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GREEN SUPPLIER SELECTION BASED ON THE INFORMATION SYSTEM PERFORMANCE EVALUATION USING THE INTEGRATED BEST-WORST METHOD

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Abstract. *Information Systems (IS) have become crucial for all the organizations to survive in contemporary technology-oriented environment. Consequently, the number of companies and organizations which have invested widely in their IS infrastructures to present better services and to produce higher value products is increasing. On the other hand, nowadays, because of the increase of governmental rules and serious requirements of more people in the case of environmental protection, it seems necessary for all the enterprises to follow these regulations if they want to survive in the global markets. However, what is at issue here is not just the companies' agreement with the environmental laws; in addition, they should apply some strategies to decrease the negative environmental impacts of their products in some countries. Thus, the aforementioned arguments are the reasons for the compulsory use of the green supplier selection (GSS) in all firms. Considering the mentioned contents, the purpose of this study is representation of the relation between ISs and GSS as two vital components of firms in a novel way which has not been done before. Actually, it shows the ISs' performance or effectiveness to select the green suppliers taking into account the different levels of importance of GSS measures (including eight criteria and 31 sub-criteria), using a multi-criteria decision-making method called Best Worst Method (BWM) to identify the weights (importance) of GSS measures and compute the GSS performance of 10 ISs in a company using the data gathered in a survey from ISs' experts.*

Key Words: *Information systems, Green supplier selection, Best worst method, Significance scoring*

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1. INTRODUCTION

Information Systems (IS) as an academic field, first of all, attracted research interest in the 1960s [1]. That was the time when the applied computer science emerged which in its turn aimed at the design and implementation of data processing applications. Information Systems (IS) have become essential for all the organizations to survive in today's technology-oriented environment. The number of companies and organizations which have invested widely in their IS infrastructures to present better services and to produce better value products is increasing. This rise has led to the question of how much those systems add value to the business or to the organization compared to their investment. The role of information systems (IS) in providing business a competitive edge has been the topic of so many discussions recently. The conclusion is that not the IS solution but their utilization is what provides competitive advantages. Thus, because of the aforementioned functions and importance of IS, there are too many studies which show a big role the ISs play in relation to the other fields such as health care and medicine [2, 3], transportation [4], energy [5], biology [6], education [7], environment [8, 9, 10], geography [11] 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.

Nowadays, because of the increase of governmental rules and serious requirements of more people in the case of environmental protection, it seems necessary for all the enterprises to follow these regulations if they want to survive in the global market. However, what is at issue here is not just the companies' agreement with the environmental laws; in addition, they should apply some strategies to decrease the negative environmental impacts of their products in some countries. Therefore, to gain sustainable development, the integration of environmental, economic and social performance turned into a complex challenge for them. Because of the above reasons, the companies working on this matter buy their required materials and services from specific suppliers which can simultaneously fulfill their expectations like low-cost, high-quality, short lead-time and environmental criteria,. On the one hand, by considering the aforementioned information about the importance of ISs, green supplier selection, and the direct impact of ISs on the selection of green suppliers so that ISs effect on numerous other factors that impress selecting process in modern organizations, and, on the other hand, because of the financial restriction in both fields, a good recognition of their relation could be helpful to the reduction of costs and their effectiveness. Inasmuch as there are various applied ISs in companies by different tasks, each of them could have individual influence on selecting process.

Hence, the purpose of this study is the evaluation of the impact of IS on the green supplier selection and actually finding the level of effectiveness of each IS on the green supplier selection process. Therefore, this paper is going to represent a great framework to support its goals. At first, it examines other research projects, literatures and experts' opinion to gather the most important criteria and sub-criteria which have effects on the green supplier selection. Then, through the Best-Worst method (BWM), the local and global weights of criteria and sub-criteria will be obtained by the experts' opinions. The next step is measuring the ISs' performance in association with green supplier selection which is gained by the experts' opinions. Ultimately, as a conclusion, companies could focus on the specific IS or ISs which play a more important role in the green supplier selection processes and reinforce them if necessary.

