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ROUGH BEST-WORST METHOD FOR SUPPLIER SELECTION IN BIOFUEL COMPANIES BASED ON GREEN CRITERIA

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Research paper

Abstract. *This paper concerns with the integration of rough set theory with the Best Worst method to evaluate information system performance within supplier selection problem of biofuel companies. First, a set of main criteria and sub-criteria are collected and then to include uncertainty in decision making, rough set theory is employed. The rough best worst method is applied for weighing and supplier evaluation with respect to information system performance and environmental impacts. Further, a case study is conducted for biofuel company supplier selection and the results imply the effectiveness of the approach in tactical performance evaluation. The best criteria effective on the green supplier selection of ISs performance is determined to be Quality.*

Key words: *Biofuel company; Information systems; supplier selection; Rough Best Worst Method*

1. Introduction

Each organization performs specific and different activities and the cornerstone of each organization's activities is information. Therefore, a proper information system (IS) is essential to better manage the flow of information in the organization. (Sweis, 2015). An organization must be able to make the right decisions to survive and improve, these decisions must be based on the proper processing of information within the organization and this information must be stored, processed and analyzed in a database, (IS) is the database. (Salmeron et al., 2001). Information systems are

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made up of different parts, the most important of which are people and information. Secondly, software and hardware for storing information and communication networks for transfer and sending information within the organization (Kim & Lee, 2004).

Information Systems (IS) have become essential for all organizations to survive in today's technology-oriented environment. The number of companies and organizations are increasing which have invested widely in their IS infrastructures to present better services and to produce more valuable products. Anyway, it has been reasoned that not the (IS) solution but their utilization provides the competitive advantages (Zaied, 2012). Thus, because of the aforementioned functions and importance of IS, there are too many studies to emphasize the impact of ISs on other contexts like health and medicine (Sirintrapun & Artz, 2016; Sahay et al., 2018), transportation (Chen et al., 2017), energy (Sicilia et al., 2017), biology (Miller, 2017), education (Duman et al., 2015), environment (Anjana et al., 2018), geography (Wagner, 2017) and so many other disciplines. But one of the most important fields that the trace of ISs has been seen is the selection of green suppliers.

Supplier selection is a significant task for modern companies considering the evolution and development of information systems. With respect to environmental factors, green supplier selection is now a substantial challenge for policy and decision makers requiring collecting and processing mass information (Stevic et al., 2018; Matic et al., 2019; Stevic et al., 2020). It is necessary to make the supplier green. Accordingly, many researchers have addressed the various aspects of the green suppliers selecting and specifically worked on the evaluation and ranking of the effective criteria which are important in choosing green suppliers (Sureeyatanapas et al., 2018; Trautrims et al., 2017; Govindan et al., 2015). A comprehensive review on defining the relevant criteria effective of sustainable supplier selection problem was investigated in (Durmić, 2019).

Banaeian et al. (2018) have selected the green supplier using the fuzzy group decision making methods. Actually, they compared the result of three different techniques- TOPSIS, VIKOR and GRA methods in a fuzzy environment. Sureeyatanapas et al (2018) used the TOPSIS technique to simplify, choosing the suppliers based on the uncertain and unavailable information. Further, they used to the rank order centroid (ROC) method, to gather the weights of criteria to decrease the degree of subjectivity required from the decision makers. Yazdani et al. (2017) represented an integrated approach through considering different environmental performance factors to select the green supplier. Therefore, they used DEMATEL technique to determine the internal-relationships between the customer requirements and used Quality Function Deployment to make a central relationship matrix in order to identify degree of relationship between each pair of supplier selection criteria through the fuzzy extended AHP method. Gupta & Barua (2017) worked on the evaluation of supplier selection based on the green innovation abilities among the small and medium companies. Jauhar & Pant (2017) tended to develop an efficient system for sustainable supplier system through the combination of the Data envelop analysis (DEA) (Despić et al. 2019) with Differential evolution (DE) algorithm and further with Multi-Objective Differential Evolution (MODE) to overcome the inherent drawbacks of DEA. And finally, Hsu and Hu (2009) applied hazardous substance management (HSM) to select the supplier through the analytic network process (ANP). In their model, there were five criteria including

Procurement management, R&D management, Process management, Incoming quality control and Management system and 19 sub-criteria.

