference in this kind of electronic companies, two criteria were considered including Restriction of Hazardous Substance (ROHS) and Waste Electrical and Electronic Equipment (WEEE). To implement DEA model, the input and output dimensions must be defined firstly. Normally, the criteria which the smaller is better consider as inputs and the criteria which the larger is better consider as outputs to increase the efficiency. So in this research price and WEEE are considered as inputs and quality, delivery, and ROHS are considered as outputs.

## 4. EXERTION AND DISCUSSION

Company X wants to select the best suppliers among six suppliers. The information about the suppliers is shown in Table 1. By applying DEA Excel Solver software and implementing DEA model considering Table 1 as inputs and outputs data, the efficient and inefficient suppliers are identified as shown in Table 2. Suppliers B and C are inefficient because their efficiency is less than one but the others which obtained the efficiency equal to one are efficient. In Table2, the optimal weights for inputs and outputs are shown. But, it is better to shift these weights because in some cases the weights are considered equal to zero. So, the target value for inputs and outputs are calculated as shown in Table3.

## 5. CONCLUSIONS

Fierce competitiveness in global markets exerts pressure on companies to provide their products and services to customers faster, cheaper, and better than the competitors. To do these, selection of appropriate suppliers is very important issue in supply chain management for organizations. On the other hand, the green issue has become other important issue in supply chain management owing to the importance of environmental protection. In this paper, the multi criteria selection including traditional criteria and environmental criteria are identified for the real case study. Then the DEA model is applied to determine the efficient and inefficient suppliers and calculate the target value for inputs and outputs.

Table 1: The data for inputs and outputs

Supplier No.	Inputs		Outputs		
	price	WEEE	Quality	Delivery	ROHS
1	0.954545	0.963119	0.5	1	0.989299
2	0.931818	0.959188	0.222222	0.615385	0.996442
3	0.988636	1	1	0.2	0.989299
4	1	0.876216	0.25	0.727273	1
5	0.863636	0.940004	1	0.266667	0.987529
6	0.568182	0.946821	0.333333	0.888889	0.998244

Table 2: Efficient and inefficient suppliers

Supplier Name	Optimal Multiplier					
	Efficiency	price	WEEE	Quality	Delivery	ROHS
A	1.00000	0.00000	1.03829	0.00000	1.00000	0.00000
B	0.93254	0.15038	0.89646	0.00000	0.00000	0.93587
C	0.94151	0.00000	1.00000	0.09921	0.00000	0.85141
D	1.00000	0.00000	1.14127	0.00000	0.00000	1.00000
E	1.00000	0.00000	1.06383	0.10554	0.00000	0.90576
F	1.00000	0.16097	0.95957	0.00000	0.00000	1.00176

Table 3: Target inputs and outputs

Supplier No.	price	WEEE	Quality	Delivery	ROHS
1	0.95455	0.96312	0.50000	1.00000	0.98930
2	0.57560	0.95919	0.33769	0.90050	1.01128
3	0.89018	1.00000	1.00000	0.34243	1.05089
4	1.00000	0.87622	0.25000	0.72727	1.00000
5	0.86364	0.94000	1.00000	0.26667	0.98753
6	0.56818	0.94682	0.33333	0.88889	0.99824

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