Cleaner Environmental Systems 2 (2021) 100034

Contents lists available at ScienceDirect

Cleaner Environmental Systems

journal homepage: www.journals.elsevier.com/cleaner-environmental-systems

AHP-TOPSIS social sustainability approach for selecting supplier in construction supply chain

Mohamed Marzouk [a,*], Marwa Sabbah [b]

[a] Structural Engineering Department, Faculty of Engineering, Cairo University, Giza, Egypt
[b] Integrated Engineering Design Management Program, Faculty of Engineering, Cairo University, Giza, Egypt

ARTICLE INFO

Keywords:
Social sustainability
Supplier selection
Construction supply chain
Multi-criteria decision making
Analytical hierarchy process
TOPSIS
Sensitivity analysis

ABSTRACT

Prequalification of suppliers in the Construction Supply Chain is considered a crucial step to assure to their ability to deliver socially sustainable projects. This research identifies the most important social sustainability prequalification criteria for supplier selection in Construction Supply Chain. Additionally, a Multi-Criteria Decision Making (MCDM) model based on social indicators of sustainability is proposed in this research. Structured interviews were organized with experienced practitioners to define the relative importance weights of criteria that have collected in the first phase using Analytic Hierarchy Process (AHP). As such, the AHP is applied to develop mathematical determination to achieve the weights of social indicators. Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method is used to evaluate the different suppliers in the construction supply chain against 17 identified attributes. Ultimately, the closeness coefficients of the suppliers are estimated in order to identify social performance. The research aims at proposing a computational model of MCDM in order to introduce it to the construction organizations to utilize in the supplier prequalification process. A computational model is developed and a case study is worked out to illustrate the proposed methodology in supplier selection to ensure sustainable construction projects. Afterwards, the model is validated and a sensitivity analysis is conducted to analyze the impact of changing the weights of the considered attributes in the model outputs.

1. Introduction

It has become clear that applying sustainability is essential for the construction industry prosperity. In response to the global competition, construction industry players such as suppliers, subcontractors, and consultants have started to develop their performance to achieve sustainable development. Unfortunately, organizations have adopted environmental pillar more than the social pillar despite the impact of the second-mentioned is more than the first-mentioned pillar on the competitive outcome (O'Riordan et al., 2015). Moreover, most of the sustainability research in supply chain management focused on environmental and/or economic pillars, whereas social pillar has been obtained less concern (Köksal et al., 2018). The interpretation of this, maybe that social sustainability issues are not generally universally understood (Rossi and Krey, 2018). Member countries of the European Union have signed a sustainable communities' specific approach which is so-called ‘Bristol Accord’. The Accord describes sustainable societies as “places where people want to live and work, now and in the future. They meet the diverse needs of existing and future residents, are sensitive to their environment, and contribute to a high quality of life. They are safe and inclusive, well planned, built and run, and offer equality of opportunity and good services for all” (Accord, 2005). In order to achieve this target in our communities, the three pillars of sustainability should be taken into account in all life aspects.

Construction industry should enable sustainable development by incorporating the social pillar throughout the whole life cycle of the project (Forsman and Jonsson, 2016). Meanwhile, the social dimension is perceived as a major challenge in developing countries because it is required well-being to be achieved, at the same time, most of the developing countries suffered from missing their well-being. To move on overcoming these challenges, evaluating social sustainable performance should be taken into consideration. The social aspects evaluation is still ignored and the assessment of multi-criteria of these aspects is still an emerging topic (Sierra et al., 2018).

Through the awareness of multi-criteria decision-making context, there are several techniques to handle the topic of supplier selection such as Fuzzy-AHP, AHP, and All of them have their benefits, barriers, and guidelines. Socially sustainable supplier evaluations are important for

* Corresponding author.
E-mail address: mmarzouk@cu.edu.eg (M. Marzouk).

https://doi.org/10.1016/j.cesys.2021.100034
Received 8 March 2021; Received in revised form 3 April 2021; Accepted 3 April 2021

several stakeholders. For instance, construction companies can improve their prospects by choosing their teamwork based on social sustainability performances. Additionally, suppliers can enhance and improve their sustainability profile. Also, the purchasing managers can utilize the decision tool to evaluate many alternatives by selecting the optimum of them without any bias. Furthermore, the outcome of this research will propose a strategy for the socially sustainable construction supply chain consequently, will provide the society with future well-being. This research aims to aid in a pre-qualification process for supplier's evaluation in construction supply chain. This is to support the decision-makers to prioritize and select the suppliers in construction projects based on social indicators for sustainability, taking into consideration quantitative and qualitative criteria to enhance the decision process.

The paper consists of four main Sections. It starts with literature review Section which describes social sustainability and suppliers' qualifications. Then, it presents TOPSIS as one of the techniques that is used in Multi-criteria decision-making problems. Subsequently, it describes the developments made in the proposed model that is used to select the best alternative of suppliers for the construction organization based on social sustainability indicators. Finally, a case study and sensitivity analysis are presented to demonstrate the main features of the proposed research methodology.

