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Green supplier selection using fuzzy Delphi method for developing sustainable supply chain

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A B S T R A C T

The objective of this paper is to examine the determinants of the supplier selection process with green consideration. Thus, this analysis gathers a collection of factors from established literature of green supplier selection (GSS), including seven categories and 58 attributes. The objective of this research is to classify the key factors which are presented as qualitative information. Fuzzy logic rules are used to transform qualitative expert knowledge into numerical data. Then, we adopt the Delphi method (DM) to filter and rate unneeded factors according to their relevance. The results indicate 24 important factors for the GSS process. Five categories are included: Performance and technology ability, Environmental management, Pollution control, Quality and Service. The most significant factors are recognized as green research and development, eco-design, green image, green packaging and remanufacturing. Finally, the debate is held on the basis of the findings and future research are also recognized and stated.

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1. Introduction

Supply chain management (SCM) very relevant at the moment and an imperative strategy for businesses to efficiently provide their consumers with secure, scalable and cheaper goods and to sustain their competitiveness (Ben Mabrouk et al., 2020). Sustainability awareness has greatly increased today, changing the way products and services are manufactured and distributed to their clients and consumers (Omri and Ben Mabrouk, 2020). Indeed, the concept of green SCM has appeared, gaining popularity among scholars and practitioners alike (Yazdani et al., 2017; Micheli et al., 2020). For the purpose of greening the entire supply chain, supplier selection is of great importance in decision making in GSCM (Li et al., 2019). Green supply chain firms are not only held liable for their own actions but also for their partners' adverse environmental effects (Micheli et al., 2020). Furthermore, buyer supplier relationship plays a crucial role for organizations in preserving their success in terms of strategy (Ben Mabrouk, 2020). Supplier selection therefore is of great importance to every participant in the SCM system. The traditional selection of suppliers is defined as the process by which firms find, assess and contract with suppliers. However, with the adoption of government regulations in recent years, and growing concern for environmental protection and sustainable development, more focus should be paid to environmental criteria and the evaluation of possible suppliers by integrating green factors into the selection process (Ghadimi et al., 2017, Gupta et al., 2019). Green supplier selection (GSS) is a decision-making process with multi-criteria and one of the most significant stages of SCM due to its long-term environmental impacts. Green supplier selection considerations in the supply chain are classified into many categories including: Cost, Quality, Delivery, Service, Pollution control, Performance and technology ability, Environmental management and Strategic alliance and technique capability. Differences in definitions and

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evaluations of linguistic preferences arise from uncertainty and lack of information, because linguistic preferences are assumed to represent opinions.
This research aims to use the fuzzy rules based on FDM approach to classify GSS variables for removing qualitative knowledge and subjective preferences. A small number of studies have discussed linguistic preferences explaining GSS attributes. Therefore, the objective of this study is to define relevant and reliable factors based on qualitative knowledge regarding GSS attributes. The main contribution of our proposed study is some three folds. First, Collecting a valid and reliable set of GSS factors. Second, understanding the factors to GSS practice. Third, by using the FDM method that is used in other domain applications, the GSS variables are then sorted out, not in the sense of determining the GSS sense.

The remainder of the paper is structured as follows. Section 2 presents a review of the relevant studies of the GSS. In section 3, the proposed FDM approach is explained. Results and discussion of the data analysis carried out using the FDM are detailed in Section 4 and 5. Finally, managerial implications and future directions are discussed in Section 6.