2. LITERATURE REVIEW

Because of the expansion of people awareness about the environmental changes and applying of the compulsory green rules which have been exerted by governments, approximately all companies should obey, to survive in these competitive markets. Therefore, there are so many studies that deal with suppliers. For instance [12] represented a green supplier selection model based on the emission of CO2 which is produced through the transportation and production processes by considering three models to maximize the total profits and the green factors, and minimize the CO2 emissions. Banaeian et al. [13] in their research 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. Kuo, et al. [14] developed a green supplier selection model in the electronic industry by using the new hybrid MCDM method including DANP and VIKOR. Environmental Permits and Reporting, Pollution Prevention and Resource Reduction, Hazardous Substances Wastewater and Solid Waste, Air Emissions and Product Content Restrictions were considered as Environmental dimension, while Company Commitment, Management Accountability and Responsibility, Legal and Customer Requirements, Risk Assessment and Risk Management, Improvement Objectives, Training, Communication, Worker Feedback and Participation, Audits and Assessments and Documentation and Records determined as Management systems dimension.

Govindan et al., [15] reviewed all the research studies related to the green supplier from 1997 till 2011, in order to find the most common used approaches for evaluating and selecting the green supplier as well as the most common criteria which have been considered in this case and finally identifying the existent limitations. For instance, their study illustrated that the fuzzy single approach has been the most repetitive applied technique and the environmental management system has been the most selected criteria. Jain et al. [16] presented an initiated decision-making process to evaluate the suppliers based on the green criteria in which there are a Carbon Market Sensitive (CMS) and a green decision-making approach based on Data Envelopment Analysis (DEA) called CMS–GDEA. Their applied model in one case displayed that the “Pay Up” factor from carbon trading adds a new dimension to competition among suppliers and increases overall supply chain profitability; finally, they encourage companies to follow the green rules. Gupta et al. [17] worked on the evaluation of supplier selection based on the green innovation abilities among small and medium companies. In their study, there are three different methodological phases including; selection of green innovative criteria through literature review and interviews with decision-makers, ranking of selection criteria using a novel best worst method (BWM) and ranking of suppliers with respect to selection criteria weights obtained in phase two using fuzzy TOPSIS. In another research, Galankashi et al. [18] prioritized the criteria which affect the green supplier selection through the fuzzy analytical network process. Hamdan and Cheaitou [19] by using the combination of three techniques including AHP, fuzzy TOPSIS and multi-objective optimization approach, evaluated the supplier selection and the order allocation based on the green criteria that led into the flexible model.

The aim of [20] was to implement hybrid Grey theory-MARCOS methods for decision-making regarding the selection of suppliers in the Libyan Iron and Steel Company (LISCO). This hybrid model was divided into two phases: the first consists of determining the weights of the criteria that contribute to decision-making, which has been done using the Grey theory, and the second phase consists of selecting the best supplier from among six suppliers, which has been completed using the MARCOS model. Durmić et al. [21] performed supplier selection to achieve sustainability, taking into account all aspects: economic, social and environmental criteria. For this purpose, a combined FUCOM - Rough SAW approach has been used. Pamucar [22] provided a multi-criteria decision-making that combines interval grey numbers and normalized weighted geometric Dombi-Bonferroni mean operator to address the situations where attribute values take the form of interval grey numbers under uncertain information.

There are too many research studies about GSS and ISs separately as two crucial parts of contemporary organizations, while, except for some limited studies in which IS is considered as an effective factor for GSS, there is no research that points to the relation between them. This is the exact reason why this paper works on. 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, although there are so many studies which have mentioned their weak points. And it is the exact reason that why this paper utilized a novel MCDM technique (BWM) that is simpler and more practical, functional and usable.

3. Statement of the Problem

On the one hand, in this contemporary business world, there is not any enterprise which would be able to compete and even survive without having close relations with outer partners; that is exactly the point where the supplier chain management (SCM) arises from and wants to optimize the information flow exchanges among all participating factors in the supplier chain. Thus, the more effective supplier chain, the more competitive the advantages; so, because of the complex condition of today's business, all companies need to have a long-term relationship with their partners – this is the reason why all corporations should be aware and alert to identify and select supply resources. Hence it can show the extreme importance of supplier selection. As mentioned, by considering the growth of worldwide awareness of environmental protection, green production has become an important issue for almost every manufacturer and will determine his long-term sustainability. Thus, the green factors have changed the face of supplier selection. Because of the growth of governmental rules and serious and increasing demands of the mass in the case of environmental protection, it seems crucial for all companies to follow these regulations if they want to remain in the market. However, the deal of companies with these environmental laws is not enough; they should apply some strategies and policies to reduce the negative environmental impacts of their products. Consequently, to obtain sustainable development, the integration of environmental, economic and social performance has turned into a complex challenge for them. Because of the above reasons, companies consider various criteria to assign their required materials to suppliers.