2. Literature review

2.1. Social sustainability

The sustainable supply chain should mitigate the risk of environmental and social consequences in different geographical regions where upstream suppliers are concentrated while preserving the financial stability of the chain (Seuring and Müller, 2008a). However, bad situations might occur in the case of focusing on profit only without covering the practices of the other two pillars of sustainability. For example, a bad situation, killing over a thousand workers when the eight-story garment factory of Rana Plaza demolished in Bangladesh (Varsei et al., 2014). Not only this bad situation affected the upstream supplier, but also affected numerous downstream enterprises in other areas as well (Greenhouse, 2013). Many researchers illustrated the relation between the three elements and noticed that implementing environmental and/or social undertaking provides a potential economic advantage (Yusuf et al., 2013). Although, many researchers argue that per-forming environmental or social initiatives which are achieving a balance between the three dimensions of sustainability performance can lead to enormous costs (Ross et al., 2012). In contrast, Focal firms might be able to prove the long-term economic advantages of supply chain-level environmental and social policies, where firms are benefited financially from engaging sustainability practices (Schaltegger et al., 2011). Therefore, firms require decision-making tools, kits, and techniques to implement sustainability assessment across their supply chains (Cousins et al., 2006). As a result, environmental or Green supply chain (GSC) management has received much greater publicity compared with the social aspect (Sarkis, 2012).

By studying sustainable supply chain management, most research efforts have not covered the social pillar of sustainability. For example, Srivastava (2007) introduced a decision-making context for SSCM that emphasizes on five strategic key areas which includes product design, choice of material, the manufacture process, product transmission to the client, and the management of product's end-of-life. Another study has not focused enough on social sustainability by Liu et al. (2012) which focused only on meeting the needs of green customers through integrating the green marketing within SSCM. Evidence (Manzini and Accorsi, 2013), formed a framework to manage each of safety, quality and sustainability in alimentation chains without concerning social sustainability dimension. Also, the framework was generated by (Esfahbodi et al., 2016) focused only on environmental performance and cost effectiveness practices which have avoided the socio-economic dimension.

According to Griessler and Littig (2005), there is no theoretical definition of social sustainability; although, there are some definitions had been mentioned in the previous studies. For example, social sustainability can be seen as a life-enhancing condition for the communities (McKenzie, 2004). Valdes-Vasquez and Klotz (2012) pointed out that social sustainability is a process of engaging all the stakeholders through supply chains such as employees, clients, and communities to meet the needs of both present and future populations. Forsman and Jonsson (2016) argued that the first definition by McKenzie (2004) is more suitable on a local level, but the second one by Valdes-Vasquez and Klotz (2013) reflected the perspectives of the stakeholders in the construction projects. It worth noting that the first one is more comprehensive than the second one because of all stakeholders in any project are already included in the communities.

On the other hand, Dempsey et al. (2011) described social sustainability as neither an absolute nor a constant, but it can be considered as a dynamic concept which can change over the time in somewhere. Also, Brent and Labuschagne (2006) described social sustainability as "the weakest pillar of sustainable development" because of the lack of theoretical and analytical basis (Zuo et al., 2012). Nevertheless, social sustainability can be considered the pillar which is responsible for most needs of human-well-being. To conclude, when personal development is guaranteed at the same time as diversity and respect come together, social sustainability can be achieved in cities and communities (Forsman and Jonsson, 2016). Despite social sustainability is considered the basic need for societies (Rossi and Krey, 2018), most of developing countries suffer from social issues such as poverty, safety, health, bonded and child labor (Mani et al., 2014). On the other hand, social issues have not been investigated significantly because of the difficulty in getting tangible outcomes (Mani et al., 2014), and also the complexity of exploring human issues makes the research on this topic very little (Mani et al., 2016).

Hutchins and Sutherland (2008) identified various social criteria and indicators like philanthropy, equity, health, and safety to measure social dimensions and showed the vital role which these indicators play in the country throughout the analysis of life cycle. Labuschagne et al. (2005) detected practices associated to poverty mitigation, welfare, administering justice, and human rights of all workers in the supply chain. Leire and Mont (2010) explored the goals of social sustainability when linked into the supply chain as unemployment reduction, securing the health and safety of worker, affirming equal treatment and social exclusion prevention. Many researchers have found the answers to the third question which has been mentioned above. For example, Socially Responsible Buying (SRB) refers to the inclusion of social topics in procurement decisions promoted by organizational stakeholders (McWilliams and Siegel 2001). Also, Purchasing Social Responsibility (PSR) and Logistics Social Responsibility (LSR) (Ciliberti et al., 2008) can improve trust and supplier commitment by the vital role of purchasing managers within the supply chain in the social responsibility field. Later, Leire and Mont (2010) research suggested how to use social criteria to control suppliers and ensure their fulfillment.