2. Literature Review

GSS has gained significant interest in the fields of academia and business, with the enhancement of environmental protection and environmental awareness. A large number of techniques have recently been proposed for GSS. There are two key classes: single-model approaches and combined-model approaches. For the single-model approaches, Almasi et al. (2019) developed a mathematical model to select sustainable supplier and order allocation in the context of automotive manufacturing. Arabsheybani et al. (2018) applied a fuzzy multi-objective optimization model based on the ratio analysis (fuzzy MOORA) for GSS. Dobos and Vörösmarty applied a data envelopment analysis (DEA) to study the GSS problem using the common weight analysis (CWA) method. Ghadimi et al. (2017) used a Fuzzy Analytical Network Process (FANP) to assess the composite weight of the different parameters in the GSS decision model. Laosirihongthong et al. (2017) developed a Fuzzy Analytical Hierarchical Process (FAHP) method in a green supplier selection issue for South East Asian cement manufacturing. Li et al. (2019) extended TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) through cloud model theory that incorporates the benefit of controlling randomness uncertainty in studying the GSS.in order to solve a two -stage GSS problem, Mohammed (2019) developed an integrated approach based on fuzzy TOPSIS-possibilistic multi objectives model. Rabbani et al. (2017) expanded a method focused on interval-valued fuzzy sets (ITFSs) into a potential statistical reference point scheme under uncertainty in a GSS for an Iranian home appliance manufacturer.

Table 1
The recent studies on GSS using MCDM methods

No	Author(s)/year	S/C model	Methodology applied	Application domain
1	Almasi et al. (2019)	SM	Mathematical model	automotive manufacturing in Iran
2	Arabsheybani et al. (2018)	SM	Fuzzy-MOORA	Iran electronic industry
3	Bakeshlou et al. (2014)	CM	ANP, DEMATEL and MOLP	-
4	Dobos and Vörösmarty (2014)	SM	DEA	-
5	Ecer (2020)	CM	AHP and IT2FSs	Home appliance manufacturing
6	Fallahpour et al.(2016)	CM	DEA and GAP	-
7	Ghadimi et al (2017)	SM	Fuzzy ANP	Automotive industry
8	Gupta et al. (2019)	CM	AHP, TOPSIS and FST	Automotive industry in India
9	Kilic, H. S., & Yalcin, A. S. (2020)	CM	Two-phase GP and IF-TOPSIS	Manufacturing industry in Turkey
10	Laosirihongthong et al. (2019)	SM	Fuzzy-AHP	Cement manufacturing in South-East Asia.
11	Li et al. (2019)	SM	TOPSIS with Rough Set Theory	Photovoltaic energy in china
12	Lu, Z., et al., (2018)	CM	Cloud model, possibility degree and fuzzy AHP	Straw biomass industry in china
13	Mohammed (2019)	SM	Fuzzy-TOPSIS	
14	Oroojeni et al. (2020)	CM	BWM and fuzzy TOPSIS	Iron and steel manufacturing in Khouzestan
15	Rabbani et al. (2019)	SM	Interval-Valued Fuzzy Sets	home appliance manufacturer in Iran
16	Sen et al. (2017)	SM	Fuzzy MULTIMOORA	-
17	Thongchattu and Siripokapiram(2010)	CM	AHP and ANN	-
18	Wu et al. (2019)	CM	BWM and fuzzy VIKOR	-
19	This paper	SM	fuzzy Delphi method	-

Single- model approaches (SM), combined-model approaches (CM)

As for the combined-model approaches, Bakeshlou et al. (2014) developed a hybrid approach that combines Multi-Objective Fuzzy Linear Programming (MOLP), Fuzzy Laboratory Testing and Evaluation Method (DEMATEL) to explain the interrelationship between criteria, and Fuzzy Analytical Network Process (ANP) to provide criteria weights for their dependencies. Ecer (2020) expanded analytical hierarchy (AHP) model under interval type-2 fuzzy environment (IT2FAHP) to overcome uncertainty and vagueness in the case of home appliance manufacturing. Fallahpour et al. (2014) proposed a GSS model by applying a DEA and genetic programming approach (GPA). Gupta et al. (2019) combined fuzzy-AHP and TOPSIS with two other techniques: Multi-Attributive Border Approximation Area Comparison (MABAC), Weighted Aggregated Sum-Product Assessment (WASPAS) to establish an integrated approach for the assessment of GSS. Kilic and Yalcin (2020) proposed a synthetical approach for GSS by combining two-phase fuzzy goal programming (GP) integrated with Intuitionistic Fuzzy TOPSIS. Lu et al. (2018) provided a GSS decision framework by integrating a Fuzzy AHP and a cloud model, and a degree of possibility is proposed to direct the optimal solutions. Oroojeni and Darvishi (2020) introduced a new decision-making system based on Best-Worst Method (BWM) and Fuzzy TOPSIS. BWM is used to rank the various GSS criteria in the multi-criteria decision-making problem and the Fuzzy TOPSIS is used to rank different suppliers based on weighted criteria for choosing the most effective suppliers. BWM is combined with fuzzy VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) in the integrated methodology presented by Wu et al. (2019) to select suppliers under environment considerations. Thongchattu and Siripokapirom (2010) developed a GSS model through the integration of artificial neural network (ANN) with AHP, enabling decision makers to structure complex issues.