To obtain sustainable development, the integration of environmental, economic and social performance turned into the complex challenge for them. Because of above reasons, companies which buy their required materials and services from specific suppliers prefer to fulfill their expectations like low-cost, high-quality, short lead-time, and environmental criteria simultaneously (Đalić et al., 2020; Durmić et al., 2020; Lee et al., 2009 Fazlollahtabar & Kazemitash, 2021).

There are too many researches about green supplier selection (GSS) and ISs separately as two crucial parts of contemporary organizations, while except some limited studies in which (IS) is considered as the effective factor for GSS, there is not any research that investigate their relation. On the other hand, the second issue that is observed in the majority of the previous studies is using the complicated and time-consuming techniques like DEMATEL, AHP, ANP, DANP, TOPSIS and VIKOR to compute the needed requirements (Stevic et al., 2017).

Through the integrated Rough Best-Worst method (RBWM) the local and global weights of criteria and sub-criteria will be obtained by the experts' opinions. Next step is measuring the ISs' performance in association with green supplier selection which are gained by the experts' opinions. Ultimately, as a conclusion, companies could be able to focus on the specific IS or ISs which play the more important role in the green supplier selection processes and reinforce them if necessary. Because of the complex condition of today's business, all companies need to have a long-term relationship with their partners, and it’s the reason why all corporations should be aware and alert to identify and select the supply resources. Hence, it can show the extreme importance of supplier selection (Gurel et al., 2015).

The aim of this paper is evaluating of each single IS on the green suppliers’ selection and actually finding the level of effectiveness of each IS on the green supplier selection process. At the first step, it represents a localized GSS model including eight criteria and 31 sub-criteria of green supplier selection, based on the GSS experts' opinions (first problem). Then it illustrates the performance of every IS in relation with green supplier selection process using the RBWM (which computes the importance (weights) of every measure of GSS model) and performance item-scores (which represents the effectiveness and performance of ISs to select the green suppliers) of all existing ISs in a company (second and third problem).

2. Methods and materials

The purpose of this study is evaluating the performance of various ISs of a company, in green supplier selection process (GSS). This aim is met by MCDM methods to gain the global weights of green supplier selection' sub-criteria, and another technique to rank the ISs based on their performances in connection with the GSS. It looks necessary to show the steps of RBWM as the MCDM method and item-scoring to rank the ISs. Best-Worst method was proposed by Rezaei (2015) that in comparison with other decision-making methods, BWM needs less data, since full pairwise comparison is not required providing a more consistent result. That is the main reason why it's applied in this study. Also, rough set theory presented by

Pawlak (1982) is a mathematical tool to deal with uncertainty. Further, the rough set theory is appropriate in practice characterized by a small amount of data. After the presentation of the model, the procedures of problems solving are demonstrated as techniques, step by step. The conceptual model is depicted in Figure 1.

