Extended MULTIMOORA method for green supplier selection based on entropy measure for objective weighting

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Abstract

Nowadays with increasing awareness of environmental protection and sustainable green development in enterprises, the green supplier selection (GSS) in supply chain has become an important issue for almost every manufacturer in firms. While the works on evaluation and selection the suppliers are abundant, but the environmental issues are rather limited. In this study, we examined multi attribute decision making (MADM) problems to determine the green supplier among the group of suppliers and ranking them with attention to attributes. Also the full Multiplicative Form added to MOORA (Multi-Objective Optimization by Ratio Analysis) under the name of MULTIMOORA is developed to solve the case study (laptop manufacturer in Malaysia). On the other side, we used objective weights based on Shannon entropy for attribute's weighting. In the numerical example we have two levels for attributes, the main attribute and sub attribute that weight them by using of AHP weighting method. The final results show the average rank of alternatives from Ratio System, Reference Point and Full Multiplicative Form.

Keywords:

Green supplier selection, MULTIMOORA, Shannon entropy measure, Environmental protection, MADM

Introduction

In the present era with so many criteria and different suppliers, how to choose a suitable supplier is important for many corporations in the today's competitive business. The importance of supply chain management and smaller than supplier selection is obvious for everyone therefore in recent years published many papers around it. For example we can mention to recently work done with Deng et al., (2014) that propose a D-AHP method for the supplier selection problem which extends the classical analytic hierarchy process (AHP) method.

Green supply chain is defined as “the extension of the traditional supply chains to include activities that aims at minimizing environmental impacts of a product throughout its entire life cycle, such as green design, resource saving, harmful material reduction and product recycle or reuse (Beamon, 1999). With the increasing of environmental pollution and parallel to it government regulation, firms today simply cannot ignore environmental issues if they want to survive in the global market. In this regard, as environmental awareness increases, buyers today are learning to purchase materials and services from suppliers that can provide them with short lead time, low cost, high quality and at the same time, with environmental responsibility. In addition, complying with the environmental regulations for selling products in certain countries, firms need to implement strategies to reduce the environmental impacts of their products (Lee et al., 2009). The most important thing in this reduce is selection the green supplier among the group of suppliers. Thus, the process for supplier selection creates a new research area known as GSS, and this area has many research gaps still to be explored (Kumar, Jain, & Kumar, 2014).

As previously mentioned the supplier selections based on environmental and green are rather limited and it spread in recent 4 or 5 years. In addition in this article we use an objective method based on entropy for weighting. The difference between objective and subjective weights is that in subjective methods decision makers determine the weights so it back to Preferences of the decision maker but objective methods utilize mathematical models automatically without considering the decision makers preferences. The approach with objective weighting is particularly applicable for situations where reliable subjective weights cannot be obtained (Deng, Yeh, & Willis, 2000). As we said one of the objective methods for weighting is entropy Shannon that we've used it.

Most of the older researches around the SS and GSS were used different MCDM methods such as AHP, TOPSIS, VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje) and something else. In this paper the MULTIMOORA was applied for solving the issue. MULTIMOORA is composed of MOORA and the Full Multiplicative Form of Multiple Objectives and in this way up till now no other approach is known including three or more methods, in this way MULTIMOORA becomes the most robust system of multiple objectives optimization. This method very rarely used in studies, we can mention to Balez¡entis, Brauers, 2012 that studied the personnel selection based on computing with words and fuzzy MULTIMOORA.

In the following sections first of all we give a brief description about supplier selection, green supply selection and also MULTIMOORA method with some related backgrounds of each one in section 2, then explain the mathematical methods of MULTIMOORA, Shannon entropy and objective weights in section 3, after that an illustrative example of green supplier selection is given to show the effectiveness of combination of MULTIMOORA and objective weights in section 4 and finally in the last section conclusion of paper.

Literature review

2.1. Supplier selection

It is a fact that nowadays supplier selection is one of the important instrument in most industries, when an organization is not able to provide all its needs so it force to use the vendors who provide raw materials, components or services for it. Supplier selection requires the use of high accuracy in decision making using specific methods and tools to analyze the various relevant factors, especially in cases where the buyers were senior managers and decision makers of large projects .The importance of this issue has caused great deal of research done in this field that some of them are Jiang, Zhuang, and Lin (2006) that evince the considerable impact of supplier selection and integration on customer satisfaction and business performance, Boran et al., (2009) that solved a multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method and also we can mention to Chai et al., (2013) who provides a systematic literature review on articles published from 2008 to 2012 on the application of decision-making (DM) techniques for supplier selection. In another paper Chen & Chao., (2012) proposed a simple method for vendor selection and utilizes the structure of criteria in AHP model and employs consistent fuzzy preference relations (CFPR) to construct the decision matrices. Organizations must pursue strategies to achieve higher quality, reduced costs and shorter lead times to extol their competitive position in the global market. Within new strategies for purchasing and manufacturing, suppliers play a key role in achieving corporate competition (Amid et al., 2009). In this regard, Amid, Ghodsypour & O'Brien published a paper in 2009 and formulated the fuzzy multi objective model in such a way as to simultaneously consider the imprecision of information and determine the order quantities to each supplier based on price breaks. As previously mentioned, the variety studies about supplier selections is abundant so we restrict ourselves until here.

2.2. Green supplier selection

In the current business environment, purchasing has become critical in establishing value-added contents of products and a vital determinant to ensure the profitability and survival of a company (Lee et al., 2009). This purchasing process becomes more important and also complicated when environmental issues are considered and it's because of green purchasing must consider the supplier's environmental commitments such as Pollution control and Green product, in additional to the traditional factors such as the supplier's costs, quality, Technology, Variety, lead-time and flexibility .