3. Proposed research framework

This research proposes a framework of potential green supplier selection in sustainable supply chain by using the FDM. This approach is implemented in two steps. in the first step, the study aims to identify key factors to green supplier selection from the literature as well as through consultation from domain experts. The experts who participated in the earlier stage of the interview discussions were approached via emails. In First round FDM, experts are asked to confirm the validity of each factor by YES or NO. Next, the second round FDM is performed to screen and rate necessary attributes based on their significance. Following steps are involved in the proposed approach: (i) GSS factors are identified by reviewing the previous works. These identified variables are then completed through a group discussion provided by experts. (ii) first round FDM is used for the refinement of the critical variables. (iii) The second round FDM is performed to improve measurement reliability and precision. The questionnaire is repeated from the first round test, in order to obtain the opinion of the experts for the best-performing assessment. In order to produce the final list of GSS factors, the FDM process is repeated and the important factors are analyzed to provide specific implications for improving GSS efficiency.

3.1 Fuzzy Delphi method (FDM)

The DM is a formal communication strategy or approach that was originally conceived as a systematic, interactive predictive process based on an expert panel. DM is based on expert opinion survey with three features: nameless response, iteration and monitored input, and ultimately statistical response by group. The conventional Delphi approach has always suffered from low convergence expert opinions, high execution costs, and the risk that unique expert opinions will be filtered out by opinion organizers. The FDM is a synthesis of the standard Delphi approach with fuzzy set theory (FST) to resolve some of the Delphi Consensus panel uncertainty and to improve the imprecision and ambiguity of DM (Ishikawa et al., 1993). Degree of membership is used to determine each participant's membership function. FDM may be used to assess the significance of parameters, as well as to screen main criteria. The FDM has been used very successfully in various applications such as; sustainable ecotourism indicators (Ocampo et al., 2018), evaluating hydrogen production technologies (Chang et al., 2011), safety performance indicators (Ma et al., 2011), identifying and analyzing of barriers in reverse logistics (Bouzon et al., 2016), recognizing of critical factors affecting on university-industry collaboration (Mosayebia et al., 2020), Six Sigma readiness indicators (Keliji et al., 2018), business web site content personal presentation (Kardaras et al., 2013).

The Fuzzy Delphi Algorithm Procedure involves the following steps:

- Identifying an adequate selection for the fuzzification of language expressions
- Fuzzy aggregation of deflected values
- Defuzzification
- Fuzzy aggregation of fuzzified values

The importance of attribute j is evaluated by expert i as $v = (x_{ij};\ y_{ij};\ z_{ij})$, $i = 1, 2, 3, \dots, n; j = 1, 2, 3, \dots, m$; furthermore, weight v_j of element j is $v_j = (x_j\ ;\ y_j\ ;\ z_j\ )$, where $x_j = \min(x_{ij})$, $y_j = \left(\prod_1^n y_{ij}\ \right)^{1/n}$, and $z_j = \max(x_{ij})$. In FDM algorithm, a suitable fuzzy range for the fuzzification of the linguistic expressions of the respondents should be developed first. Therefore, triangular fuzzy spectrum for five-point likert scale on the significance of criteria is used in this study. Therefore, the triangular fuzzy numbers (TFNs) and linguistic concepts are converted into linguistic values, as presented in Table 1.