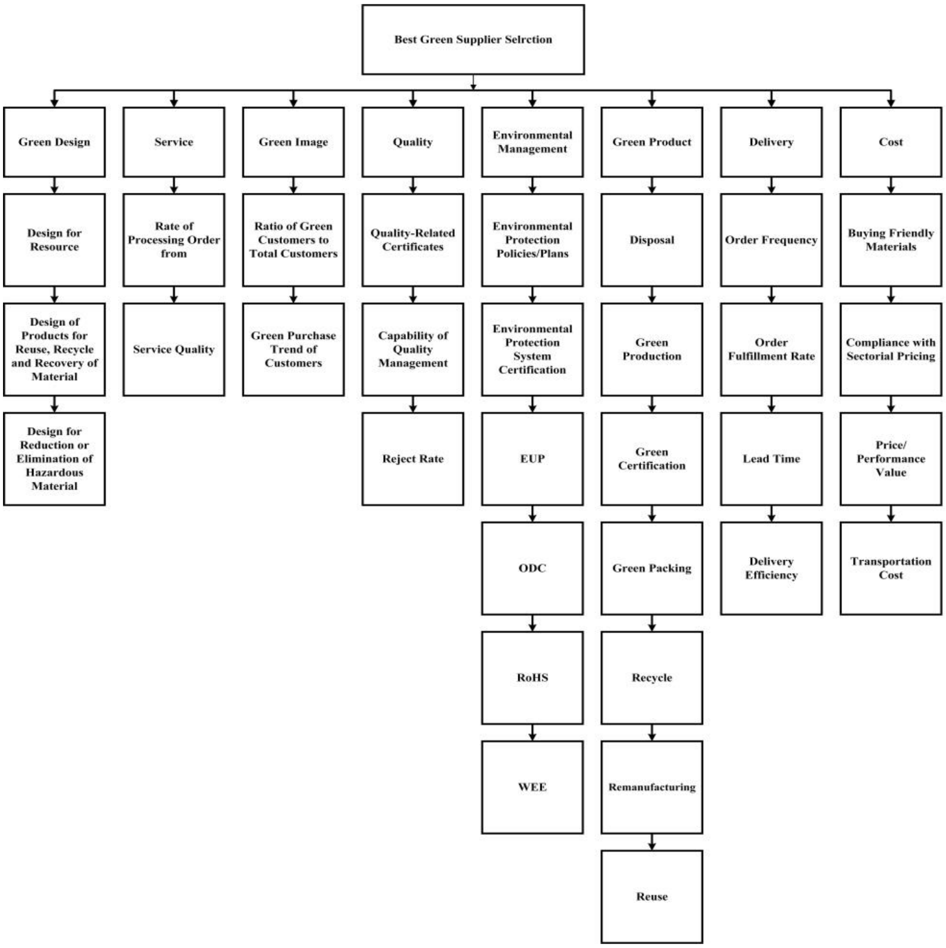

Figure 1. The conceptual model of green supplier selection's criteria and sub-criteria

As it's been pictured, there are three primitive operations in which 8 criteria and 31 sub-criteria have been selected by a number of organization's experts that have been extracted from the literature. Then, the integrated Rough BWM as the MCDM technique is started including three sub-sections in which the local weights of criteria, the local weights of sub-criteria and finally the global weights of sub-criteria are computed, respectively. As the last step, by determining the ISs' performances regarding the meeting the green supplier selection criterion, the scores of the ISs are calculated. Ultimately, based on the computed final scores of ISs, they are ranked. Through this way, the determined goals of study are achieved, or indeed, the mentioned problems of the study are solved.

2.1. Rough Best-Worst Method

Given that Best-Worst is a new but well-known method. The steps of the (RBWM) are briefly mentioned as follow:

Step 1. Determining the set of evaluation criteria.

Step 2. Determining the most and the least significant criteria.

Step 3. Determining the preferences of the most significant criterion (B) from set C;

$$A_B^e = (a_{B1}^e, a_{B2}^e, ..., a_{Bn}^e); 1 \le e \le m \tag{1}$$

Step 4. Repeat Step 3 for the worst criterion (W) and the set C ;

$$A_W^e = (a_{1W}^e, a_{2W}^e, ..., a_{nW}^e); 1 \le e \le m \tag{2}$$

Step 5. Determining the rough BO matrix for the average answers of the experts.

$$A_B^{*e} = [a_{B1}^m, a_{B2}^m, ..., a_{B1}^k; a_{B2}^1, a_{B2}^2, ..., a_{B2}^m; ...; a_{Bn}^1, a_{Bn}^2, ..., a_{Bn}^m]_{1\times n} \tag{3}$$

BO matrix $A_B^{*1}, A_B^{*2}, ..., A_B^{*m}$ is obtained from the sequence $RN(a_{Bj}^e)$. Then, the average rough sequence is computed using Equation (4).

$$RN(\overline{a}_{Bj}) = RN(a_{Bj}^1, a_{Bj}^2, ..., a_{Bj}^e) = \begin{cases} \overline{a}_{Bj}^L = \dfrac{1}{m}\sum_{e=1}^{m} a_{Bj}^{eL} \\ \overline{a}_{Bj}^U = \dfrac{1}{m}\sum_{e=1}^{m} a_{Bj}^{eU} \end{cases} \tag{4}$$

where, e represents the $e-th$ expert $(e = 1, 2, ..., m)$, $RN(a_{Bj}^e)$ represents the rough sequences. We thus obtain the averaged rough BO matrix of average responses:

$$\overline{A}_B = [\overline{a}_{B1}, \overline{a}_{B2}, ..., \overline{a}_{Bn}]_{1\times n} \tag{5}$$

Step 6. Determining the rough OW matrix of average expert responses.

$$A_W^{e*} = [a_{1W}^1, a_{1W}^2, ..., a_{1W}^m; a_{2W}^1, a_{2W}^2, ..., a_{2W}^m; ...; a_{nW}^1, a_{nW}^2, ..., a_{nW}^m]_{1\times n} \tag{6}$$

The sequence for the worst criterion is also computed.