As time passed with Increasing environmental pollution and awareness of environmental protection, organizations are obliged to take into account environmental practices to strengthen the green image of their own companies, alongside with the true intent of protecting the environment (Yang et al., 2011; Tseng, 2011a; Tseng and Chiu, 2012; Lin, 2013). In this context, Noci (1997) was among the first researchers and in the 1997 published a paper and suggests effective techniques for developing the supplier selection procedure according to an environmental viewpoint. Noci represent a preliminary framework that identifies 4 groups of measures for assessing environmental performance as green competencies, current environmental efficiency, supplier's green image and net life cycle cost. then Some years later Handfield et al in 2002 illustrate the use of the AHP as a decision support model to help managers understand the trade-offs between environmental dimensions and then demonstrate how AHP can be used to evaluate the relative importance of various environmental traits and to assess the relative performance of several suppliers along these traits. After that in 2003 Humphreys et al in two papers examine supplier environmental.

In recent years Lee et al., 2009 Studied the green supplier selection model for high-tech industry, and kuo et al., 2010 study development of green supplier selection model which integrates artificial neural network (ANN) and two multi-attribute decision analysis (MADA) methods: data envelopment analysis (DEA) and analytic network process (ANP). Also in the last years Kannan et al., 2014 explore this issue in an article entitled "selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company" and in another one Rostamzadeh et al (2014) develops a quantitative evaluation model to measure the uncertainty of GSCM activities based on VIKOR method which is an extension of intuitionistic fuzzy environment aiming to solve the green multi-criteria decision making (GMCDM) problem.

2.3. MULTIMOORA method

For the first time in 2006 someone called Brauers, W. K. M with his teammate Zavadskas, E. K proposed a new method called MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) for multi-objective optimization with discrete alternatives. This method refers to a matrix of responses of alternatives to objectives, to which ratios are applied (Brauers, W. K. M., & Zavadskas, E. K. 2006). Subsequently, four years later the authors of MOORA expand their method (Brauers, W. K. M., & Zavadskas, E. K. 2010a) and expose to discussion MULTIMOORA method (Full Multiplicative Form added to MOORA).

This method is very new so the articles published in this field is very limited and confined only to some authors (Brauers, W. K. M., & Zavadskas, E. K. 2006, 2010a, 2010b, 2011a; Kracka, M., Brauers, W. K. M., & Zavadskas, E. K. 2010; Balezˇentis, A., Balezˇentis, T., & Valkauskas, R. 2010; Brauers, W. K. M., Balezˇentis, A., & Balezˇentis, T. 2011). In addition Balezˇentis (2012) evaluate personnel selection based on computing with words and fuzzy MULTIMOORA. Finally Liu et al (2014) are applied a new risk priority model for evaluating the risk of failure modes based on fuzzy set theory and MULTIMOORA method.

2.4. Research gap

The nearest studies in this area are Liu et al (2014), Balezˇentis (2012), Rostamzadeh et al (2014) and Shemshadi et al., 2011. But in the modern world of today none of them aren't comprehensive. Industry needs a method that in addition to being careful, pay attention to environmental issues and decrease consideration of decision maker simultaneously.in this paper we tried to reduce this problem and establish a complete method.

Mathematical method

3.1. Shannon entropy and objective weights

As we mentioned before two different weights are used in the proposed method: objective weights and subjective weights. On the contrary of objective weights, Subjective weights could be obtained from the decision makers' opinions like many other MADM processes (Shemshadi et al., 2011).

Entropy is a key concept in the physical sciences, social sciences and information theory. In 1947, Shannon and Weaver proposed the entropy concept, which is a measure of uncertainty in information formulated in terms of probability theory. A MADM decision matrix model contains information that entropy concept can be used it as an attribute for evaluation. This method starts with a matrix of responses of different Alternatives to different attribute, Consider a decision matrix in which its elements X_{ij} denote the ratings of Alternative i resecting attribute j, $i = 1, 2, \dots, m$, $j = 1, 2, \dots, n$:

$$\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} a_1 & a_2 & \cdots & a_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \Rightarrow X = \left[x_{ij} \right]_{m \times n} \quad \textbf{(Decision matrix)} \qquad (1)$$

Once the decision matrix is known, rather than use point views of DM (decision maker), we can directly calculate the weight of each attribute by using of entropy concept.

To calculate weights using Shannon entropy concept, the following procedure is conducted (Wang & Lee 2009):

Step 1: Normalize the evaluation index as:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \text{, for every i and j} \qquad (2)$$

Step 2: Calculate entropy measure of every index using the following equation:

$$E_j = -k\sum_{i=1}^{m}(P_{ij}.\ln p_{ij}) \text{ , for every j} \tag{3}$$

In which $k = \frac{1}{\ln(m)}$

Step 3: Uncertainty or degree of deviation of the data that is generated for the j-th index:

$$\mathrm{d}_j = 1 - E_j \text{ , for jth} \tag{4}$$

Step 4: Finally obtain the normalized weights of indexes as:

$$w_j = \frac{\mathrm{d}_j}{\sum_{j=1}^{n}\mathrm{d}_j}\text{, for jth} \tag{5}$$

3.2. MULTIMOORA

As previously said the MOORA was introduced by Brauers and Zavadskas (2006) and then MOORA spread by the full multiplicative form and became to MULTIMOORA method. MOORA is based on a set of different assumptions: The assumption of cardinal numbers, the assumption of discrete choices and the assumption of attributes. The MOORA method consists of two parts: the ratio system and the reference point approach. So, we express the MOORA at the first and then expand it to MULTIMOORA.

