Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia - Social and Behavioral Sciences 65 (2012) 879 – 884
Procedia
Social and Behavioral Sciences

International Congress on Interdisciplinary Business and Social Science 2012

(ICIBSoS 2012)

Sustainable Supplier Selection Based on Self-organizing Map Neural network and Multi Criteria Decision Making approaches

Amir Hossein Azadnia[a], Muhamad Zameri Mat Saman[a, *], Kuan Yew Wong[a], Pezhman Ghadimi[b], Norhayati Zakuan[c]

[a]*Department of Manufacturing & Industrial Engineering, Universiti Teknologi Malaysia, Skudai 81310, Malaysia*

[b]*Enterprise research centre,University of Limerick,Limerick, Ireland*

[c]*Faculty ofManagement and Human Resource Development, Universiti Teknologi Malaysia, Skudai 81310, Malaysia*

Abstract

Due to increasing public awareness, government regulation and market pressure on sustainability issues, companies have found out that in order to have a competitive edge, sustainable operational activities should be adopted with their supply chain. Sustainable supplier selection as a crucial decision can affect the overall degree of sustainability in a supply chain. In this paper, an integrated approach of clustering and multi criteria decision making methods have been proposed in order to solve sustainable supplier selection problem. Firstly, self- organizing map as one of the well-known neural network methods has been utilized in order to cluster and prequalify the suppliers based on customer demand attribute and sustainability elements. Then, multi criteria decision making methods will be utilized in order to rank the cluster of suppliers to make coordination between them and customers. A case study has been carried out in order to show the efficiency of proposed approach.

© 2012 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of JIBES University, Jakarta

Keywords: Sustainability, supplier selection, self-organizing map, multi-criteria decision making

* Corresponding author. Tel.: +6075534833.
E-mail address: zameri@fkm.utm.my.

1877-0428 © 2012 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of JIBES University, Jakarta
doi:10.1016/j.sbspro.2012.11.214

1. Introduction

The Supplier Selection Problem consists of analysing and evaluating the performance of a set of suppliers in order to rank and select them for enhancing the efficiency of a supply chain system (Genovese et al., 2012). Nowadays, due to increasing government regulation and stronger public awareness regarding sustainability issues companies are trying to improve their sustainability profile. Companies have found out that in order to enhance their sustainability degree, sustainability issues should be integrated with their supply chain activities. Combining the two concepts of sustainable development and supply chain management would have been known as sustainable supply chain management (Zainali et al., 2012). Sustainable supplier selection as a crucial decision in the management of supply chain can affect the overall degree of sustainability in a supply chain (Amindoust et al., 2012). Supplier selection is a kind of (MCDM) problem that needs a trade-off between conflicting quantitative and qualitative criteria. Most of the researchers have used MCDM techniques in order to solve supplier selection problem such as Analytical Hierarchy Process (AHP), TOPSIS, Analytic Network Process and etc. (Liao & Kao, 2011; Xu & Ding, 2011; Xu & Yan, 2011). However, excessive numbers of suppliers increase the burden of computational complexity to be done by MCDM techniques. To solve this issue, clustering analysis techniques have been combined with MCDM methods which allow reducing the problem dimension by grouping objects based on their similarities. Azadnia et al. (2011a) mentioned that in the problem of supplier selection, cluster analysis can facilitate the decision making process by categorizing similar suppliers into same group . Moreover, by dividing the suppliers to different cluster it is possible for manager to meet customers' demand in different segments of market by their relative. Also, this matter can improve supplier relationship management system (Che, 2012). K-means, Fuzzy C-means, Self-Organization Maps (SOM) are the mostly used clustering algorithms. Among the clustering techniques, SOM has been successfully applied to many applications. However, there is limited research activities existed in the literature that focuses on the SOM approach alone or integrated with other techniques in order to deal with sustainable supplier selection. Also, we believe that the problem of supplier selection has been fully investigated by various researchers. However, based on the existed literature there is limited published research activities on sustainable supplier selection problem which consider all aspect of sustainability. Based on above mentioned situation, in this research, a new approach using SOM clustering method and MCDM techniques have been developed in order to deal with sustainable supplier selection problem. Fuzzy AHP (FAHP) was applied to weight the criteria for sustainable supplier selection. Then, SOM has been utilized to cluster the suppliers. Finally, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has been applied in order to rank the suppliers. The rest of this paper is organized as follows: some notations are presented in sections 1. This is followed by section 2 which introduces proposed method being applied to the case study and discussed in section 3. The final section is about conclusion.

