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

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ABSTRACT

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.

Keywords: Green supplier selection
Sustainable supply chain
Fuzzy Delphi method
Fuzzy set theory

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
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. Arabshebani et al. (2018) applied 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   | Arabshebani et al. (2018) | SM        | Fuzzy-MOORA        | Iron electronic industry |
| 3   | Bakeshloiu 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   | Fallahpouir 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        | BW and fuzzy TOPSIS | Iron and steel manufacturing in Khuzestan |
| 15  | Rabbani et al. (2019) | SM        | Interval-Value Fuzzy Sets | Home appliance manufacturing in Iran |
| 16  | Sen et al. (2017) | SM        | Fuzzy MABAC        | - |
| 17  | Thongchattu and Siripokapiam(2010) | CM        | AHP and ANN        | - |
| 18  | Wu et al. (2019) | CM        | BW and fuzzy VIKOR  | - |
| 19  | This paper      | SM        | fuzzy Delphi method | - |

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

As for the combined-model approaches, Bakeshloiu 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. Fallahpouir 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 Darvish (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 (Višekriterijumska 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 $v = (x_{ij}; y_{ij}; z_{ij}), \ i = 1, 2, 3, ..., n; j = 1, 2, 3, ..., m$; furthermore, weight $v_j$ of element $j$ is $v_j = (x_j; y_j; z_j)$, where $x_j = \min(x_{ij})$, $y_j = \left(\prod y_{ij}\right)^{1/n}$, 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.

| Linguistic terms | Very Unimportant | Unimportant | Moderately Important | Important | Very Important |
|------------------|------------------|-------------|----------------------|----------|---------------|
| Corresponding TFNs | (0, 0, 0.25) | (0.25, 0.5) | (0.25, 0.5, 0.75) | (0.5, 0.75, 1.0) | (0.75, 1.0, 1.0) |
In order to produce the value of the convex combination \( F_j \), we use the following equation (wu et al., 2016) by adopting \( \alpha \) cut to generate a result:

\[ u_j = z_j - \alpha(z_j - y_j), l_j = x_j - \alpha(y_j - x_j), j = 1, 2, 3, \ldots, m \]  

(1)

\( \alpha \) 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 \( F_j \):

\[ F_j = \int (u_j, l_j) = \beta(u_j + (1 - \beta)l_j), \]  

(2)

where \( \beta \) 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 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   | A           |
| 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  | R           | 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           |
### 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 |
| A14                | A9      | Delivery time | A41                | A29     | Eco-design |
| A16                | 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                              | \( l_i \) | \( u_i \) | \( F_i \) | 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       |

### Table 5

Factors screening out after FDM round 2

| Initial attributes | \( l_i \) | \( u_i \) | \( F_i \) | Decision | Initial attributes | \( l_i \) | \( u_i \) | \( F_i \) | Decision |
|--------------------|-----------|-----------|-----------|----------|--------------------|-----------|-----------|-----------|----------|
| A1                 | 0.062     | 0.813     | 0.422     | A        | A2                 | 0.351     | 0.851     | 0.338     | A        |
| A2                 | 0.152     | 0.652     | 0.288     | R        | A2                | 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        |
Table 6
Categories and factors screening out after FDM round 2

| Categories                        | Initial attributes | Renamed Attributes      | Attributes                  | Ranking |
|-----------------------------------|--------------------|-------------------------|-----------------------------|---------|
| C1 Cost                           | A1                 | A1                      | Product price              | 7       |
| C2 Quality                        | A3                 | A2                      | Buying friendly materials   | 15      |
| C3 Delivery                       | A4                 | A3                      | Process improvement        | 4       |
| C4 Service                        | A5                 | A5                      | low toxicity               | 17      |
| C5 Pollution control              | A6                 | A4                      | Quality related certificates| 14      |
| C6 Performance and technology     | A7                 | A5                      | Environmental management   | 3       |
| C7 Environmental management       | A8                 | A10                     | Capability of technology support | 20     |
| C8 Strategic alliance and technique capability | A9 | A11                     | Energy consumption         | 8       |
| C9 Technology and product         | A10                | A12                     | Average volume of air pollutants | 10     |
| C10 Performance                    | A11                | A13                     | Green packaging            | 1       |
| C11 Environment                   | A12                | A14                     | Remanufacturing            | 5       |
| C12 Quality                       | A13                | A15                     | Green research and development | 1    |
| C13 Service                       | A14                | A16                     | Green image                | 3       |
| C14 Technology                     | A15                | A17                     | Validity of clean technique | 7       |
| C15 Environmental                 | A16                | A18                     | Eco-design                 | 2       |
| C16 Pollution                      | A17                | A19                     | Environment-related certificates | 6    |
| C17 Performance                    | A18                | A20                     | Green process planning     | 10      |
| C18 Technology                     | A19                | A21                     | Environmental competencies | 12      |
| C19 Environmental                 | A20                | A22                     | Environmental regulations  | 15      |
| C20 Pollution                      | A21                | A23                     | Technological development  | 8       |
| C21 Performance                    | A22                | 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. Environmental-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.

References

Almasi, M., Khoshfetrat, S., & Rahiminezhad Galankashi, M. (2019). Sustainable Supplier Selection and Order Allocation Under Risk and Inflation Condition. IEEE Transactions on Engineering Management, 1-15.

Arabsheybani, A., Paydar, M. M., & Safaei, A. S. (2018). An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier’s risk. Journal of Cleaner Production, 190, 577–591.