On the other hand, ISs have become vital for all of companies to survive and remain in today’s technology-oriented market. The number of companies and firms which have invested widely in their IS infrastructures to present better services and to produce better value products is increasing. Nowadays in majority of the companies, there are some practical and basic information systems which have changed from competitive advantage to necessity and as it was expressed, because of the significance of the flow of information in the supplier chain, the information systems emerge as one of the most effective factors in the green supplier selection.

But there are some barriers and even problems which have played hidden roles in selection of the best green supplier and never have been paid attention to: 1- There is no localized green supplier selection model for the examined industry. 2- Although all the evidence shows the impact of ISs on green supplier selection, there is not any study showing the impact of different types of ISs on criteria and sub-criteria of the green supplier selection which leads to the evaluation of the ISs' effectiveness regarding green supplier selection. 3 -there is not any research that indicates which IS plays the most important role in connection with selecting the green supplier. As the aim of this paper is evaluating of each single IS in effecting on the green suppliers' selection and actually finding the level of effectiveness of each IS on the green supplier selection process, it could cope with the aforementioned problems. 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 WBM (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 existent ISs in a company (second and third problem).

After the presentation of the model, the procedures of problems solving are demonstrated as techniques, step by step.

As shown above, there are three primitive operations in which 8 criteria and 31 sub-criteria have been selected by 12 number of organization experts that have been extracted from the principal literature. Then, the BWM as the MCDM technique consists of 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 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. In this way, the determined goals of study are achieved, or indeed, the mentioned problems of the study are solved.

4. Methods and Materials

The purpose of this study is to evaluate the performance of various ISs of a company, in the green supplier selection process (GSS). As this aim is met by a MCDM method to gain the global weights of the 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 BWM as the MCDM method and item-scoring to rank the ISs. The proposed conceptual model is depicted in Fig. 1.

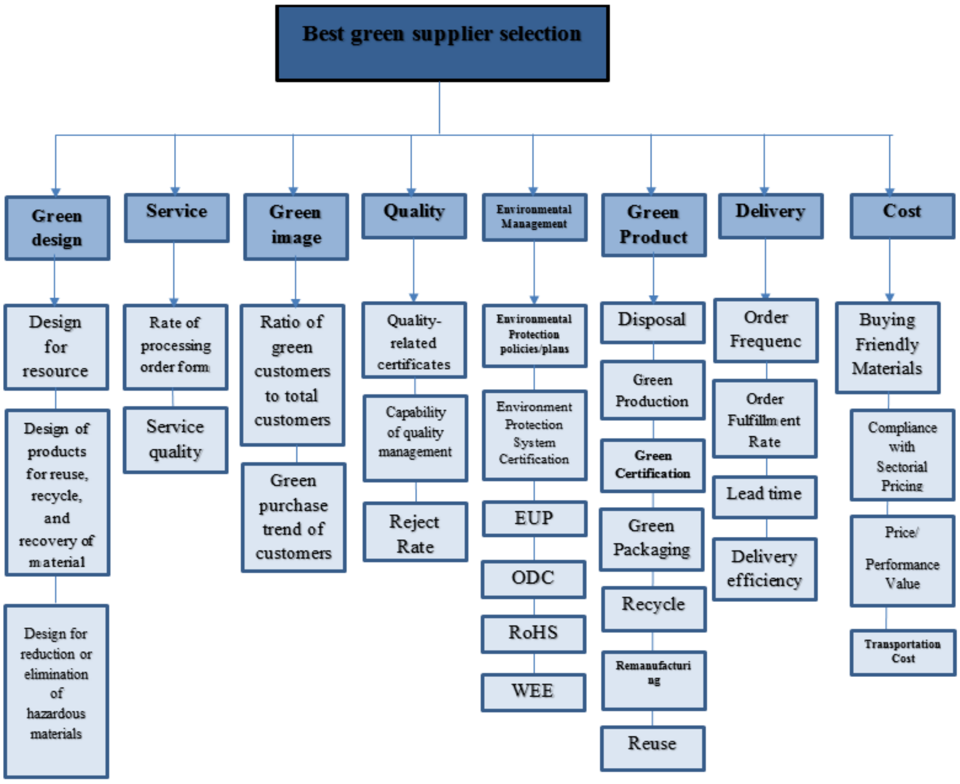

Fig. 1 The conceptual model of green supplier selection's criteria and sub-criteria