2.2. Supplier qualification

The first stage for launching the supplier-buyer relationship is supplier selection to reduce the risks in a relationship (Koufteros et al., 2012). The goal of supplier selection is to choose a supplier who can achieve the requirements of the buyer to enhance the performance of the firm (Krause et al., 2000). Over the past years, the researchers used multi-criteria decision making in the process of supplier selection (Tsai and Hung, 2009). Already, there is a different type of criteria like operational or sustainable criteria. The operational criteria are considered as price, quality, and delivery performance (Kwong et al., 2002). The importance is given to features of sustainability, environmental criteria which have gained more attention in the supplier selection decision-making process (Baskaran et al., 2012). Also, environmentally sustainable criteria have gained predominant studies rather than socially sustainable criteria in the literature (Marshall et al., 2019). To note the consequence in recent research studies, researchers go on handling the social criteria to deal with this shortage. When evaluating the supplier performance, price, flexibility and quality are usually the most parameters used in the selection process (Dowlatshahi, 2000). Later, in addition to these parameters, the purchasing process becomes more complex due to the interlinking of sustainability which plays an important role in the supply chain according to the pressure of environmental and social pillar (Bai and Sarkis, 2010). To achieve sustainable performance, supplier selection was considered more important than supplier integration and development (Seuring and Müller, 2008b). Evidence, focusing on the social dimension in the supply chain detected as much needs to be done (Seuring and Müller, 2008a).

Social sustainability has been investigated in other industries such as automotive and electronics industry. This research addresses this by providing a computational model for supplier selection considering the social indicators of sustainability. The research aims at aiding in the pre-qualification process for supplier's evaluation in the construction industry. This is to support the decision-makers to prioritize and select the suppliers in construction projects based on social indicators for sustainability. The main objective of this research is to develop a multi-criteria decision-making model that ranks and prioritizes suppliers, taking into consideration quantitative and qualitative criteria to enhance the decision process.

Social sustainability has been studies extensively in literature in different industries such as automotive and electronics industries. However, construction industry is lacking behind specially with respect to the integration of social criteria in sustainable supply chain. Hence, this research covers this gap as such social indicators of sustainability are addressed in the construction supply chain through a real case study in the construction organization. The study provides a computational model for supplier selection considering the social indicators of sustainability.

3. Methods

3.1. TOPSIS technique

Multi-criteria decision-making problems have been usually faced in practice. Several MCDM methods can be implemented to solve these problems, and among these methods, the concept of TOPSIS method is simple (Chaharsooghi and Ashrafi, 2014). The classical TOPSIS has been proposed by Hwang and Yoon who explored that the best alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative one. Despite TOPSIS has a high weakness that it does not provide a good alternative (Chaharsooghi and Ashrafi, 2014), in contrast, that TOPSIS affords the decision-maker the nearest alternative which is considered the best one according to the score which has been illustrated by the judgement. As such, if one decision-maker gives a score for each alternative, the result will be an alternative ranking according to this score. If another decision-maker provides different scores, consequently the alternative ranking will be different. Hence, TOPSIS gives judgement the perfect solution with respect to the perspective of each decision-maker. TOPSIS decision-making technique is classified into five main steps (Triantaphyllou et al., 1998). Converting performance attributes into non-dimensional ones is the first step, the decision matrix is normalized using Equation (1).

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \tag{1}$$

After normalization, the second step is to determine the normalized weighted decision matrix by multiplying the normalized decision matrix by its corresponding weights. The normalized weighted value vi j is taken using Equation (2).

$$v_{ij} = r_{ij} {}^* w_j \tag{2}$$

The third step is to identify the positive or most ideal solutions and negative ideal solutions which are produced by using Equation (3) and Equation (4). A+ shows the most positive ideal solution. Conversely, A- shows the negative ideal solution. For benefit criteria, the decision-maker obtains the most extreme value of any alternatives. Meanwhile, for cost criteria, the decision-maker requires obtaining minimum value among all alternatives.

$$A+ = \left\{ \left(max\ v_{ij} \middle| \in J\right), \left(min\ v_{ij} \middle| \in J'\right), i = 1, 2, 3....M \right\} = \{v+_1, v\ +\ _2......v\ +\ _N\} \tag{3}$$

$$A- = \left\{ \left(max\ v_{ij} \middle| \in J\right), \left(min\ v_{ij} \middle| \in J'\right), i = 1, 2, 3....M \right\} = \{v-_1, v-_2......v-_N\} \tag{4}$$

where;

$$J = \{j = 1, 2, 3......N | j\ associated\ with\ benefit\ criteria\} \tag{5}$$

$$J' = \{j = 1, 2, 3......N | j\ associated\ with\ cost\ criteria\} \tag{6}$$

The fourth step is to measure the difference between each alternative to the positive ideal (PIS) A+ and negative ideal solutions (NIS) A-. Further, $S+_i$ describes the distance separating every alternative from the ideal positive solution in the Euclidien way. On the contrary, $S\text{-}_i$ illustrates the separation distance between each alternative in the Euclidean way from the optimal negative solution using equations (7) and (8) respectively.