Table 1
Linguistic terms and the corresponding triangular fuzzy number of five-point likert scale

Linguistic terms	*Very Unimportant*	*Unimportant*	*Moderately Important*	*Important*	*Very Important*
Corresponding TFNs	(0, 0, 0.25)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1.0)	(0.75, 1.0, 1.0)

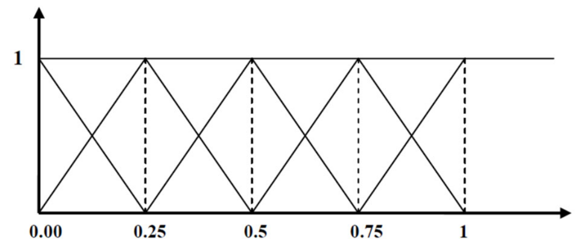

Fig 1. Triangular fuzzy membership functions

In order to produce the value of the convex combination F_j, we use the following equation (wu et al., 2016) by adopting α cut to generate a result:

$$u_j = z_j - \alpha(z_j - y_j), l_j = x_j - \alpha(y_j - yx_j), j = 1, 2, 3, \ldots, m \tag{1}$$

α is equal to 0.5 for the common situation, and ranged between 0 and 1 depending on expert appreciation. We use the following equation in order to generate the precise value of F_j:

$$F_j = \int (u_j, l_j) = \beta(u_j + (1 - \beta)l_j), \tag{2}$$

where β is used to define a decision-maker 's degree of positivity and to strike a balance between the expert group 's fundamental judgments. Then, $\delta = \sum_{i=1}^{n}(F_j/n)$ is the filtering threshold for the critical attributes. Attribute j is accepted if $F_j \geq \delta$, otherwise it must be discarded.

4. Results

58 factors based on eight initial attribute categories are suggested in this research (Appendix 1). Tables 2–6 displays the results of FDM (rounds 1 and 2) along with their weight and threshold for filtering out attributes. The initial list of GSS variables (Appendix 1) will be analyzed in round 1, based on the expertise and judgement of the experts. After review, Table 2 is obtained according to the corresponding TFNs of linguistic terms, presented in table 1. The implementation of the FDM is used to improve the significant factors with the threshold ($\delta = 0.399$), as shown in table 2. 39 factors are accepted in this round, which are later retitled, as presented in Table 3. This list is employed as input in the second round. then, along with the eight categories proposed, the findings of round 1 are repeated to experts for redefinition. Table 4 displays the FDM- round 2 for category. Based on the obtained results, there are five categories having a level of importance above the threshold ($\delta = 0.446$), and are ranked as important categories from the first to the fifth; these include Performance and technology ability (C1), Environmental management (C2), Pollution control(C3), Quality(C4), Service (C5). Table 5 designates the degree of expert acceptance for a refined list of factors from Table 3 in which 24 factors ($\delta = 0.412$) are approved, while the other 15 factors are refused. Table 6 displays the final results, with the top five variables ranked from the most to the least important being Green research and development (A15), Eco-design (A18), Green image (A16), Green packaging (A13), Flexibility (A8).