4.1 Best Worst Method

As discussed above, because the green supplier selection is a multi-criteria concept, to measure it, we should use MCDM method. MCDM methods allow considering multiple criteria with different weights. There are several MCDM methods that have been applied in literature but in this study, a newly developed MCDM method called best worst method (BWM) is used [23, 24]. In comparison with similar existing MCDM methods, BWM needs less data as it does not require a full pairwise comparison matrix, and its results are more consistent due to its structured pairwise comparison system; that is the main reason why it is applied in this study. Further, it is perceived by the decision-makers as simple and very close to the way they judge and reason while making decision. Subsequently, the steps of the BWM are described briefly as follows:

Step 1 - Determine a set of decision criteria. In this study, the criteria are presented in two levels as criteria and sub-criteria.

Step 2 - Determine the best (*B*) (e.g., the most desirable, the most important) and the worst (*W*) (e.g., the least desirable, the least important) decision criteria based on the decision-maker(s)/expert(s) opinion.

Step 3 - Determine the preference of the best decision criterion (*B*) over all the other decision criteria, using Linguistic 9-point scale for pairwise comparison for best worst method (Table 1). The result is a best-to-others (*BO*) vector as follows:

$$A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})$$

whereas a_{Bj} represents the preference of *B* over *j* and as expected a_{BB} =1.

Table 1 Linguistic scale for pairwise comparison for best worst

Linguistic scale	Equally important	Equal to moderately more important	Moderately more important	Moderately to strongly more important	Strongly more important
Equivalent number	1	2	3	4	5
Linguistic scale	Strongly to very strongly more important	Very strongly more important	Very strongly to extremely more important	Extremely more important	-
Equivalent number	6	7	8	9	-

Step 4 - Determine the preference of all the decision criteria over the worst criterion (*W*), using Linguistic 9-point scale for pairwise comparison for best worst method (Table 1), which results in the others-to-worst (*OW*) vector as follows:

$$A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})^T$$

whereas a_{jW} represents the preference of *j* over *W* and, as expected, a_{WW} =1.

Step 5 - Find the optimal weights (W_1^*, W_2^*,..., W_n^*). The optimal weights should be determined so that the maximum absolute differences $\{|W_B - a_{Bj}W_j|, |W_j - a_{jW}W_w|\}$ for all *j* is minimized, or equivalently;

$$min\ max\{|W_B - a_{Bj}W_j|, |W_j - a_{jW}W_w|\}$$

subject to

$$\sum_j W_j = 1$$

$$W_j \geq 0\ for\ all\ j \tag{1}$$

Problem (2) is equal to the following linear problem:

$$min\ \xi^L$$

subject to

$$|W_B - a_{Bj}W_j| \leq \xi^L\ for\ all\ j$$

$$|W_j - a_{jW}W_w| \leq \xi^L\ for\ all\ j$$

$$\sum_j W_j = 1$$

$$W_j \geq 0\ for\ all\ j \tag{2}$$

Solving the above model (2), optimized weights (W_1^*, $W_2^*, \ldots, W_n^*$) and the optimal objective function value ξ^L will be gained. For this model ξ^L can be directly considered as an indicator of the consistency of the comparisons (here we do not use Consistency Index, so that values close to zero show a high level of consistency of the pairwise comparisons provided by the decision-maker(s)/expert(s).

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 [25].