$$RN(\overline{a}_{jW}) = RN(a_{jW}^1, a_{jW}^2, ..., a_{jW}^e) = \begin{cases} \overline{a}_{jW}^L = \dfrac{1}{m}\sum_{e=1}^{m} a_{jW}^{eL} \\ \overline{a}_{jW}^U = \dfrac{1}{m}\sum_{e=1}^{m} a_{jW}^{eU} \end{cases} \tag{7}$$

The average rough sequence is in hand:

$$\overline{A}_W = [\overline{a}_{1W}, \overline{a}_{2W}, ..., \overline{a}_{nW}]_{1\times n} \tag{8}$$

Step 7. Calculation of the optimal rough weight coefficients of the criteria $[RN(W_1), RN(w_2), \ldots, RN(w_n)]$ from set *C*.

$$\left|\frac{RN(w_B)}{RN(w_j)} - RN(a_{Bj})\right| and \left|\frac{RN(w_j)}{RN(w_W)} - RN(a_{jW})\right| \tag{9}$$

The previously defined limits will be presented in the following min-max model:

$$\min \max_j \left\{\left|\frac{RN(w_B)}{RN(w_j)} - RN(a_{Bj})\right|, \left|\frac{RN(w_j)}{RN(w_W)} - RN(a_{jW})\right|\right\}$$

$$s.t. \tag{10}$$

$$\begin{cases} \sum_{j=1}^{n} w_j^L \leq 1 \\ \sum_{j=1}^{n} w_j^U \geq 1 \\ w_j^L \leq w_j^U, \forall\, j = 1,2,\ldots,n \\ w_j^L, w_j^U \geq 0, \forall\, j = 1,2,\ldots,n \end{cases}$$

Model (10) is equivalent to the following model:

$$\min \xi$$

$$s.t.$$

$$\begin{cases} \left|\frac{w_B^L}{w_j^U} - \overline{a}_{Bj}^{U}\right| \leq \zeta; \left|\frac{w_B^U}{w_j^L} - \overline{a}_{Bj}^{L}\right| \leq \zeta \\ \left|\frac{w_j^L}{w_W^U} - \overline{a}_{jW}^{U}\right| \leq \zeta; \left|\frac{w_j^U}{w_W^L} - \overline{a}_{jW}^{L}\right| \leq \zeta \\ \sum_{j=1}^{n} w_j^L \leq 1 \\ \sum_{j=1}^{n} w_j^U \geq 1 \\ w_j^L \leq w_j^U, \forall\, j = 1,2,\ldots,n \\ w_j^L, w_j^U \geq 0, \forall\, j = 1,2,\ldots,n \end{cases} \tag{11}$$

where $RN(w_j) = [w_j^L, w_j^U]$ represents the optimum values of the weight coefficients, $RN(w_B) = [w_B^L, w_B^U]$ and $RN(w_W) = [w_W^L, w_W^U]$ represents the weight coefficients of the best and worst criterion respectively. By solving model (11) we obtain the optimal values of the weight coefficients for the evaluation criteria $[RN(w_1), RN(w_2), \ldots, RN(w_n)]$ and ξ^*.

For MCDM problems with more than one level of criteria such as this study, first of all, the weights for different levels should be obtained through the BWM steps. Then, the weights of different levels have to be multiplied to determine the global weights (Salimi & Rezaei, 2018). To show this process clearly, in Figure 2 the sub-steps of every single technique, the order of them and major techniques and finally the output of them are observed. In Figure 2, there are three main steps and their corresponding sub-steps from collecting the criteria and sub-criteria, purification, weighing, ranking and performance evaluation.