1.1. FAHP

In this research, Chang's (Chang, 1996) FAHP method for weighting sustainable criteria for supplier selection problem was utilized. It is one of the Linear Weighting approaches which works based on fuzzy ratio for expressions of decision makers regarding to the pair wise comparisons. Ghadimi et al.(2012) addressed a comprehensive presentation of FAHP steps in their article which was utilized in this paper.

1.2. SOM

SOM (Kohonen, 1988) is a kind of neural networks using unsupervised training. In unsupervised training, no target output is provided and the network evolves until stabilization. Generally, SOM can be used for data clustering (or classification), vector projection and a variety of other purposes. The SOM learning algorithm is described as follows:

- *Step1*: SOM starts from initializing the weight vectors and each node's weights are initialized. Assume that denotes a high-dimensional vector of real numbers and $w_j = \{w_{ji}; j = 1, \ldots\ldots, M\}$ denotes the connection weights vector between competition layer neuron j and input layer neurons i , where M is the total number of all neurons.

- *Step 2*: From input space there, a sample vector is selected randomly and the map of weight vectors is searched to find which weight best represents that sample. Every node is examined to determine Best Matching Unit (BMU). The node with a weight vector nearest to the input vector is marked as the BMU. BMU can be determined by iterating through all the nodes and determine the Euclidean distance between the current input vector and each node's weight vector. The Euclidean distance is formula is given as :

$$d_j = \sqrt{\sum_{i=1}^{N} (x_i - w_{ji})^2} \qquad (1)$$

-*Step3:* In this step, the radius of the neighbourhood is determined. Then, it should be calculated which of the other nodes are inside the BMU's neighbourhood. A unique feature of the Kohonen learning algorithm is that the area of the neighbourhood (radius) shrinks over time by exponential decay function:

$$\sigma(t) = \sigma_0 \exp(\frac{-t}{\gamma}) \qquad (2)$$

Where, σ_0 presents the width of the lattice at time t_0 , γ denotes a time constant, $\sigma(t)$ is width of the lattice at time *t* and *t* is time steps.

-*Step4:* The weight of each node in BMU neighbourhood even BMU must be modified by Equation *(3):*

$$w_{ji}(t+1) = w_{ji}(t) + \eta\,(t).h_{j,i}(t).(x_i - w_{ji}) , \quad \eta(t) = \eta_0 \exp\left(\frac{-t}{\gamma}\right), \; h_{j,i}(t) = \exp(-\frac{D_{ji}}{2\sigma^2(t)}) \qquad (3)$$

Where $0 < \eta\,(t) < 1$ denotes decay learning rate function and η_0 represents the learning rate of initial value. $h_{j,i}(t)$ represents neighbourhood function in which$D_{ji}$is the lateral distance between neurons i and j on the grid of neurons.

- Step 5: Repeat step 2 for N iterations.

1.3. TOPSIS

Hwang and Yoon (1981) introduced TOPSIS as a method for ranking alternatives regarding defined criteria which works based on the distance of alternatives to the negative ideal solution (NIS) and the positive ideal solution (PIS). The best alternative must be nearest to PIS and farthest to NIS. In this research, TOPSIS is applied to rank the clusters and suppliers regarding sustainability criteria. Due to the limited space we didn’t present the steps of TOPSIS in this paper. A comprehensive steps of TOPSIS was presented in Azadnia et al. (2011b).

2. Proposed approach

In this research, a new model namely FAST is proposed which is organized step by step as follows:

- Step1: In this step, after defining the sustainable criteria and sub criteria, FAHP is utilized in order to determine the importance and weight of them based on experts’ opinions inside the company.

- Step 2: In this phase, SOM clustering technique is used to cluster the suppliers based on their scores regarding each sustainable criterion. Suppliers with similar scores on sustainable criteria are group in same cluster.
- Step 3: In this step, TOPSIS is applied to rank the clusters of suppliers and select the best of them. TOPSIS technique is used again to rank the suppliers inside the best cluster in order to select the best supplier. The Proposed methodology is illustrated in details with a case study in section 3.