Table 2

Factors screening out after FDM round 1

Initial attributes	l_j	u_j	F_j	Decision A/R	Initial attributes	l_j	u_j	F_j	Decision A/R
A1	0.147	0.728	0.401	A	A31	0.029	0.846	0.430	A
A2	0.106	0.769	0.411	A	A32	0.138	0.737	0.403	A
A3	0.461	0.961	0.365	R	A33	0.097	0.778	0.413	A
A4	0.254	0.754	0.314	R	A34	0.258	0.992	0.560	A
A5	0.057	0.932	0.452	A	A35	0.000	0.500	0.25	R
A6	0.351	0.851	0.338	R	A36	0.290	0.960	0.552	A
A7	0.161	0.661	0.290	R	A37	0.049	0.924	0.450	A
A8	0.042	0.917	0.448	A	A38	0.038	0.837	0.428	A
A9	0.258	0.992	0.560	A	A39	0.062	0.813	0.422	A
A10	0.290	0.960	0.552	A	A40	0.145	0.730	0.401	A
A11	0.254	0.754	0.314	R	A41	0.625	1.00	0.656	A
A12	0.006	0.881	0.439	A	A42	0.083	0.792	0.417	A
A13	0.083	0.792	0.417	A	A43	0.028	0.903	0.444	A
A14	0.000	0.500	0.25	R	A44	0.197	0.697	0.299	R
A15	0.197	0.697	0.299	R	A45	0.152	0.652	0.288	R
A16	0.097	0.778	0.413	A	A46	0.266	0.984	0.558	A
A17	0.094	0.781	0.414	A	A47	0.147	0.728	0.401	A
A18	0.095	0.780	0.414	A	A48	0.054	0.821	0.424	A
A19	0.000	0.500	0.25	R	A49	0.095	0.780	0.414	A
A20	0.062	0.813	0.422	A	A50	0.049	0.924	0.450	A
A21	0.147	0.728	0.401	A	A51	0.106	0.769	0.411	A

A22	0.152	0.652	0.288	R	A52	0.000	0.500	0.25	R
A23	0.380	0.880	0.345	R	A53	0.331	0.831	0.333	R
A24	0.126	0.749	0.406	A	A54	0.000	0.500	0.25	R
A25	0.077	0.952	0.457	A	A55	0.197	0.697	0.299	R
A26	0.266	0.984	0.558	A	A56	0.145	0.730	0.401	A
A27	0.106	0.769	0.411	A	A57	0.228	0.728	0.307	R
A28	0.000	0.500	0.25	R	A58	0.341	0.909	0.540	A
A29	0.062	0.813	0.422	A				**0.399**	
A30	0.073	0.802	0.419	A					

A/R: Accepted/Rejected

Table 3
Results after FDM round 1

Initial attributes	Renamed	Attributes	Initial attributes	Renamed	Attributes
A1	A1	Product price	A32	A21	Inventory of hazardous substances
A2	A2	Logistics cost (manufacturing and transportation)	A33	A22	waste water
A5	A3	Buying friendly materials	A34	A23	Green packaging
A8	A4	Process improvement	A36	A24	Remanufacturing
A9	A5	Quality assurance	A37	A25	Reuse
A10	A6	Quality related certificates	A38	A26	Green research and development
A12	A7	low toxicity	A39	A27	Green image
A13	A8	Order processing speed	A40	A28	Validity of clean technique
A16	A9	Delivery time	A41	A29	Eco-design
A17	A10	Delivery reliability	A42	A30	Environment-related certificates
A18	A11	Delivery delays	A43	A31	Energy Using Product
A20	A12	Credible delivery	A46	A32	Green process planning
A21	A13	Responsiveness	A47	A33	Waste electrical electronic equipment
A24	A14	Flexibility	A48	A34	low carbon measures
A25	A15	Warranty	A49	A35	Environmental competencies
A26	A16	Capability of technology support	A50	A36	Environmental regulations
A27	A17	Material substitution for green materials	A51	A37	Willingness to Information Sharing
A29	A18	Energy consumption	A56	A38	Technological development
A30	A19	Use of harmful material	A58	A39	Capability of preventing pollution
A31	A20	Average volume of air pollutants			

Table 4
FDM (round 2) for categories

Categories	l_j	u_j	F_j	Ranking
C1: Cost	0.251	0.751	0.313	7
C2: Quality	0.074	0.949	0.456	4
C3: Delivery	0.106	0.769	0.411	6
C4: Service	0.057	0.932	0.452	5
C5: Pollution control	0.361	0.889	0.535	3
C6: Performance and technology ability	0.266	0.984	0.558	1
C7: Environmental management	0.341	0.909	0.54	2
C8: Strategic alliance and technique capability	0.228	0.728	0.307	8
			0.446	