Based on the Fig .1, the MULTIMOORA is composed of the MOORA, plus Full Multiplicative Form.

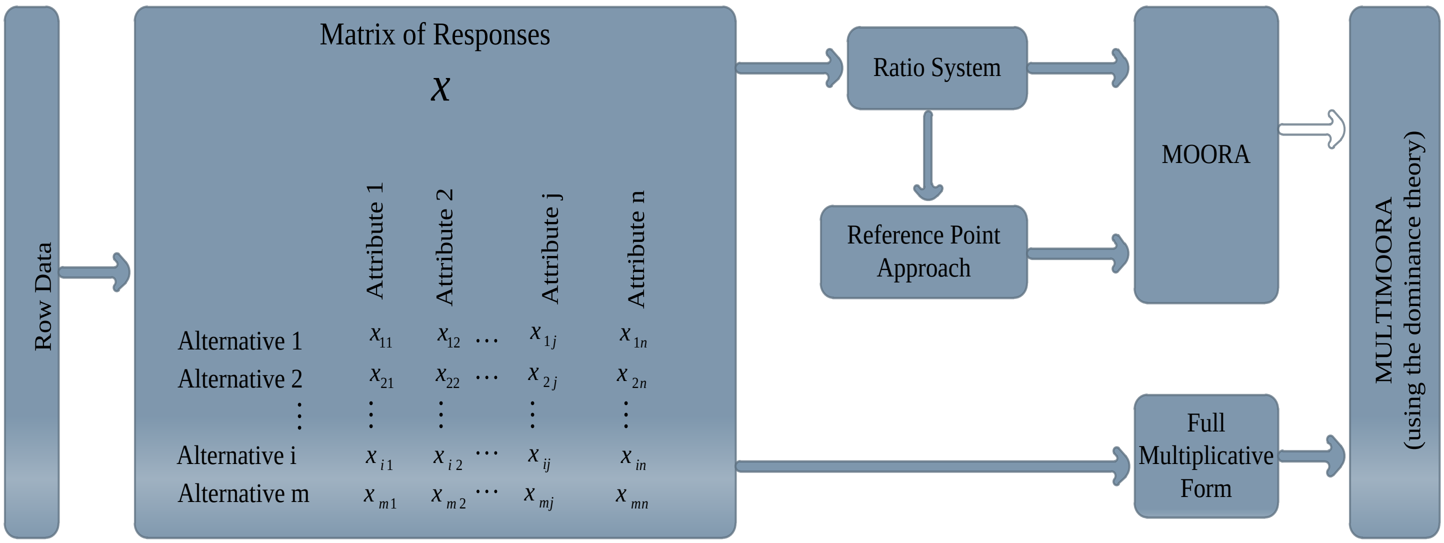

Fig. 1. Diagram of MULTIMOORA (Brauers & Zavadskas, 2011a)

3.2.1. The ratio system

MOORA refers to a ratio system that compares each response of an alternative on an objective to a denominator, which is representative for all alternatives concerning that objective (Brauers & Zavadskas, 2006):

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}, \qquad (۶)$$

Usually these numbers belong to the interval [0; 1]. These normalized values are added (if desirable value of indicator is maximum) or subtracted (if desirable value is minimum), thus, the summarizing index of each alternative is derived in this way:

$$y_{i}^{*} = \sum_{j=1}^{g} w_{j} x_{ij}^{*} - \sum_{j=g+1}^{n} w_{j} x_{ij}^{*} \qquad (۷)$$

y_i^* is the normalized assessment of the ith alternative with respect to all attributes. Then the rank of alternatives is given according to every ratio: the higher the index, the higher the rank.

3.2.2. The reference point theory

Reference point approach is based on the Ratio System and starts from the normalized ratios as defined in the Ratio System (Eq. 1), The coordinate j of the reference point vector is equal to $r_j = \max_i x_{ij}^*$ in case of maximization or $r_j = \min_i x_{ij}^*$ in case of minimization. Every coordinate of this vector represents maximum or minimum of certain objective (indicator). In order to measure the distance between the alternatives and the reference point and final rank, the Tchebycheff Min-Max metric is chosen:

$$\min_i \left(\max_j \left| w_j r_j - w_j x^*_{ij} \right| \right), \qquad (٨)$$

3.2.3. The full multiplicative form

Full multiplicative form method embodies maximization as well as minimization of purely multiplicative utility function. The objectives to be minimized are denominators in the formula:

$$U_i^* = \frac{A_i}{B_i}, \qquad (٩)$$

Where $A_i = \prod_{j=1}^{g} (x^*_{ij})^{w_j}$, $i = 1, 2, \ldots, m$ denotes the product of objectives of the ith alternative to be maximized with $g = 1, 2, \ldots n$ being the number of objectives to be maximized and where $B_i = \prod_{j=g+1}^{n} (x^*_{ij})^{w_j}$ denotes the product of objectives of the ith alternative to be minimized with $n - g$ being the number of objectives to be minimized.

3.2.4. The final ranking of the MULTIMOORA method based on the dominance theory

The three methods of MULTIMOORA are assumed to have the same importance. Stakeholders or their representatives like experts may have a different importance in ranking but this is not the case with the three methods of MULTIMOORA (Brauers, W. K. M., & Zavadskas, E. K. 2011a).

In 2011, Brauers and Zavadskas developed a theory of dominance to summarize the three rank lists provided by different parts of MULTIMOORA into a single one. For more detailed information regarding the dominance theory, readers can refer to (Brauers and Zavadskas, 2011, 2012).