3. Case study and discussion

In order to enlighten the efficiency of the FAST, a case study of automotive industry was selected. SAIPA is one of the main manufacturing companies in the automotive industry of Iran. In order to improve the supplier management system based on sustainable issues, the managers of SAIPA decide to cluster their supplier based on sustainable criteria and find the best cluster of them. For this case study, fuel filter was selected to be the sample component to be examined. There are 31 suppliers to be evaluated which produce this kind of fuel filter.

3.1. Criteria selection and weighting

In this step, company's experts were asked to select the criteria and sub criteria which are relevant to their company for sustainable supplier selection practice. Then, FAHP was utilized in order to determine the weights of selected criteria and sub criteria. Based on fuzzy scales company's experts as a team were asked to do pairwise comparison in order to achieve the weights of criteria and sub criteria. Regarding the limited space, only the final results of the selected criteria and sub criteria and their related weights were shown in Table 1. Based on the results, Environmental management system, Occupational health and safety management systems and cost are the most important criteria for evaluating the suppliers in SAIPA

Table 1. Weights of selected criteria and sub criteria

Criteria	Weight	Sub-criteria	Weight	Final weight
Economic	0.3847	Cost (C1)	0.384	0.1477248
		Quality (C2)	0.330	0.126951
		Delivery (C3)	0.286	0.1100242
Social	0.2305	Occupational health and safety management systems (C4)	0.684	0.157662
		The rights of stakeholders (C5)	0.316	0.072838
Environmental	0.3847	Pollution (C6)	0.253373	0.097472593
		Environment friendly product design (C7)	0.20187	0.077659389
		Environmental management system(C8)	0.544757	0.209568018

3.2. Clustering of suppliers

In this step, suppliers have been categorized into different cluster based on their similarity. Supplier's input data have been shown in Table 2. Suppliers have been evaluated regarding each criterion and their scores have been achieved based on their information. For evaluating the suppliers, expert opinion, euro Plastics Europe Data set version 2.0, their background and some other sources have been used. As shown in table 2, data inputs are measured in different scales. In order to prevent the effect of larger values on the final solution a normalization process is needed to put the fields into comparable scales. In this paper, all record values in the range between 0 and 1 are recalled using a min-max approach. Then, based on these normalized data, suppliers have been categorized in different clusters using SOM. In order to perform SOM, MATLAB R2009b software has been utilized. The results of suppliers clustering were shown in Table 3. It shows four clusters with average score of each cluster regarding each criterion.

Table 2. Suppliers' data matrix

Supplier	C1	C2	C3	C4	C5	C6	C7	C8
1	18755	3	3	5	2	4	3	4
2	19722	3	5	3	3	5	2	3
3	18915	4	5	5	2	2	5	5
.	.	.	.	.	.	.	.	.
29	19707	4	4	3	2	5	3	2
30	18219	3	3	3	5	5	2	3
31	18691	4	3	3	3	4	2	4

Table 3. Suppliers clustering results

Cluster	Average scores regarding each criterion								Number of suppliers
	C1	C2	C3	C4	C5	C6	C7	C8	
1	18704.5	3.2	3.1	3.8	3.7	3.9	2.1	3.2	10
2	19641.8	3.6	2.6	2.6	2	4.4	3	2.8	5
3	19365.7	3.8	4.5	4	3.6	4.3	3.7	3.3	10
4	19177.5	4.33	3.66	3.67	2.33	2.17	4.17	4.67	6
Average	19222.4	3.7	3.47	3.52	2.91	3.7	3.24	3.49	

3.3. Ranking suppliers

In this step, TOPSIS method was used to rank the clusters of suppliers and to select the best supplier within the best cluster in terms of sustainability. The clusters have been ranked base on their average scores in each criterion which have been shown in Table 3. FAHP has been used in order to weight the criteria which are used in TOPSIS processes. The results for suppliers' clusters ranking have been shown in Table 4. According to table 8, the suppliers' clusters ranking is cluster NO. 4, 3, 1 and 2 based on the TOPSIS Cli index which represents the relative closeness to the ideal solution (large is better).So, cluster 4 is the best cluster. It means the suppliers among cluster 4 are the potential suppliers to allocate SAIPA's orders to them. So, in this case, the suppliers inside this cluster are ranked in order to select the most appropriate supplier. There are 6 suppliers inside cluster 4. These 6 suppliers were ranked using TOPSIS method similar to the process that used for ranking the clusters. Due to limited space only the final ranking result is shown in table 5. From the result it can be perceived that supplier number 18 is the best one regarding sustainability issues. Suppliers No. 27,19,11,26 and 3 are ranked respectively.