Bakeshlou, E. A., Khamseh, A. A., Asl, M. A. G., Sadeghi, J., & Abbasazadeh, M. (2014). Evaluating a green supplier selection problem using a hybrid MODM algorithm. Journal of Intelligent Manufacturing, 28(4), 913–927.

Ben Mabrouk, N. (2020). Interpretive structural modeling of critical factors for buyer-supplier partnerships in supply chain management. Uncertain Supply Chain Management, 8(3), 613-626.

Ben Mabrouk, N., Omri, A., & Jarraya, B. (2020). Factors influencing the performance of supply chain management in Saudi SMEs. Uncertain Supply Chain Management, 8(3), 569-578.

Bouzon, M., Govindan, K., Rodriguez, C. M. T., & Campos, L. M. S. (2016). Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resources, Conservation and Recycling, 108, 182–198.

Chang, B., Chang, C.W., & Wu, C.H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. Expert Systems with Applications, 38(3), 1850–1858.

Chang, P.L., Hsu, C.W., & Chang, P.C. (2011). Fuzzy Delphi method for evaluating hydrogen production technologies. International Journal of Hydrogen Energy, 36(21), 14172–14179.

Dobos, I., & Vörösmarty, G. (2014). Green supplier selection and evaluation using DEA-type composite indicators. International Journal of Production Economics, 157, 273–278.

Ecer, F. (2020). Multi-criteria decision making for green supplier selection using interval type-2 fuzzy AHP: a case study of a home appliance manufacturer. Operational Research, 1-35.

Fallahpour, A., Olugu, E., Musa, S., Khezrimotlagh, D., & Wong, K. (2016). An integrated model for green supplier selection under fuzzy environment: Application of data envelopment analysis and genetic programming approach. Neural Computing and Applications, 27, 707–725.

Ghadimi, P., Dargi, A., & Heavey, C. (2017). Making sustainable sourcing decisions: practical evidence from the automotive industry. International Journal of Logistics Research and Applications, 20(4), 297–321.

Gupta, S., Soni, U., & Kumar, G. (2019). Green supplier selection using multi-criterion decision making under fuzzy environment: A case study in automotive industry. Computers & Industrial Engineering, 136, 663-680.

Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., Mieno, H., 1993. The max-min Delphi method and fuzzy Delphi method via fuzzy integration. Fuzzy Sets and Systems, 55(3), 241–253.

Kardaras, D. K., Karakostas, B., & Mamakou, X. J. (2013). Content presentation personalization and media adaptation in tourism web sites using Fuzzy Delphi Method and Fuzzy Cognitive Maps. Expert Systems with Applications, 40(6), 2331-2342.

Keli, B. P., Abadi, B. S. D., & Abedini, M. (2018). Investigating readiness in the Iranian steel industry through six sigma combined with fuzzy delphi and fuzzy DANP. Decision Science Letters, 7, 465–480.

Kilic, H. S., & Yalcin, A. S. (2020). Modified two-phase fuzzy goal programming integrated with IF-TOPSIS for green supplier selection. Applied Soft Computing, 106371.

Laosirihongthong, T., Samaranyake, P., & Nagalingam, S. (2019). A holistic approach to supplier evaluation and order allocation towards sustainable procurement. Benchmarking: An International Journal, 26(8), 2543-2573.

Li, J., Fang, H., & Song, W. (2019). Sustainable supplier selection based on SSCM practices: A rough cloud TOPSIS approach. Journal of Cleaner Production, 222, 606-621.

Lu, Z., Sun, X., Wang, Y., & Xu, C. (2018). Green supplier selection in straw biomass industry based on cloud model and possibility degree. Journal of Cleaner Production, 209, 995-1005.

Ma, Z., Shao, C., Ma, S., & Ye, Z. (2011). Constructing road safety performance indicators using Fuzzy Delphi Method and Grey Delphi Method. Expert Systems with Applications, 38(3), 1509–1514.
Micheli, G. J. L., Cagno, E., Mustillo, G., & Trianni, A. (2020). Green supply chain management drivers, practices and performance: A comprehensive study on the moderators. *Journal of Cleaner Production*, 121024.

Mohammed, A. (2019). Towards a sustainable assessment of suppliers: an integrated fuzzy TOPSIS-possibilistic multi-objective approach. *Annals of Operations Research*, 1-30.

Mosayebia, A., Ghorbanib, S. & Masoomi, B. (2020). Applying fuzzy delphi and best-worst method for identifying and prioritizing key factors affecting on university-industry collaboration. *Decision Science Letters*, 9, 107–118.

Ocampo, L., Ebisa, J. A., Ombe, J., & Geen Escoto, M. (2018). Sustainable ecotourism indicators with fuzzy Delphi method – A Philippine perspective. *Ecological Indicators*, 93, 874–888.

Omri, A., & Ben Mabrouk, N. (2020). Good governance for sustainable development goals: Getting ahead of the pack or falling behind? *Environmental Impact Assessment Review*, 83, 106388.

Oroojeni, M.J., & Darvishi, M. (2020). Green Supplier Selection for the Steel Industry Using BWM and Fuzzy TOPSIS: A case study of Khuzestan Steel Company. *Sustainable Futures*, 100012.

Quan, J., Zeng, B., & Liu, D. (2018). Green Supplier Selection for Process Industries Using Weighted Grey Incidence Decision Model. *Complexity*, 1–12.

Appendix 1

| 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 |