Application of the extended MULTIMOORA method

4.1. Case study

Because of its practicality, this section may be cited as the most important part of this article. This study combines issues related to the environment (green issues) with business aspects (supply chain) Therefore, the appropriate case study to get the required data from should ideally have notes about the two aspects.After several studies we chose the Malaysian company that produce laptop hard disk and external hard drives with 4 branches spread in the country. This company with ISO 14001 certification has been selected to participate in the research because it was expected that the green initiatives were adopted within its operations (Eltayeb et al., 2010; Sroufe, 2003; Zhu et al., 2007a,b).

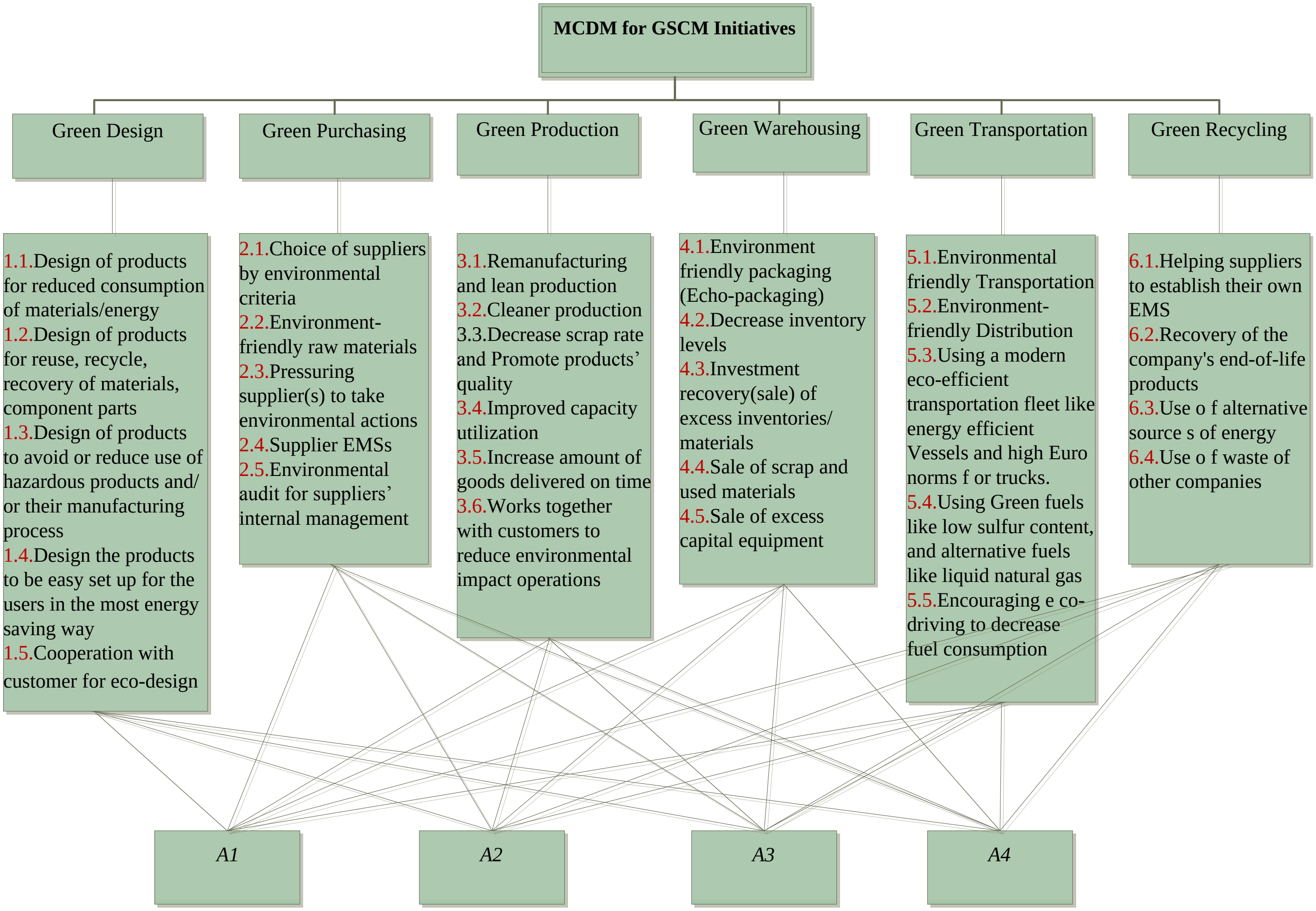

Fig. 2. Hierarchy of the problem

It should be noted that the base attributes and sub-attribute and also the weighting of them are taken from the article by Rostamzadeh et al (2014). So we've done a brief comparison between the result of this article and Rostamzadeh et al (2014) in the end of article.In what follows, the steps of the MULTIMOORA method based on entropy Shannon are implemented as follows:

First of all, we illustrated the importance weight of the attributes including main attribute and sub attribute with respect to the Fig.2 and helped of decision makers in Table 1.Then rates of the alternatives assessed by decision makers with respect to the main attribute and sub attribute and shown in Table 2 and Table 3. So far we've collected the opinions of decision makers and it's time to calculate the integrated matrix because of diversity of decision makers, for this part we average the different number of decision makers. The results shown in Table 4.