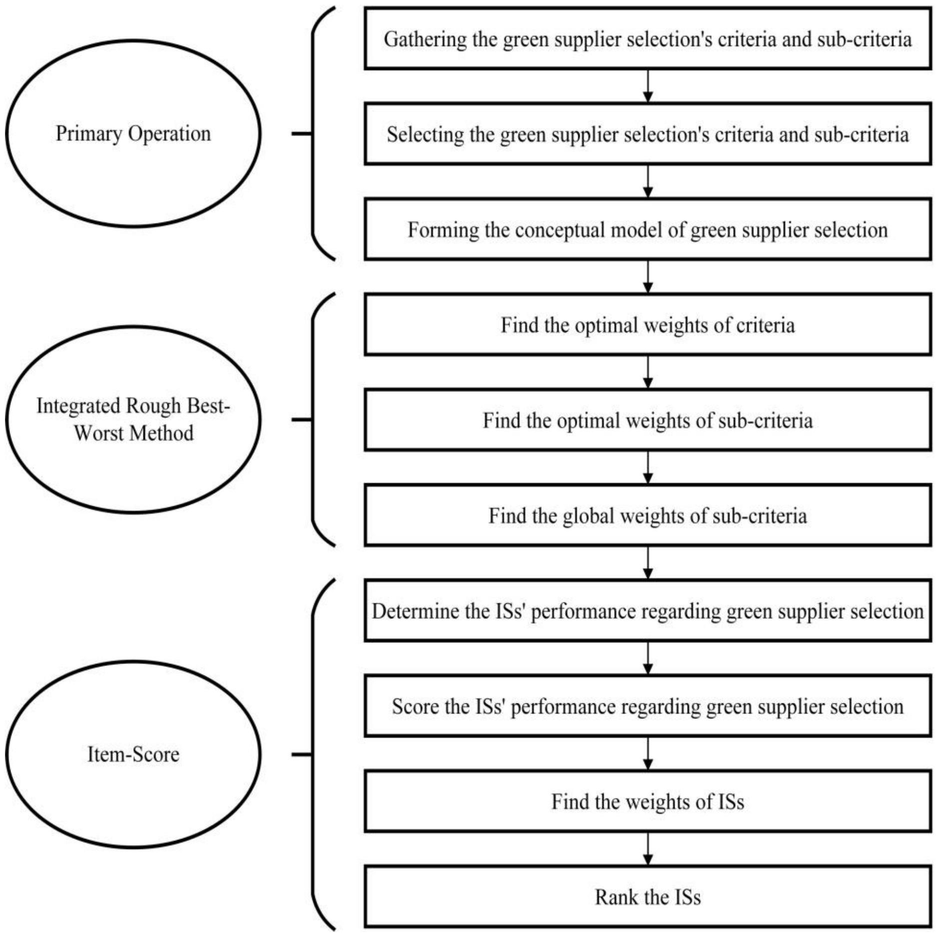

Figure 1. The proposed hybrid MCDM model

3. Case study

The proposed information system effectiveness model is tested to evaluate and rank the using ISs in Biofuel Company. To ensure sustainability, new energies have recently attracted a lot of attention. So far, the supply chain and the select of supplier of these energies have been presented from different perspective. Biofuel, as one of the types of renewable energy, has a significant amount of use in this type of fuel because this type of fuel can be obtained from the recycling of other materials. The optimal weights are obtained through the expert opinions, while the scores, are computed based on the data from a survey among the 100 experts of ISs.

3.1. Weights of green supplier selection measures:

To obtain the weights of the criteria and sub-criteria, the comparison data needed for BWM is gained by interviewing with 20 experts in the field of green supplier selection, individually. Next, the weights of criteria and their sub-criteria are determined using BWM. Finally, the overall weights for the criteria and sub-criteria are computed by using the aggregation (based on a simple average). Table 1 shows the aggregated weights of the eight main criteria and the sub-criteria based on the inputs which are provided by the experts. Based on these results, design for reduction or elimination of hazardous materials as the third sub-criteria of the Green Design (weight = 0.1176) has the most weight which illustrates the most effectiveness role which sub-criteria could play with respect to the green supplier selection, though the Green Product has the most amount of weight among the criteria.

3.2. Green supplier selection item-scores of ISs:

As the first step, in a survey among the 50 ISs' experts of the mentioned firm, their opinions about the ISs performance and effectiveness with respect to the selection of green suppliers are provided, in which the respondents rated the 10 most common ISs level based on items from different GSS determined sub-criteria on a nine-point Likert type scale. And finally, the last operation of this step is that the experts' opinions for every single sub-criterion are averaged.

Table 1. Global rough weights for criteria and sub-criteria.

Criteria	Local weights	Sub-criteria	Local weights	Global weights of sub-criteria
Green design	[0.1729,0.1786]	Design for resource efficiency	[0.0878,0.0890]	[0.0149,0.0162]
		Design of products for reuse, recycle, and recovery of material	[0.2336,0.2388]	[0.0405,0.0417]
		Design for reduction or elimination of hazardous materials	[0.6731,0.6774]	[0.1169,0.1181]
Service	[0.0978,0.1107]	Rate of processing order	[0.2323,0.2342]	[0.0230,0.0238]
		Service quality	[0.7655,0.7679]	[0.0757,0.0793]
Green Image	[0.0155,0.0451]	Ratio of green customers to total customers	[0.8406,0.8429]	[0.0285,0.0307]
		Green purchase trend of customers	[0.1573,0.1596]	[0.0047,0.0063]
Quality	[0.1233,0.1339]	Quality-related certificates	[0.6303,0.6324]	[0.0828,0.0854]
		Capability of quality management	[0.2520,0.2550]	0.0327,0.0345
		Reject Rate	[0.1141,0.1157]	[0.0149,0.0156]
Environmental Management	[0.0884,0.1057]	Environmental Protection policies/plans	[0.1463,0.1481]	[0.0136,0.0155]
		Environment Protection System	[0.1091,0.1123]	[0.0101,0.0122]