$$S+_i = \sqrt{\left(\sum_{j=1}^{n} \left(v_{ij} - v+_j\right)^2\right)} \tag{7}$$

$$S-_i = \sqrt{\left(\sum_{j=1}^{n} \left(v_{ij} - v-_j\right)^2\right)} \tag{8}$$

Fifth step: measure the relative closeness of an alternative Ai to the ideal solution A+ using Equation (9). The alternatives are positioned in descending order and the optimum alternative has the shortest distance to the ideal solution, and consequently, the most distant separation to the negative-ideal solution.

$$C+_i = \frac{s_i}{(s+_i) + (s-_i)}\ and\ 0 \leqslant c+_i \leqslant 1 \tag{9}$$

3.2. Proposed model

The objective of this research is to develop a model that capable to select the best alternative of suppliers for the construction organization based on social sustainability indicators. The proposed model considers the pre-qualification process during the planning phase. The model mechanism is illustrated in the flowchart shown in Fig. 1. It is worth noting that TOPSIS and AHP techniques are utilized due to their advantages (Kochkina et al., 2017). The advantages of TOPSIS include ease of application, universality, and consideration of distances to an ideal solution. Whereas the advantages of AHP include universality, reduction of subjectivity due to the consideration of the human factor, and verification of data inconsistency.

3.2.1. Data collection

In data collection stage, several techniques have been adopted to extract the required data: 1) Literature review to form the theoretical framework and perform a list of social criteria for supplier selection, 2) The personal interview (face-to-face) in the form of semi-structured interviews to classify the data and construct the hierarchy, 3) Developing

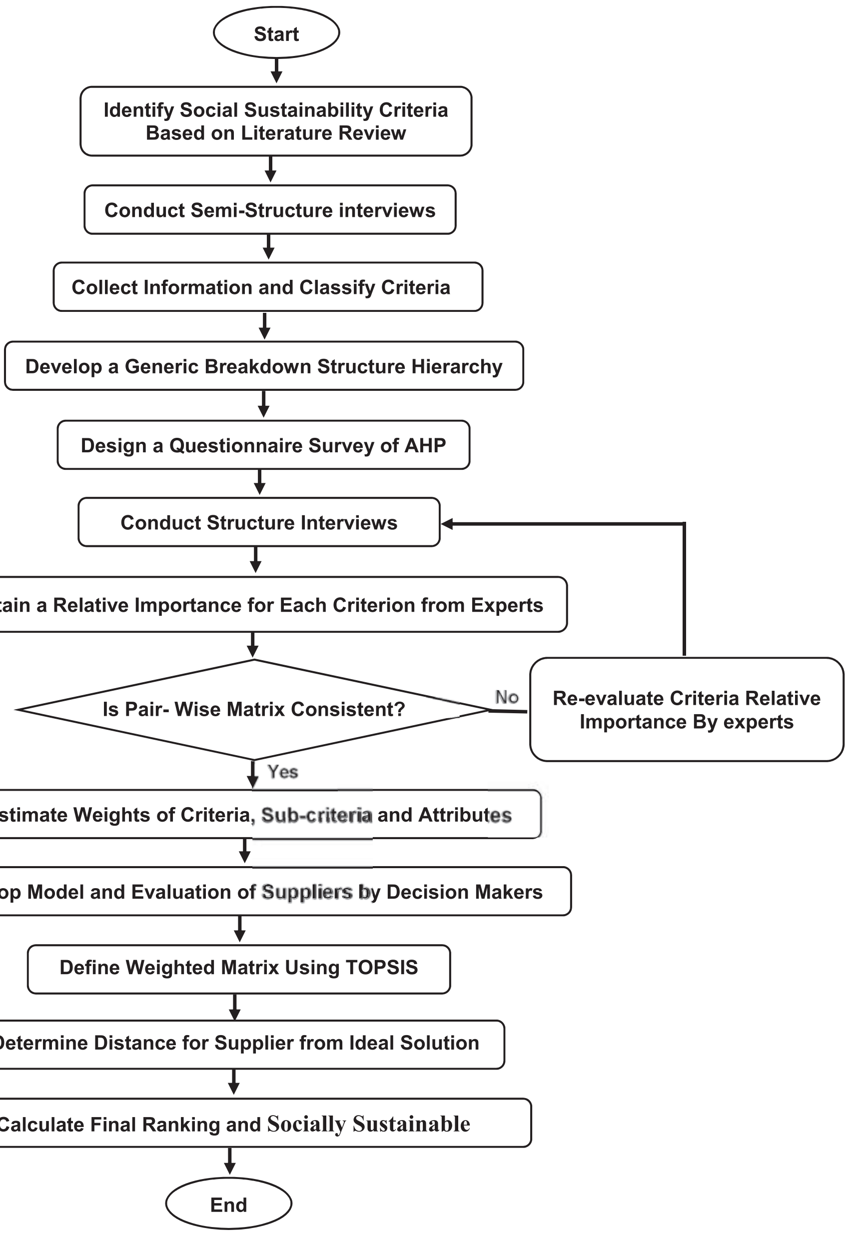

Fig. 1. Flowchart of proposed model.

the generic hierarchy of AHP model, 4) Developing the questionnaire survey, and 5) conducting structured interviews to obtain the relative importance for each social criteria and indicator.