Table 1

Importance weights of the attributes assessed by decision makers

	D_1	D_2	D_3	D_4

a_1	0.9	0.9	0.8	0.9
a_2	0.9	0.8	0.8	0.8
a_3	0.8	0.9	0.9	0.8
a_4	0.7	0.5	0.7	0.5
a_5	0.8	0.9	0.7	0.7
a_6	0.8	0.8	0.8	0.8
a_{11}	0.8	0.8	0.9	0.8
a_{12}	0.8	0.9	0.9	0.8
a_{13}	0.8	0.8	0.7	0.8
a_{14}	0.8	0.7	0.7	0.8
a_{15}	0.7	0.7	0.8	0.7
a_{21}	0.9	0.8	0.8	0.8
a_{22}	0.8	0.7	0.8	0.8
a_{23}	0.7	0.7	0.7	0.5
a_{24}	0.8	0.8	0.8	0.8
a_{25}	0.9	0.8	0.8	0.9
a_{31}	0.9	0.9	0.9	0.9
a_{32}	0.9	0.9	0.8	0.9
a_{33}	0.8	0.8	0.8	0.7
a_{34}	0.8	0.8	0.8	0.8
a_{35}	0.8	0.8	0.8	0.7
a_{36}	0.9	0.8	0.7	0.7
a_{41}	0.9	0.8	0.8	0.8
a_{42}	0.8	0.7	0.8	0.8
a_{43}	0.8	0.7	0.7	0.8
a_{44}	0.7	0.8	0.7	0.8
a_{45}	0.7	0.8	0.8	0.7
a_{51}	0.9	0.7	0.9	0.9
a_{52}	0.8	0.7	0.7	0.7
a_{53}	0.9	0.9	0.9	0.9
a_{54}	0.9	0.9	0.9	0.9
a_{55}	0.9	0.8	0.8	0.8
a_{61}	0.9	0.8	0.9	0.8
a_{62}	0.8	0.8	0.8	0.8
a_{63}	0.8	0.7	0.8	0.9
a_{64}	0.7	0.7	0.7	0.8

Table 2

Ratings of the alternatives with respect to the main attribute assessed by decision makers

		a_1	a_2	a_3	a_4	a_5	a_6
D_1	A_1	0.8	0.8	0.8	0.9	0.8	0.8
	A_2	0.7	0.7	0.5	0.7	0.5	0.7
	A_3	0.8	0.8	0.7	0.7	0.7	0.8

	A_4	0.3	0.5	0.5	0.5	0.3	0.3
D_2	A_1	0.8	0.8	0.3	0.8	0.5	0.3
	A_2	0.5	0.5	0.3	0.3	0.3	0.5
	A_3	0.7	0.8	0.5	0.8	0.5	0.3
	A_4	0.8	0.8	0.7	0.7	0.5	0.5
D_3	A_1	0.7	0.7	0.8	0.8	0.5	0.3
	A_2	0.8	0.8	0.5	0.8	0.7	0.5
	A_3	0.5	0.5	0.5	0.5	0.5	0.3
	A_4	0.8	0.8	0.8	0.8	0.5	0.5
D_4	A_1	0.7	0.8	0.8	0.8	0.5	0.5
	A_2	0.5	0.5	0.5	0.7	0.7	0.3
	A_3	0.7	0.8	0.5	0.7	0.5	0.3
	A_4	0.7	0.8	0.7	0.7	0.5	0.3

Table 3

Ratings of the alternatives with respect to the sub-attribute assessed by decision makers