4.2 Evaluation of ISs by item-scoring

Using the BWM, the optimal weights of the criteria (W_1^*, $W_2^*, \ldots, W_n^*$) are calculated. Now the IS_i so that ($i=1,\ldots,m$) with respect to its green supplier selection measurement j, so that ($j=1,\ldots,n$) is obtained. Therefore, x_{ij} using, for instance, a 7-point scale (very low to very high), to determine the overall green supplier selection's performance of IS_i. For the GSSi the following formula:

$$GSS_i = \sum_{j=1}^{n} W_j * x_{ij}\,, \quad and\ i = 1,2,\ldots,m. \tag{3}$$

5. CASE STUDY

The proposed information system effectiveness model is tested to evaluate and rank the use of ISs in Emdad-Khodro Company. Saipa automotive group as one of the two biggest automotive companies of Iran decided to found Emdad-khodro firm as its subdivision company with the purpose of responding to relief requirements of their customers to complete the after-sale services network in 2003. To achieve the planned goals and be adaptable in the contemporary market compared with the rivals, it has implemented some management systems such as Quality Management Systems based on ISO9001, Complaints Management System based on ISO10002, Training Management System based on ISO10015 and Risk Management System based on ISO31000 and information systems which are explained in detail in the following.

According to the functions of the determined model, it is obviously necessary to specify using ISs in the company and start the analysis. Based on the record of company, there have existed windows-based ISs for 15 years; although almost all the web-based systems which have been implemented since 2011, have replaced the windows-based ISs as a major platform, there are some minor parts which still use windows-based systems. Web-based systems work in the field of employees, customers and representations. Finally, mobile ISs have been applied since 2014 which actually cover the whole activities related to company.

However, there are 10 active information systems such as transaction processing system (TPS), electronic commerce (EC), customer relation management (CRM), decision support system (DSS), management information system (MIS) and office automation system (OAS), knowledge management (KM), supply chain management (SCM), enterprise resource planning (ERP) and business intelligence (BI). But there is not any research of their performance and effectiveness in the case of GSS; this is an opportunity to try to do that and that is the reason why it is selected as the case study.

Here, firstly, the conceptual framework of GSS is presented which adopted from the literature to measure ISs' performance as a multi-criteria decision-making problem, as shown in Fig. 1. In fact, it is a visualization of Table 2, including eight perspectives (main criteria) to measure ISs' performance (green design, Service, Green Image, Quality, Environmental Management, Green Product, Delivery and Cost), as well as the items (sub-criteria) of each perspective (three sub-criteria to measure Green Design perspective, two sub-criteria to measure Service perspective, two sub-criteria to measure Green Image perspective, three sub-criteria to measure Quality perspective, six sub-criteria to measure Environmental Management perspective, seven sub-criteria to measure Green Product perspective, four sub-criteria to measure Delivery perspective and ultimately four sub-criteria to measure Cost perspective). As mentioned before, to measure the ISs' performance of a firm, it is necessary to have two sets of data: the optimal weight for the criteria (W_1^*, $W_2^*, \ldots,$ W_n^*) and the ISs' score on various sub-criteria, x_{ij}. 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. In the following sections, gaining weights is described firstly, and then the scores and, finally, the use of the equation (3) to calculate the overall performance of each IS.

5.1 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 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 2 shows the aggregated weights of the eight main criteria and their items (sub-criteria) based on the inputs which are provided by the experts. The consistency ratios are all close to zero ranging from 0 to 0.17, which shows a high reliability of the results. As can be seen from Table 2, Column 2, Green Product (weight = 0.2468) criteria is the most important green supplier selection perspective, followed by Green Design perspective (weight = 0.1741), Quality perspective (weight = 0.1330), Delivery perspective (weight = 0.1219), Service perspective (weight = 0.1008), Environmental Management perspective (weight = 0.0994), Cost perspective (weight = 0.0894) and Green Image perspective (weight = 0.0346) which is by far the least important perspective of the green supplier selection based on the experts' opinion.

The global weights of the sub-criteria (the multiplication of the weights of the sub-criterion by the weights of the main criterion to which it belongs) are calculated in Table 2, Column 5. 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 a sub-criterion could play with respect to the green supplier selection, though the Green Product has the most amount of weight among the criteria.