3.2.2. *Factors identification*

A literature review was performed to gather data. In this study, 23 criteria have found from the literature on social criteria for supplier selection. These criteria have divided into main four categories which classified according to gathering data from literature and semi-structured interviews. The parameters have taken from previous studies of (Zimmer et al., 2016) who considered the top ten social criteria for supplier selection. Other parameters are included based on semi-structured interviews and literature. Moreover, the main output from the documentation reviews and information collection is to identify the list of social criteria for selecting the supplier to support sustainability performance. This list is used in structured interviews to help the experts in understanding the research study. The criteria definitions have summarized and listed in Table 1.

3.2.3. *Personal semi-structured interviews*

In this research, two semi-structured interviews have started up with the first draft of the hierarchy in the form of a brainstorming session. Then, the professional experts have reconstructed the classification of criteria and have added some other attributes such as the color which has found in the literature. It has realized that having a dialogue about social issues as well as filling in the hierarchy is the best way to avoid any confusions might have occurred. Finally, the generic breakdown structure hierarchy as shown was developed based on semi-structured interviews and literature.

3.2.4. *Developing the generic hierarchy*

Several weighting methods have been introduced in literature (Keshavarz-Ghorabaee et al., 2021; Peng et al., 2021). These include SECA (Simultaneous Evaluation of Criteria and Alternatives) and MEREC (MEthod based on the Removal Effects of Criteria) as well as new MCDM methods like EDAS (Evaluation based on Distance from Average Solution) and CoCoSo (Combined Compromise Solution), and CRITIC (Criteria Importance Through Inter-criteria Correlation). On the other

Table 1
Social criteria definitions.

Social Criteria	Definition
Social strategies	It addresses the commitment level of improving social sustainability progress achieved by the supplier's company. For example, conducting code to be applied as a guide for social sustainability.
Health and Safety	It points to the physical and mental health human safety at work. Also, it takes up hazardous working conditions which might leave long-term effects of the personal health of the worker.
Stakeholder involvement	It represents stakeholder involvement; it assesses the construction company's relationships with the supplier's organization by monitoring the communications efficiency between the two parties.
Social management commitment	Establishment of social commitment team or department to manage and control social activities.
Social code of conduct	Conducting code to meet the social sustainability requirements.
Donation for Sustainable Projects	It is the ability to donate cash for sustainable projects in support of the community.
Occupational health and safety management system	Conducting code to meet the health and safety requirements such as OHSAS18001.
Safety practices	It is issues related to safety and labour health for a worker.
Annual number of accidents	It is the accident rate – fatal accidents.
The rights of stakeholders	The capability of suppliers in respecting to regulations and contractual relationships with the contractor.
Stakeholders relations	It is the strategies of the supplier in the relations with a contractor such as long-term relationships.
Training of employees	It is support for education and job training program.
Child labour	Working by children of age under 18 years that is dangerous to physical and mental health, also prevents school attendance.
Equity	Non-discrimination in color, national, and religion.
Gender diversity	Female to male ratio.

hand, AHP model aims at classifying all social criteria, sub-criteria and attributes. This classification consequently facilitates the process of obtaining relative importance of each social indicator. The hierarchy of social sustainability metrics had been constructed in the form of a tree as shown in Fig. 2. The main tree branch consists of three criteria and one attribute that could identify as a social strategy (C1), health and safety (C2), stakeholder involvement (C3) and technical training of employee (A1). First, Social Strategy describes the commitment level of improving social sustainability progress achieved by the supplier's company. For example, conducting code to be applied as a guide for social sustainability. Second, health and safety are considered as physical and mental health of human safety at work. Also, it takes up hazardous working conditions that might leave long-term consequences of the personal health of the worker.

Third, stakeholder involvement is defined as the construction company's relationships with the supplier's organization by monitoring the effectiveness of the communications between both parties. Fourth, the attribute of training of employee is support for education and job training program in the supplier's organization. A second branch of the tree composed of four levels; the first level contains social strategy criterion (C1) which is divided to one sub-criterion employee rights (S1) and three attributes which are a donation for sustainable projects (A2.1), social management commitment (A2.2) and social code of conduct (A2.3). In particular, the employee rights sub-criterion (S1) is made up of two sub-criteria: Equity (S2), working conditions (S3) and two attributes: gender diversity (A3.1) and child labour (A3.2) at the third level.