	D_1				D_2				D3				D4			
	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4	A_1	A_2	A_3	A_4
a_{11}	0.7	0.5	0.7	0.7	0.5	0.5	0.8	0.7	0.5	0.7	0.5	0.8	0.7	0.5	0.8	0.5
a_{12}	0.5	0.3	0.7	0.7	0.3	0.5	0.7	0.5	0.5	0.5	0.3	0.7	0.5	0.5	0.7	0.3
a_{13}	0.5	0.5	0.8	0.8	0.5	0.5	0.8	0.8	0.5	0.3	0.7	0.7	0.5	0.3	0.7	0.7
a_{14}	0.3	0.3	0.5	0.8	0.5	0.3	0.7	0.7	0.5	0.5	0.7	0.7	0.5	0.5	0.8	0.8
a_{15}	0.5	0.5	0.7	0.7	0.5	0.3	0.7	0.7	0.5	0.3	0.7	0.7	0.5	0.3	0.7	0.7
a_{21}	0.3	0.5	0.8	0.8	0.7	0.3	0.7	0.8	0.3	0.3	0.7	0.8	0.5	0.5	0.5	0.7
a_{22}	0.3	0.3	0.7	0.8	0.7	0.5	0.5	0.7	0.5	0.3	0.7	0.7	0.3	0.7	0.8	0.5
a_{23}	0.5	0.7	0.5	0.7	0.5	0.5	0.5	0.8	0.3	0.3	0.7	0.8	0.5	0.3	0.7	0.8
a_{24}	0.5	0.5	0.5	0.7	0.5	0.5	0.5	0.8	0.5	0.3	0.7	0.7	0.5	0.3	0.7	0.8
a_{25}	0.3	0.3	0.7	0.8	0.5	0.5	0.5	0.7	0.3	0.3	0.7	0.8	0.5	0.5	0.7	0.8
a_{31}	0.7	0.5	0.5	0.8	0.3	0.3	0.7	0.8	0.5	0.3	0.7	0.7	0.5	0.5	0.7	0.8
a_{32}	0.3	0.3	0.7	0.8	0.5	0.5	0.5	0.7	0.5	0.5	0.7	0.7	0.5	0.3	0.7	0.8
a_{33}	0.7	0.5	0.8	0.8	0.3	0.3	0.7	0.8	0.5	0.3	0.7	0.7	0.3	0.3	0.5	0.7
a_{34}	0.7	0.7	0.7	0.8	0.5	0.7	0.7	0.7	0.3	0.3	0.7	0.8	0.5	0.5	0.7	0.8
a_{35}	0.7	0.7	0.8	0.8	0.3	0.7	0.7	0.7	0.5	0.5	0.7	0.5	0.5	0.5	0.7	0.8
a_{36}	0.5	0.7	0.5	0.7	0.5	0.7	0.7	0.7	0.3	0.3	0.7	0.8	0.3	0.3	0.5	0.7
a_{41}	0.5	0.5	0.7	0.8	0.5	0.5	0.5	0.8	0.7	0.7	0.8	0.8	0.3	0.7	0.8	0.5
a_{42}	0.5	0.7	0.8	0.8	0.5	0.7	0.7	0.7	0.7	0.8	0.8	0.3	0.3	0.3	0.5	0.7
a_{43}	0.3	0.5	0.7	0.8	0.5	0.3	0.7	0.8	0.5	0.3	0.7	0.7	0.5	0.5	0.7	0.8
a_{44}	0.3	0.3	0.8	0.7	0.5	0.5	0.5	0.8	0.5	0.3	0.7	0.7	0.5	0.5	0.7	0.8
a_{45}	0.5	0.5	0.7	0.7	0.5	0.5	0.7	0.7	0.3	0.3	0.7	0.8	0.3	0.7	0.8	0.5
a_{51}	0.5	0.5	0.7	0.7	0.5	0.5	0.5	0.8	0.5	0.3	0.7	0.7	0.5	0.5	0.7	0.8
a_{52}	0.5	0.7	0.7	0.7	0.5	0.5	0.7	0.7	0.3	0.3	0.7	0.8	0.3	0.7	0.8	0.5
a_{53}	0.3	0.3	0.5	0.7	0.3	0.5	0.5	0.8	0.5	0.3	0.7	0.7	0.3	0.7	0.8	0.5
a_{54}	0.3	0.5	0.5	0.7	0.3	0.5	0.7	0.7	0.3	0.5	0.7	0.7	0.5	0.3	0.7	0.8
a_{55}	0.3	0.5	0.7	0.7	0.5	0.5	0.5	0.8	0.5	0.5	0.7	0.7	0.5	0.3	0.7	0.8
a_{61}	0.2	0.3	0.8	0.8	0.5	0.3	0.7	0.8	0.3	0.5	0.7	0.7	0.3	0.3	0.5	0.7
a_{62}	0.5	0.5	0.7	0.8	0.5	0.3	0.7	0.8	0.3	0.5	0.7	0.7	0.3	0.7	0.8	0.5
a_{63}	0.3	0.3	0.5	0.7	0.3	0.5	0.5	0.8	0.5	0.3	0.7	0.7	0.3	0.3	0.5	0.7
a_{64}	0.2	0.3	0.5	0.7	0.3	0.3	0.7	0.8	0.5	0.3	0.7	0.7	0.3	0.3	0.5	0.7

Table 4

Decision matrix

	A_1	A_2	A_3	A_4
a_1	0.75	0.625	0.675	0.65
a_2	0.775	0.625	0.725	0.725
a_3	0.675	0.45	0.55	0.675
a_4	0.825	0.625	0.675	0.675
a_5	0.575	0.55	0.55	0.45
a_6	0.475	0.5	0.425	0.4
a_{11}	0.6	0.55	0.7	0.675
a_{12}	0.45	0.45	0.6	0.55
a_{13}	0.5	0.4	0.75	0.75
a_{14}	0.45	0.4	0.675	0.75
a_{15}	0.5	0.35	0.7	0.7
a_{21}	0.45	0.4	0.675	0.775
a_{22}	0.45	0.45	0.675	0.675
a_{23}	0.45	0.45	0.6	0.775
a_{24}	0.5	0.4	0.6	0.75
a_{25}	0.4	0.4	0.65	0.775
a_{31}	0.5	0.4	0.65	0.775
a_{32}	0.45	0.4	0.65	0.75
a_{33}	0.45	0.35	0.675	0.75
a_{34}	0.5	0.55	0.7	0.775
a_{35}	0.5	0.6	0.725	0.7
a_{36}	0.4	0.5	0.6	0.725
a_{41}	0.5	0.6	0.7	0.725
a_{42}	0.5	0.625	0.7	0.625
a_{43}	0.45	0.4	0.7	0.775
a_{44}	0.45	0.4	0.675	0.75
a_{45}	0.4	0.5	0.725	0.675
a_{51}	0.5	0.45	0.65	0.75
a_{52}	0.4	0.55	0.725	0.675
a_{53}	0.35	0.45	0.625	0.675
a_{54}	0.35	0.45	0.65	0.725
a_{55}	0.45	0.45	0.65	0.75
a_{61}	0.325	0.35	0.675	0.75
a_{62}	0.4	0.5	0.725	0.7
a_{63}	0.35	0.35	0.55	0.725
a_{64}	0.325	0.3	0.6	0.725

Decision matrix is as a starting table for the rest of the procedure.so at this stage the values of Shannon entropy such as P_{ij}, K, E_j, d_j and W_j are determined according to objective weights using Eqs. (2), (3), (4), (5). The results are shown in Table 5.With a little attention to the hierarchy of the environmental problem it can be seen two level of attributes, so we used AHP method for merged normalized weights of indexes to reach the one level. For this purpose, the normalized weight of first attribute that computed in the previous step was multiplied in its sub attribute, the weight of second attribute was multiplied in its sub attribute and so on up to 6th attribute. After doing so and integration of the coefficients, continued calculation only according to sub attributes. In the next step weighted integrate matrix calculated With respect to objective weight of entropy measure and Integrate matrix .The result of these calculation is shown in Table 6.