Table 2 Relative importance (weights) of the criteria and sub-criteria

Criteria	Local weights	Sub-criteria	Local weights	Global weights of sub-criteria
Green design	0.1741	Design for resource efficiency	0.0885	0.0154
		Design of products for reuse, recycle, and recovery of material	0.2360	0.0411
		Design for reduction or elimination of hazardous materials	0.6755	0.1176
Service	0.1008	Rate of processing order	0.2336	0.0235
		Service quality	0.7664	0.0773
Green Image	0.0346	Ratio of green customers to total customers	0.8418	0.0291
		Green purchase trend of customers	0.1582	0.0055
Quality	0.1330	Quality-related certificates	0.6316	0.0840
		Capability of quality management	0.2535	0.0337
		Reject Rate	0.1149	0.0153
Environmental Management	0.0994	Environmental Protection policies/plans	0.1472	0.0146
		Environment Protection System Certification	0.1106	0.011
		EUP	0.4448	0.0442
		ODC	0.0543	0.0054
		RoHS	0.1151	0.0114
		WEE	0.1280	0.0127
Green Product	0.2468	Cost of Component Disposal	0.1376	0.034
		Green Production	0.2922	0.0721
		Green Certifications	0.1190	0.0294
		Green Packaging	0.1351	0.0333
		Recycle	0.1272	0.0314
		Remanufacturing	0.0427	0.011
		Reuse	0.1463	0.0361
Delivery	0.1219	Order Frequency	0.0866	0.011
		Order Fulfillment Rate	0.2520	0.0307
		Lead time	0.1810	0.0221
		Delivery efficiency	0.4804	0.0586
Cost	0.0894	Buying Friendly Materials	0.0837	0.0075
		Compliance with Sectorial Pricing	0.1422	0.0127
		Performance Value/Price	0.5277	0.0472
		Transportation Cost	0.2463	0.0220

5.2 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 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 3). Then, the aggregated GSS performance of the various ISs with respect to different perspectives (Columns 2, 4, 6, 8, 10, 12, 14, 16), as well as the ranking of each IS based on each perspective (Columns 3, 5, 7, 9, 11, 13, 15, 17) are computed (Table 4). Furthermore, the overall aggregated GSS performance of each IS based on items of all perspectives and overall ranking based on this aggregated number are shown in Table 4, Columns 18 and 19, respectively. Assigning weights to different items (sub-criteria) and to different perspectives (main criteria) produces significant differences in the overall (and perspective-based) GSS score of different ISs.

Table 3 Green supplier selection item-scores of 10 ISs

	Green Design			Service		Green Image		Quality		
	G_1	G_2	G_3	S_1	S_2	G_1	G_2	Q_1	Q_2	Q_3
TPS	3.67	4.31	4.52	7.16	3.09	5.07	4.14	4.59	5.56	5.14
OAS	3.54	3.78	4.63	7.86	3.96	5.26	4.39	4.48	6.21	5.49
MIS	6.53	7.09	6.9	5.87	5.48	6.79	7.54	7.87	7.79	7.19
DSS	5.92	6.73	7.08	6.16	4.97	6.66	6.92	6.67	6.86	6.97
EC	5.01	6.19	4.74	8.27	6.07	7.51	6.74	6.13	5.45	4.77
ERP	8.69	4.99	7.21	7.12	5.13	5.12	6.59	6.19	7.37	4.16
SCM	8.15	4.96	7.59	7.66	5.34	4.88	5.9	5.79	7.03	4.99
CRM	5.79	8.14	6.68	7.7	7.93	7.99	8.43	7.28	7.84	6.18
KM	4.91	5.61	5.63	6.02	5.18	5.64	6.47	6.47	5.72	5.45
BI	6.13	7.17	5.13	6.59	6.11	7.26	7.09	6.52	5.02	6.16

	Environmental Management						Green Product						
	E_1	E_2	E_3	E_4	E_5	E_6	G_1	G_2	G_3	G_4	G_5	G_6	G_7
TPS	4.31	4.62	4.09	4.18	3.75	3.62	2.42	4.39	4.73	5.29	6.14	5.92	6.27
OAS	4.57	5.26	3.68	4.3	4.12	3.79	3.59	4.79	5.02	5.4	6.52	6.3	6.55
MIS	7.7	7.41	5.58	5.73	7.96	5.8	6.23	8.08	7.28	7.58	7.91	7.44	7.4
DSS	6.23	6.52	4.78	6.14	6.47	6.26	5.89	7.53	6.46	6.79	6.57	6.81	6.78
EC	6.69	6.17	6.59	6.93	6.85	7.47	6.44	6.12	7.26	5.55	5.59	6.85	6.62
ERP	7.85	7.55	5.18	5.63	7.69	7.15	7.13	7.71	7.93	8.32	8.21	8.06	7.79
SCM	8.1	7.29	5.14	5.22	6.67	7.81	7.61	6.18	7.89	5.14	6.83	7.14	7.34
CRM	5.94	6.26	4.49	5.06	4.53	5.34	5.7	5.18	6.23	6.67	7.43	6.99	6.76
KM	5.63	5.2	5.01	5.29	5.37	5.76	6.09	7.03	5.35	5.81	6.86	7.16	7.51
BI	5.15	5.51	5.37	5.71	6.11	4.39	6.43	7.1	5.03	6.32	5.94	6.05	6.16