Table 5
Factors screening out after FDM round 2

Initial attributes	l_j	u_j	F_j	Decision A/R	Initial attributes	l_j	u_j	F_j	Decision A/R
A1	0.062	0.813	0.422	A	A21	0.351	0.851	0.338	R
A2	0.152	0.652	0.288	R	A22	0.152	0.652	0.288	R
A3	0.038	0.837	0.428	A	A23	0.320	0.930	0.545	A
A4	0.106	0.769	0.411	R	A24	0.341	0.909	0.540	A
A5	0.331	0.831	0.333	R	A25	0.228	0.728	0.307	R
A6	0.011	0.864	0.435	A	A26	0.625	1.000	0.656	A
A7	0.054	0.821	0.424	A	A27	0.306	0.944	0.548	A
A8	0.000	0.500	0.25	R	A28	0.074	0.949	0.456	A
A9	0.095	0.780	0.414	A	A29	0.267	0.983	0.558	A
A10	0.152	0.652	0.288	R	A30	0.361	0.889	0.535	A
A11	0.380	0.880	0.345	R	A31	0.147	0.728	0.401	R
A12	0.083	0.792	0.417	A	A32	0.033	0.908	0.446	A
A13	0.228	0.728	0.307	R	A33	0.126	0.749	0.406	R
A14	0.097	0.778	0.413	A	A34	0.081	0.794	0.417	R
A15	0.049	0.924	0.450	A	A35	0.019	0.894	0.442	A
A16	0.073	0.802	0.419	A	A36	0.038	0.837	0.428	A

A17	0.351	0.851	0.338	R	A37	0.213	0.713	0.303	R
A18	0.057	0.932	0.452	A	A38	0.006	0.881	0.439	A
A19	0.343	0.843	0.336	R	A39	0.069	0.806	0.420	A
A20	0.033	0.908	0.446	A				**0.412**	

A/R: Accepted/Rejected

Table 6
Categories and factors screening out after FDM round 2

Categories		Initial attributes	Renamed	Attributes	Ranking	
C1	Cost	A1	A1	Product price	7	18
		A3	A2	Buying friendly materials		15
C2	Quality	A4	A3	Process improvement	4	24
		A6	A4	Quality related certificates		14
		A7	A5	low toxicity		17
C3	Delivery	A9	A6	Delivery time	6	22
		A12	A7	Credible delivery		21
C4	Service	A14	A8	Flexibility	5	23
		A15	A9	Warranty		9
		A16	A10	Capability of technology support		20
C5	Pollution control	A18	A11	Energy consumption	3	8
		A20	A12	Average volume of air pollutants		10
C6	Performance and technology ability	A23	A13	Green packaging	1	4
		A24	A14	Remanufacturing		5
		A26	A15	Green research and development		1
		A27	A16	Green image		3
		A28	A17	Validity of clean technique		7
		A29	A18	Eco-design		2
C7	Environmental management	A30	A19	Environment-related certificates	2	6
		A32	A20	Green process planning		10
		A35	A21	Environmental competencies		12
		A36	A22	Environmental regulations		15
C8	Strategic alliance and technique capability	A38	A23	Technological development	8	13
		A39	A24	Capability of preventing pollution		19