At the fourth level, there are six attributes; three attributes as well, color (A4.1), national origin (A4.2) and Ethnic (A4.3) are generated from the equity criterion (S2). Additionally, three other attributes: wages (A4.4), working hours (A4.5) and contract labour (A4.6) are generated from the working condition sub-criterion (S3). Moreover, the third branch consists of two levels; the first one involves health and safety criterion (C2) which is composed of three attributes; occupational health and safety management (A2.4), safety practices (A2.5) and the annual number of accidents (A2.6). Finally, the fourth branch comprised of two attributes, which are the rights of stakeholder (A2.7) and stakeholder relation (A2.8) which shares Stakeholder criterion (C3).

3.2.5. Structured interviews

After that, 23 structured interviews have been conducted with 23 professional experts to answer the research questions which are structured in a questionnaire survey. Through using the structured interview, the interviewees were free to select which one is the more important criterion than the other. After the professional experts were asked to fill in the questionnaire survey with respect to the relative importance of

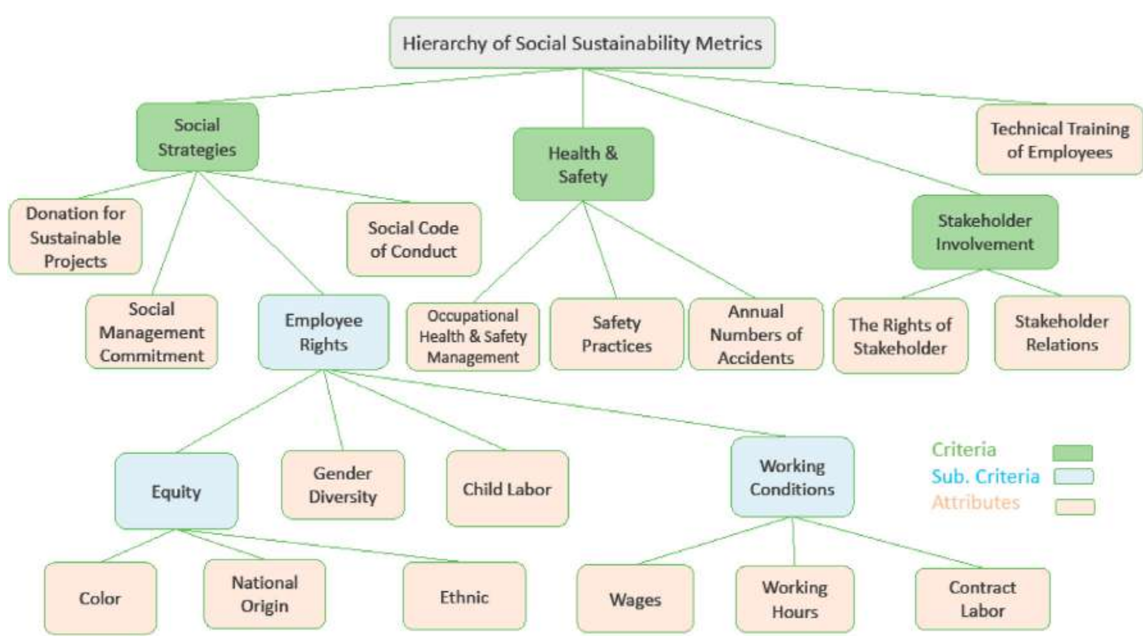

Fig. 2. Hierarchy model of social sustainability indicators.

each criterion to the other one from 1 to 9, AHP is carried out on each respondent data. After finishing the 23 interviews, all of them have not passed the consistency test. Only 54% of the matrices have been successfully passed the consistency test.

Generally, decision-makers' decisions are based on the attitude, circumstances, education and personal experience (Yadav and Jayswal, 2013). Hence, in this study, the second round of AHP had been taken into consideration. The interviewer asked the experts who had inconsistent data to re-interview to modify the model. The same process was repeated, the consistency index became much lower than the limit of 10% for 84% of respondents of the question. That represents the logical and reasonable answers by the experts have been obtained which enable moving to the other steps to perform the alternative selection. To perform weights calculations using the arithmetic mean (Plackett 1958), questionnaire respondents have been divided into two groups, the first group is the social experts while the second group is interviewee with the engineering background. The weights were calculated using the percentage average of arithmetic weights after solving all AHP matrices. Also, the attributes weights are calculated using geometric mean sometimes referred to the Logarithmic Least Squares Method (Fichtner 1986). Table 2 lists the weights using both arithmetic mean and geometric mean.

3.2.6. AHP-TOPSIS model implementation

After obtaining criteria weights that were estimated through feeding pairwise comparison using the AHP process proposed by Saaty (1977, 1990), the model utilizes TOPSIS method to achieve the objective of suppliers ranking for the construction organizations. The model is coded in Microsoft Excel. TOPSIS is used to evaluate the different suppliers in the construction supply chain. Initially, a decision matrix for the suppliers with respect to the 17 attributes. All of them have measured according to five points Likert scale method. Equation (5) is used to determine the normalized decision matrix. Then, a normalized weighted matrix is calculated also the distance of the suppliers from the positive ideal solution and the negative ideal solution. Ultimately, the closeness coefficients of the suppliers are estimated in order to identify social performance.