	Delivery				Cost			
	D_1	D_2	D_3	D_4	C_1	C_2	C_3	C_4
TPS	3.13	5.48	5.77	4.69	5.6	5.47	6.71	5.4
OAS	3.47	6.23	6.12	5.66	6.07	5.9	6.8	5.81
MIS	6.27	5.69	6.49	6.17	6.35	7.83	6.55	6.79
DSS	6.14	4.18	5.83	5.67	5.71	6.79	6.97	5.54
EC	6.77	6.17	6.16	6.47	7.01	7.35	7.49	7.74
ERP	6.52	7.38	7.59	7.53	8.14	5.15	6.73	5.18
SCM	6.63	7.09	8.13	7.79	7.57	6.58	7.76	5.12
CRM	7.19	5.57	5.88	7.63	5.04	7.12	6.37	4.65
KM	5.12	4.25	5.27	6.92	5.44	6.03	6.34	4.3
BI	6.38	4.27	6.43	6.51	6.56	6.52	6.86	5.95

According to Table 4, there are two different ways in which it is possible to evaluate and investigate the performance of ISs to support the GSS process it is based on. On the one hand, it is 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 is the first information system as the best one.

Table 4 Green supplier selection performance of 10 ISs.

	BI	KM	CRM	SCM	ERP	EC	DSS	MIS	OAS	TPS
Green Design	5.6999	5.5616	6.9458	7.0189	6.8171	5.1069	6.8947	6.9121	4.3329	4.3952
Rank	6	7	2	1	5	8	4	3	10	9
Service	6.2221	5.3762	7.8763	5.882	5.5949	6.5839	5.248	5.5711	4.871	4.0408
Rank	3	7	1	4	5	2	8	6	9	10
Green Image	7.2331	5.7713	8.0596	5.0414	5.3526	7.3882	6.7011	6.9087	5.1224	4.9229
Rank	3	6	1	9	7	2	5	4	8	10
Quality	6.0984	6.1627	7.2956	6.0124	6.2559	5.8014	6.707	7.7716	5.0346	4.8991
Rank	6	5	2	7	4	8	3	1	9	10
Environmental Management	5.3313	5.2749	5.0436	6.3357	6.4006	6.7193	5.6437	6.4047	4.0841	4.0866
Rank	6	7	8	4	3	1	5	2	10	9
Green Product	6.3269	6.5908	6.173	6.7338	7.8298	6.2602	6.8152	7.5151	5.2772	4.8444
Rank	6	5	8	4	1	7	3	2	10	9
Delivery	5.9198	5.7926	6.756	7.5747	7.4156	6.3673	5.3642	6.1156	5.6972	4.9495
Rank	6	7	3	1	2	4	9	5	8	10
Cost	6.562	5.718	5.941	6.462	6.241	7.491	6.486	6.774	6.366	6.117
Rank	3	10	9	5	7	1	4	2	6	8
Overall	6.081	5.898	6.632	6.576	6.799	6.193	6.321	6.88	5.064	4.746
Rank	7	8	3	4	2	6	5	1	9	10

It means that it has the most effectiveness and best performance in relation 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 is 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 is the best one to compare two different ISs which have close overall aggregations (not exactly 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 could not clearly explain the superiority of MIS over ERP. 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 consisting of Service, Delivery and Green Product in which the ERP has the best performance, while in the other criteria MIS has better scores and rankings. Based on the given information in Table 4, CRM as the third ranked IS according to the overall aggregated has the best performance (score) in two perspectives including Service and Green Image. In the same situation, SCM as the fourth effective IS, possesses two first ranks in Green Design and Delivery criteria and finally as the sixth effective IS in relation to GSS, EC is placed as the first one in Environmental Management and Cost criteria, even though it is mentioned as the most effective IS, it is the best just in one perspective.