5. Discussion and managerial implication

This section has explored the consequences both theoretical and administrative. This study's theoretical contribution has been deepened, and practitioners were given managerial guidance. This research makes several significant contributions to the domain of GSS by identification of critical factors affecting the performance of process. As a result of the analysis, there are five essential categories in GSS process including Performance and technology ability (C6), Environmental management (C7), Pollution control (C5), Quality (C2) and Service (C4). The result shows that Performance and technology ability (C6) is the important factor in the GSS process. Technology ability is the life of a business. The capacity for technology will assist the organization to become a market leader in its business. This result supports the results of previous studies (Chang et al., 2011; Quan et al., 2018), pointing out the critical factors affecting GSS. Therefore, the manufacturing skills of the supplier and evolving capabilities for technology advancement are needed to meet the current and future demands of the business. In addition, the supplier should consider green research and development, eco-design, green image, green packaging, remanufacturing, and validity of clean technique. Addressing the second influenced factor Environmental management (C7), it is used to pressure businesses to minimize the negative effects of production on the environment and to push consumers to be more environmentally responsible, affecting businesses in their decision-making. Environment-related certificates, Green process planning, Environmental competencies are the key called environmental management attributes. The quality of the product delivered to consumers is another aspect. In this regard, the product quality can be partially affected by problems which are more or less directly related to their suppliers: Process improvement, Quality related certificates, and low toxicity. In general, management deals with monitoring and guarantee of quality. Management is aimed at increasing production; initiating, guiding and regulating goal focused activities. Quality assurance and related certificates addressed consumer expectations to maximize the usage of resources and to comply with the policy of the organization. Addressing the service factor (C4), firms not only have to strive to meet consumers ' demand for high-quality goods at reasonable prices in a competitive market setting, but also to attain customer fulfillment. The market today needs rapid response and a great deal of flexibility in movement through the network and across all the participants. Firms can achieve this goal by fast deliveries, quick response, high productivity and serious warranties.

6. Conclusions and future researches

Sustainable Supply Chain Management (SSCM) has rapidly emerged as an important approach to being environmentally friendly for many companies and organizations. This research seeks to examine the views of GSS experts in order to identify the major factors influencing process success. A set of 86 factors divided on eight categories including: Cost, Quality, Delivery, Service, Pollution control, Performance and technology ability, Environmental management and Strategic alliance and technique capability, is suggested for analysis using FDM. In addition, FST is utilized for the transformation of qualitative expert knowledge into quantitative data. Then, the DM is used to identifying unnecessary attributes based on their significance. Five categories of factors are considered as the most significant elements that have a positive influence on GSS process, including, Performance and technology ability, Environmental management, Pollution control, Quality and Service. In particular, 24 of 58 attributes are indicated as major attributes, among which research and development, eco-design, green image, green packaging and remanufacturing are distinct as the top important GSS factors. This research makes several significant contributions to the domain of GSS by identifying the major attributes. Despite the significance of these outcomes, limitations exist. First, present variables have been chosen from the literature review, which renders the current structure incomplete. In future research, this extension should be supported. Second, the method 's effectiveness is built upon expert validation. It is also suggested that, for future research, an additional professional validity assessment be built to prevent prejudices impacting the final outcome.

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Appendix 1

Proposed measure factors

No.	Factors	No.	Factors
A1	Product price	A30	Use of harmful material
A2	Logistics cost (manufacturing and transportation)	A31	Average volume of air pollutants
A3	Waste disposal cost	A32	Inventory of hazardous substances
A4	Cost reduction performance	A33	waste water
A5	Buying friendly materials	A34	Green packaging
A6	Compliance with sectoral pricing strategy	A35	Recycling
A7	Product stability	A36	Remanufacturing
A8	Process improvement	A37	Reuse
A9	Quality assurance	A38	Green research and development
A10	Quality related certificates	A39	Green image
A11	Product qualification ratio	A40	Validity of clean technique
A12	low toxicity	A41	Eco-design
A13	Order processing speed	A42	Environment-related certificates
A14	Order Fulfillment Rate	A43	Energy Using Product
A15	Supplier lead time	A44	Ozone Depleting Chemicals
A16	Delivery time	A45	Restriction of hazardous substance
A17	Delivery reliability	A46	Green process planning
A18	Delivery delays	A47	Waste electrical electronic equipment
A19	Waiting time	A48	low carbon measures
A20	Credible delivery	A49	Environmental competencies
A21	Responsiveness	A50	Environmental regulations
A22	Stock management	A51	Willingness to Information Sharing
A23	Design Capability	A52	Capability of Sharing Benefits & Risks
A24	Flexibility	A53	Capability of Understanding
A25	Warranty	A54	Ultimate Aims and Business Processes
A26	Capability of technology support	A55	Capability of Building Long- Term Relationships
A27	Material substitution for green materials	A56	Technological development
A28	Solid wastes	A57	Technological compatibility
A29	Energy consumption	A58	Capability of preventing pollution

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