		Certification		
		EUP	[0.4438,0.4460]	[0.0429,0.0457]
		ODC	[0.0525,0.0566]	[0.0048,0.0070]
		RoHS	[0.1133,0.1162]	[0.0110,0.0119]
		WEE	[0.1275,0.1293]	[0.0120,0.0340]
Green Product	[0.2409,0.2519]	Cost of Component Disposal	[0.1367,0.1381]	[0.0326,0.0353]
		Green Production	[0.2909,0.2944]	[0.0716,0.0728]
		Green Certifications	[0.1176,0.1201]	[0.0287,0.0303]
		Green Packaging	[0.1328,0.1375]	[0.0321,0.0349]
		Recycle	[0.1266,0.1285]	[0.0301,0.0327]
		Remanufacturing	[0.0414,0.0439]	[0.0100,0.0120]
		Reuse	[0.1451,0.1487]	[0.0359,0.0365]
Delivery	[0.1198,0.1271]	Order Frequency	[0.0857,0.0872]	[0.0103,0.0206]
		Order Fulfillment Rate	[0.2518,0.2524]	[0.0296,0.0318]
		Lead time	[0.1802,0.1819]	[0.0215,0.0232]
		Delivery efficiency	[0.4783,0.4826]	[0.0575,0.0590]
Cost	[0.0891,0.0903]	Buying Friendly Materials	[0.0825,0.0848]	[0.0052,0.0096]
		Compliance with Sectorial Pricing	[0.1407,0.1440]	[0.0112,0.0145]
		Performance Value/Price	[0.5254,0.5291]	[0.0466,0.0479]
		Transportation Cost	[0.2460,0.2467]	[0.0214,0.0223]

There are two different ways that it's possible to evaluate and investigate the performance of ISs to support the GSS process based on. In one hand, it's available to assess the performance of ISs through their overall aggregations and rankings, so that the more overall aggregation, the better ranking. For instance, MIS possesses the most overall aggregation (6.8800), so it’s the first information system as the best one. It means that it has the most effectiveness and best performance in related with GSS. And after that, ERP (6.7986), CRM (6.6319), SCM (6.5756), DSS (6.3210), EC (6.1931), BI (6.0805), KM (5.8977), OAS (5.0642) and TPS (4.7460) are placed in the following ranking respectively. On the other hand, it's possible to investigate the ISs based on their scores and rankings in every single part (the aggregation of every criterion). For example, MIS performance as the best one among the 10 mentioned ISs, is placed as the first one in the Quality criteria, the second one in three criteria, including Environmental Management, Green Product and Cost criteria, the third one in the Green Design criteria, the fourth one in the Green Image criteria and the sixth one in the Service criteria. As this way evaluates the performance of ISs in every GSS criteria, it’s the best one to compare two different ISs which have close overall aggregations (not exact the same). For example, there is a slight difference between the overall aggregation of MIS and ERP which are 6.8800 and 6.7986 respectively, thus in the eyes of someone, it couldn't explain the superiority of MIS rather than ERP clearly. Therefore, they rely on the second way to describe the differences and performance of every one in comparison with others. In this case, ERP's performance (rank or actually aggregated score) is better than MIS in three criteria in consist of Service, Delivery and Green Product in which the ERP has the best performance, while in other criteria MIS has better scores and rankings.

The developed method in this paper can be employed to compare the GSS with respect to ISs performance; this way the position of ISs in the final ranking can be considered.

4. Conclusions

This research tried to take into account the green supplier selection indices to allow each IS to determine its overall weight. Moreover, ISs can improve their green supplier selection performance based on the importance of each perspective. More precisely, if an IS wants be prominent in Green Product as the most important criteria in GSS process, it should focus on and invest in Green Production, since the given information in Table 1 display that the Green Production level is the most important item from a Green Product perspective. Therefore, the criteria and sub-criteria effective on the GSS with respect to the corresponding weights leading to improve the IS performance of green supplier selection. As such, these results can help ISs enhance their overall performances.

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