5.3 Managerial implications

Our results possess critical managerial implications. Firstly, positioning is an important participator in GSS performance because it provides an acceptable basis for ISs to compare their GSS performance to that of other ISs. Secondly, regardless of positioning, having knowledge about the importance of different GSS perspectives, and about the different items of each perspective, GSS related managers can formulate more effective strategies to improve their GSS performance based on their own purposes. The presented methodology in this study has been used to determine the weight and importance of different aspects of overall IS performance. This gives managers a chance to have a good view of critical aspects of performance and allows them to focus more on the important aspects. This study has considered GSS performance from eight perspectives which have been used in the literature. As such, GSS related managers can enhance GSS performance of their ISs, based on their purposes. According to this study's findings, Green Product criteria of GSS play the most important role in enhancing GSS performance, which means that, if the Green Product aspects should be the purpose of a firm, focusing more on the Green Production measurements will improve the firm’s GSS performance, as this measure is the most important of all Green Product measurements. Furthermore, for other criteria, this study also determines the sub-criteria which are the most important and how the green supplier selection related managers can improve their firms’ GSS performance based on different goals.

6. CONCLUSIONS

Although there are so many research studies of the GSS and information systems separately, and there are some studies which refer to the IS as one of the criteria or sub-criteria to select the green supplier, there is not any study to evaluate and investigate the direct relation between these two vital elements of the disciplines that are related to firms and identify the performance of every IS and its effectiveness with respect to GSS, though ISs have been turned into the necessity of all companies. Actually, the advantages of this evaluation is that understanding the importance of different GSS measures helps managers spend more time, money, energy and resources on the critical aspects on their objectives. The methodology proposed in this paper can be utilized in two general contexts: (1) as a systematic way to compare the GSS performance of a set of ISs. In this context, based on the results of similar evaluation and the determined purposes of the companies, the position of every ISs and their superiorities could be found. Plus, the results can also be used by other stakeholders, for instance allowing venture capitalists to identify the best investment opportunities; (ii) as a systematic way to specify the importance (weight) of different criteria and measurements for a single IS. In this context, the results can be used by the firm in question to formulate effective GSS strategies that are adjusted to its competitive strategy.

6.1 Findings

The results show the importance of taking into account the weights of different green supplier selection items, which allows each IS to determine not only its overall aggregation position (Quality), while at the same time providing accurate information of its position with regards to each criterion. Moreover, ISs can improve their green supplier selection performance based on the importance of each perspective. For example, if SCM wants to maintain or improve this ranking, it should focus more on the Ratio of green customers to total customers which has the highest importance among all items of Green Image perspective, in which SCM is located in the ninth place (see Table 2). Moreover, in some situations, where the aim is not to compare the position of ISs with each other or such a comparison is impossible to make, knowing the importance of each criterion and their sub-criteria can help ISs to improve their performance based on their main objectives. 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 2 shows that the Green Production level is the most important item from a Green Product perspective. In addition, by changing their objectives, ISs can change their strategy and invest more in specific perspective(s) in line with their new purposes. For instance, if an IS has thus far concentrated more on the Quality perspective, focusing more on Green Design aspects can help the IS improve its GSS by looking at Design for reduction or elimination of hazardous materials since the results in Table 2 show that it is the most important measurement within the Green Design perspective. Therefore, regardless of knowing its position relative to other firms, based on the weight of the sub-criteria of different GSS perspectives (Table 2), an IS can recognize which sub-criteria(s) can improve or change its green supplier selection performance from each perspective. As such, these results can help ISs enhance their overall performances.

6.2 Limitations

The proposed methodology utilized to solve the defined problem, has no limitations and can be used for solving any MCDM problem. What makes this paper stand out from others is that it is the first time that one study evaluates the direct relation of ISs and GSS individually, and, on the other hand, it is the first time that a study measures the GSS performance of ISs in which the contributions of ISs in related to GSS are computed. But, like every other study, interviewing numerous experts in every part of methodology took the time out of standard range. Plus, gathering the data through the questionnaire from 100 experts is too hard and time-consuming, and consequently, the calculations and operations of their opinions are so complicated.

6.3 Future research direction

In the future research, it could be possible to measure the same thing with different GSS model including different criteria and sub-criteria. As another suggestion for future, it is possible to change the first or second part of this relation, for instance, the evaluation of online ISs' performance in GSS.

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