Table 2
Estimated Weights of attributes using Arithmetic and Geometric Mean.

Attributes	Arithmetic Mean			Geometric Mean
	Engineering Experts	Social Experts	Overall	
1. Donation for sustainable projects	0.11	0.21	0.16	0.134
2. Social management commitment	0.24	0.18	0.21	0.214
3. Social code of conduct	0.19	0.24	0.21	0.205
4. Occupational health and safety management	0.20	0.32	0.25	0.259
5. Safety practices	0.33	0.54	0.42	0.427
6. Annual number of accidents	0.47	0.14	0.34	0.314
7. Right of stakeholder	0.61	0.81	0.68	0.647
8. Stakeholder relations	0.44	0.19	0.35	0.353
9. Gender diversity	0.13	0.15	0.14	0.133
10. Child labour	0.37	0.20	0.29	0.234
11. Color	0.37	0.20	0.28	0.269
12. National Origin	0.36	0.39	0.37	0.380
13. Ethnic	0.37	0.34	0.35	0.350
14. Wages	0.30	0.33	0.35	0.358
15. Working hours	0.26	0.25	0.26	0.218
16. Contract labour	0.39	0.42	0.40	0.424
17. Training of Employee	0.25	0.22	0.24	0.25

4. Case study

4.1. Case description

A case study is considered for an actual project in Egypt, which is performed by a multinational construction company as the main subcontractor. The project has a positive economic, social and, environmental impact. The significant benefits have illustrated below: 1) the project meets Egyptian and International Environmental Standards to protect the well-being of people and the environment surrounding the facility; 2) the project sponsors community social/health programs for women and children; 3) Working with community NGOs, the project will support socio-economic development; 4) providing 10,000 jobs during the construction phase and more than 700 positions during the operation phase, and 5) providing local community area with Schools, and teachers to deliver advance development throughout the phases of construction and operation.

4.2. Running the model

The model was shared with the project manager of the project in Orascom construction company. The project manager suggested that S1 represent Country 1 workers' supplier in the proposed model, whereas, S2 to represent the Country 2 workers' supplier in the proposed model. Then, the model was explained to the project manager with detail descriptions of social performance indicators. After that, the project manager was asked to rate the supplier's performance against each social indicator with a scale from one to five. Further, score one indicates the least performance while five indicates the highest performance as listed in Table 3.

After the decision matrix is formed and the performance score is performed by the decision-maker in the first step of the model, the normalized matrix is created through calculations using Equation (5). To clarify, the square of the decision judgement is obtained for each supplier in order to get the normalized decision matrix. The normalized decisions for the two suppliers can be obtained by finding the total summation of each row and applied Equation (1).

Then, Table 4 lists a weighted normalized decision matrix for TOPSIS. Through this MCDM computational model (AHP-TOPSIS), the positive and negative ideal solutions for each attribute are defined in this table as well. The calculations of the weighted normalized matrix are implemented according to Equation (6). Additionally, the calculations of the +ve and -ve ideal solution are performed according to Equations (3) and (4), respectively. To clarify, the weighted normalized matrix can be obtained through multiplying each attribute weight by normalized decision

Table 3
Score generated by ERC project manager.

ID	Attributes	Weights	Score	
			S1	S2
1	Rights of stakeholder	0.125	4	3
2	Safety practices	0.083	5	2
3	contract labour	0.082	5	3
4	National origin	0.074	4	4
5	Wages	0.069	5	3
6	Stakeholder relation	0.068	2	5
7	Ethnic	0.068	5	3
8	Annual number of accidents	0.061	5	3
9	Color	0.228	5	3
10	Occupational health and safety management system	0.05	4	2
11	Technical training of employee	0.05	2	2
12	Child labour	0.05	5	5
13	Working hours	0.04	4	3
14	Social management commitment	0.04	3	1
15	Social code of conduct	0.04	4	2
16	Donation for sustainable projects	0.03	1	1
17	Gender diversity	0.03	5	1

Table 4
Weighted normalized decision matrix.