Table 5

Shannon entropy

	p_{ij}							
	A_1	A_2	A_3	A_4	k	E_j	d_j	w_j
a_1	0.2778	0.2315	0.2500	0.2407	0.7213	0.9983	0.0017	0.0733
a_2	0.2719	0.2193	0.2544	0.2544	0.7213	0.9979	0.0021	0.0923
a_3	0.2872	0.1915	0.2340	0.2872	0.7213	0.9904	0.0096	0.4110
a_4	0.2946	0.2232	0.2411	0.2411	0.7213	0.9960	0.0040	0.1729
a_5	0.2706	0.2588	0.2588	0.2118	0.7213	0.9970	0.0030	0.1307
a_6	0.2639	0.2778	0.2361	0.2222	0.7213	0.9972	0.0028	0.1198
a_{11}	0.2376	0.2178	0.2772	0.2673	0.7213	0.9968	0.0032	0.0387
a_{12}	0.2195	0.2195	0.2927	0.2683	0.7213	0.9942	0.0058	0.0687
a_{13}	0.2083	0.1667	0.3125	0.3125	0.7213	0.9755	0.0245	0.2916
a_{14}	0.1978	0.1758	0.2967	0.3297	0.7213	0.9756	0.0244	0.2907
a_{15}	0.2222	0.1556	0.3111	0.3111	0.7213	0.9740	0.0260	0.3104
a_{21}	0.1957	0.1739	0.2935	0.3370	0.7213	0.9736	0.0264	0.2400
a_{22}	0.2000	0.2000	0.3000	0.3000	0.7213	0.9855	0.0145	0.1322
a_{23}	0.1978	0.1978	0.2637	0.3407	0.7213	0.9806	0.0194	0.1764
a_{24}	0.2222	0.1778	0.2667	0.3333	0.7213	0.9810	0.0190	0.1728
a_{25}	0.1798	0.1798	0.2921	0.3483	0.7213	0.9694	0.0306	0.2787
a_{31}	0.2151	0.1720	0.2796	0.3333	0.7213	0.9780	0.0220	0.1956
a_{32}	0.2000	0.1778	0.2889	0.3333	0.7213	0.9766	0.0234	0.2082
a_{33}	0.2022	0.1573	0.3034	0.3371	0.7213	0.9685	0.0315	0.2805
a_{34}	0.1980	0.2178	0.2772	0.3069	0.7213	0.9888	0.0112	0.0993
a_{35}	0.1980	0.2376	0.2871	0.2772	0.7213	0.9926	0.0074	0.0655
a_{36}	0.1798	0.2247	0.2697	0.3258	0.7213	0.9830	0.0170	0.1510
a_{41}	0.1980	0.2376	0.2772	0.2871	0.7213	0.9926	0.0074	0.0881
a_{42}	0.2041	0.2551	0.2857	0.2551	0.7213	0.9949	0.0051	0.0609
a_{43}	0.1935	0.1720	0.3011	0.3333	0.7213	0.9726	0.0274	0.3287
a_{44}	0.1978	0.1758	0.2967	0.3297	0.7213	0.9756	0.0244	0.2922
a_{45}	0.1739	0.2174	0.3152	0.2935	0.7213	0.9808	0.0192	0.2301
a_{51}	0.2128	0.1915	0.2766	0.3191	0.7213	0.9852	0.0148	0.1456
a_{52}	0.1702	0.2340	0.3085	0.2872	0.7213	0.9828	0.0172	0.1694
a_{53}	0.1667	0.2143	0.2976	0.3214	0.7213	0.9769	0.0231	0.2273
a_{54}	0.1609	0.2069	0.2989	0.3333	0.7213	0.9717	0.0283	0.2778
a_{55}	0.1957	0.1957	0.2826	0.3261	0.7213	0.9817	0.0183	0.1799
a_{61}	0.1548	0.1667	0.3214	0.3571	0.7213	0.9521	0.0479	0.3118
a_{62}	0.1720	0.2151	0.3118	0.3011	0.7213	0.9797	0.0203	0.1325
a_{63}	0.1772	0.1772	0.2785	0.3671	0.7213	0.9646	0.0354	0.2307
a_{64}	0.1667	0.1538	0.3077	0.3718	0.7213	0.9501	0.0499	0.3250

Table 6

Normalization of decision matrix (x_{ij})