Table 4. Suppliers' clusters ranking

Cluster No.	Cli	Rank
1	0.419981	3
2	0.28925	4
3	0.599265	2
4	0.65075	1

Table 5 suppliers ranking in the best cluster (4)

Supplier	Cli	Rank
3	0.253375	6
11	0.355041	4
18	0.657083	1
19	0.375834	3
26	0.352337	5
27	0.596566	2

4. Conclusion

In this research, an integrated approach of self-organizing map and MCDM techniques has been proposed to deal the problem of sustainable supplier selection. First, FAHP was utilized to determine the weights of sustainable criteria and sub-criteria regarding supplier selection problem. Next, SOM neural network has been utilized in order to cluster the suppliers into different group. Clustering the suppliers facilitated the process of sustainable supplier selection by reducing the data dimension which used in MCDM methods by categorizing and clustering the suppliers into different groups based on their similarity. This issue also helps companies' managers to decide better when different segments of suppliers are available in the market. They can allocate different suppliers to different segments of markets and meet demands of each segment. Also, clustering analysis can provide a prequalification process for sustainable supplier selection problem. Finally, TOPSIS as one of the capable techniques of MCDM methods has been applied to rank and select the best cluster of suppliers and the best supplier. The results show that among 31 suppliers 6 suppliers belong to the best cluster. These six suppliers identified as the most appropriate sustainable suppliers within all of the suppliers. Based on our proposed approach, within these 6 suppliers, supplier number 18 achieved the best score and identified as the best sustainable supplier. There are opportunities to develop a comprehensive framework and mathematical programming for sustainable supplier selection and order allocation which consider all aspects of sustainability beside traditional aspect.

References

Amindoust, A., Ahmed, S., Saghafinia, A., & Bahreininejad, A. (2012). Sustainable supplier selection: A ranking model based on fuzzy inference system. *Applied Soft Computing, 12*(6), 1668-1677. doi: 10.1016/j.asoc.2012.01.023.

Azadnia, A. H., Ghadimi, P., Mat Saman, M. Z., Wong, K. Y., & Sharif, S. (2011a). Supplier Selection: A Hybrid Approach Using ELECTRE and Fuzzy Clustering. *Informatics Engineering and Information Science*, 663-676.

Azadnia, A. H., Saman, M. Z. M., Wong, K. Y., & Hemdi, A. R. (2011b). *Integration model of Fuzzy C means clustering algorithm and TOPSIS Method for Customer Lifetime Value Assessment*.

Chang, D.-Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research, 95*(3), 649-655. doi: 10.1016/0377-2217(95)00300-2.

Genovese, A., Koh, S. C. L., Bruno, G., & Bruno, P. (2010). *Green supplier selection: A literature review and a critical perspective*.

Ghadimi, P., Azadnia, A. H., Mohd Yusof, N., & Mat Saman, M. Z. (2012). A weighted fuzzy approach for product sustainability assessment: a case study in automotive industry. *Journal of Cleaner Production, 33*(0), 10-21. doi: 10.1016/j.jclepro.2012.05.010.

Hwang, C. L., & Yoon, K. (1981). *Multiple attribute decision making: methods and applications: a state-of-the-art survey* (Vol. 13): Springer-Verlag New York.

Kohonen, T. (1988). Self-organization and associative memory. *Self-Organization and Associative Memory, 100 figs. XV, 312 pages.. Springer-Verlag Berlin Heidelberg New York. Also Springer Series in Information Sciences, volume 8, 1*.

Liao, C.-N., & Kao, H.-P. (2011). An integrated fuzzy TOPSIS and MCGP approach to supplier selection in supply chain management. *Expert Systems with Applications, 38*(9), 10803-10811. doi: 10.1016/j.eswa.2011.02.031.

Xu, J., & Ding, C. (2011). A class of chance constrained multiobjective linear programming with birandom coefficients and its application to vendors selection. *International Journal of Production Economics*.

Xu, J., & Yan, F. (2011). A multi-objective decision making model for the vendor selection problem in a bifuzzy environment. *Expert Systems with Applications*.

Zailani, S., Jeyaraman, K., Vengadasan, G., & Premkumar, R. (2012). Sustainable supply chain management (SSCM) in Malaysia: A survey. *International Journal of Production Economics*.