Decision matrix	***Objective weight***	***Normalization of decision matrix***

	A_1	A_2	A_3	A_4	W_{ij}	A_1	A_2	A_3	A_4
a_{11}	0.6	0.55	0.7	0.675	0.0028	0.0197	0.0181	0.0230	0.0222
a_{12}	0.45	0.45	0.6	0.55	0.0050	0.0148	0.0148	0.0198	0.0181
a_{13}	0.5	0.4	0.75	0.75	0.0214	0.0167	0.0134	0.0251	0.0251
a_{14}	0.45	0.4	0.675	0.75	0.0213	0.0151	0.0134	0.0226	0.0251
a_{15}	0.5	0.35	0.7	0.7	0.0228	0.0168	0.0117	0.0235	0.0235
a_{21}	0.45	0.4	0.675	0.775	0.0222	0.0150	0.0134	0.0226	0.0259
a_{22}	0.45	0.45	0.675	0.675	0.0122	0.0149	0.0149	0.0223	0.0223
a_{23}	0.45	0.45	0.6	0.775	0.0163	0.0149	0.0149	0.0199	0.0257
a_{24}	0.5	0.4	0.6	0.75	0.0159	0.0166	0.0133	0.0199	0.0249
a_{25}	0.4	0.4	0.65	0.775	0.0257	0.0134	0.0134	0.0218	0.0260
a_{31}	0.5	0.4	0.65	0.775	0.0804	0.0140	0.0112	0.0182	0.0217
a_{32}	0.45	0.4	0.65	0.75	0.0856	0.0126	0.0112	0.0182	0.0210
a_{33}	0.45	0.35	0.675	0.75	0.1153	0.0127	0.0099	0.0190	0.0211
a_{34}	0.5	0.55	0.7	0.775	0.0408	0.0139	0.0153	0.0194	0.0215
a_{35}	0.5	0.6	0.725	0.7	0.0269	0.0138	0.0166	0.0201	0.0194
a_{36}	0.4	0.5	0.6	0.725	0.0620	0.0111	0.0139	0.0167	0.0202
a_{41}	0.5	0.6	0.7	0.725	0.0152	0.0165	0.0198	0.0232	0.0240
a_{42}	0.5	0.625	0.7	0.625	0.0105	0.0165	0.0206	0.0231	0.0206
a_{43}	0.45	0.4	0.7	0.775	0.0568	0.0151	0.0135	0.0235	0.0261
a_{44}	0.45	0.4	0.675	0.75	0.0505	0.0151	0.0134	0.0226	0.0252
a_{45}	0.4	0.5	0.725	0.675	0.0398	0.0134	0.0167	0.0242	0.0226
a_{51}	0.5	0.45	0.65	0.75	0.0190	0.0166	0.0149	0.0216	0.0249
a_{52}	0.4	0.55	0.725	0.675	0.0221	0.0133	0.0183	0.0241	0.0224
a_{53}	0.35	0.45	0.625	0.675	0.0297	0.0117	0.0150	0.0209	0.0225
a_{54}	0.35	0.45	0.65	0.725	0.0363	0.0117	0.0151	0.0218	0.0243
a_{55}	0.45	0.45	0.65	0.75	0.0235	0.0150	0.0150	0.0216	0.0249
a_{61}	0.325	0.35	0.675	0.75	0.0373	0.0137	0.0147	0.0284	0.0315
a_{62}	0.4	0.5	0.725	0.7	0.0159	0.0164	0.0205	0.0297	0.0286
a_{63}	0.35	0.35	0.55	0.725	0.0276	0.0145	0.0145	0.0228	0.0301
a_{64}	0.325	0.3	0.6	0.725	0.0389	0.0137	0.0126	0.0253	0.0305

Finally, by using of Eqs. (۶), (۷), (۸) and (۹), the ranks of alternatives by MULTIMOORA method are shown in Table 7.

Table 7

Ranks of MULTIMOORA

	y_i^*	Ratio sistem	max[(Wj×rj)-(Wj×Xij*)]	Reference point	U_i^*	Full Multiplicative	final ranking

Alternative1	*0.3722*	*3*	*0.0298*	*3*	*0.3704*	*3*	*3*
Alternative2	*0.3633*	*4*	*0.0398*	*4*	*0.3595*	*4*	*4*
Alternative3	*0.5681*	*2*	*0.0084*	*2*	*0.5675*	*2*	*2*
Alternative4	*0.6329*	*1*	*0.0017*	*1*	*0.6317*	*1*	*1*

4.2. Comparisons

In this study we examined the alternatives of Malaysian firm and Based on final ranking from Table 7, alternatives ranked as follows: alternative 4 placed in the first priority, alternative 3 in the second place, alternative ۱ in the third place and alternative ۲ acquired the lowest importance. By comparing of this article and the paper of Rostamzadeh et al (2014) that solved this problem with fuzzy VIKOR method we achieve to difference between results as shown in Table 8.

Table 8

Comparing between final rank of this paper and previous paper (Rostamzadeh et al 2014)

	Final rank of MULTIMOORA method with objective weights	*Final rank of fuzzy VIKOR method*
Alternative1	*3*	*2*
Alternative2	*4*	*4*
Alternative3	*2*	*3*
Alternative4	*1*	*1*

Conclusion

Through selection the suitable supplier with environmental productions, business organizations can generate benefits to the environment, in the form of reduced waste and better resource utilization, in addition to economic benefits and cost reductions to the organizations.

Malaysia is moving forward to be an industrialized economy and shifted from material production to manufacturing. One of the main contributors for the environmental deterioration in Malaysian economy is manufacturing industry. In order to investigate and further understand GSS in Malaysia we choose one of the Malaysian leading firms in producing laptop hard disk and external hard drives. For this purpose, the new MULTIMOORA method and Shannon entropy are extended simultaneously. The MULTIMOORA method, which considers all attributes together with their relative importance, can provide a more accurate evaluation of alternatives and also we can decline human error by using of objective weights. Finally, the theory of dominance was used to evaluate and rank the alternatives. MULTIMOORA is composed of MOORA and of the Full Multiplicative Form of Multiple Objectives and in this way as up till now no other approach is known satisfying the precious six conditions of robustness and including three or more methods, MULTIMOORA becomes the most robust system of multiple objectives optimization under condition of support from the Ameliorated Nominal Group Technique and Delphi (Brauers and Zavadskas 2010a).

Future studies could involve other MADM methods to assess the GSCM of firms. How to assign orders after ranking all suppliers is another important issue that have many usage in inventory topics. In addition, fuzzy set theory is a strong tool which can deal with the uncertainty in case of subjective and vague information.

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