ID	Attributes	Normalized Score		Weighted Normalized Score		A+	A-
		S 1	S 2	S1	S2		
1	Rights of stakeholder	0.8	0.6	0.1	0.08	0.10	0.08
2	Safety practices	0.93	0.37	0.08	0.03	0.08	0.03
3	Contract labour	0.86	0.51	0.07	0.04	0.07	0.04
4	National origin	0.1	0.71	0.05	0.05	0.05	0.05
5	Wages	0.86	0.51	0.06	0.04	0.06	0.04
6	Stakeholder relation	0.37	0.93	0.03	0.06	0.06	0.03
7	Ethnic	0.86	0.51	0.06	0.03	0.06	0.03
8	Annual number of accidents	0.86	0.51	0.05	0.03	0.05	0.03
9	Color	0.86	0.51	0.20	0.12	0.20	0.12
10	Occupational health and safety management system	0.89	0.45	0.04	0.02	0.04	0.02
11	Technical training of employee	0.71	0.71	0.03	0.03	0.03	0.03
12	Child labour	0.71	0.71	0.03	0.03	0.03	0.03
13	Working hours	0.8	0.6	0.03	0.03	0.03	0.03
14	Social management commitment	0.95	0.32	0.04	0.01	0.04	0.01
15	Social code of conduct	0.98	0.45	0.04	0.02	0.04	0.02
16	Donation for sustainable projects	0.71	0.71	0.02	0.02	0.02	0.02
17	Gender diversity	0.98	0.2	0.03	0.01	0.03	0.01

for each supplier against each attribute. On the other hand, Table 5 describes the separation of each supplier from the positive and negative ideal solutions for each attribute. Specifically, it indicates the contribution of each attribute to the total separation from the positive and negative ideal solutions. Also, the separation from the ideal negative solution for both suppliers can be obtained by getting the square root for the sum of each column elements.

Fig. 3 illustrates the spider diagram for supplier's separation from the negative ideal solution and the positive ideal solution. S1 describes evidence that it is separated from the ideal negative solution at both of social management commitment, rights of stakeholder, safety practice, wages, and color attributes. On the other hand, S2 is separated from the ideal negative solution at the stakeholder relations, rights of stakeholder, and color attributes. Hence, the worst-case scenario for the negative ideal solution is to be S1. Consequently, S1 is considered the best scenario for the positive ideal solution. The project manager rated the two suppliers from two different countries as; Supplier number 1 scored 0.75 and rated 1 in social performance then, Supplier number 2 with the social score of

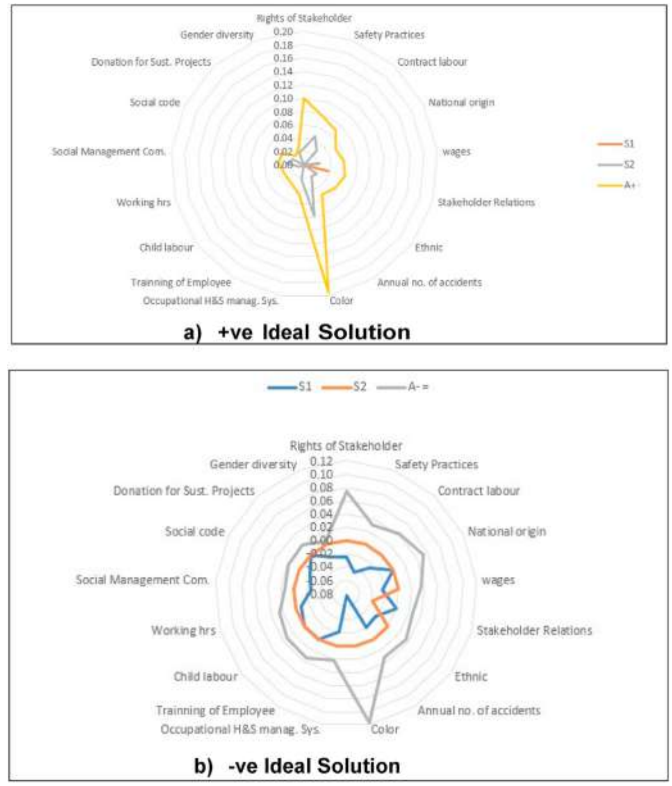

Fig. 3. Separation from the positive and negative ideal solutions for attributes.

0. This social performance and/or supplier ranking has been delivered according to the calculations of the closeness coefficient as shown in Table 6.

Table 6
Final supplier ranking.

	Sum. of S+ and S-	Performance	Rank	Comment
Supplier 1	0.1530	0.75	1	Ideal + ve Supplier
Supplier 2	0.1530	0.25	2	Ideal -ve Supplier

Table 5
Distance from ideal + ve & -ve solution.

ID	Attributes	Ideal + ve Solution				Ideal -ve Solution			
		(A+)-(S1)	(A+)-(S2)	S1	S2	(A-)-(S1)	(A-)-(S2)	S1	S2
1	Rights of stakeholder	0.00	0.03	0.00	0.00063	−0.03	0.00	0.001	0.00
2	Safety practices	0.00	0.05	0.00	0.002	−0.05	0.00	0.002	0.00
3	contract labour	0.00	0.03	0.00	0.001	−0.03	0.00	0.001	0.00
4	National origin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Wages	0.00	0.02	0.00	0.001	−0.02	0.00	0.001	0.00
6	Stakeholder relation	0.04	0.00	0.001	0.00	0.00	0.00	0.00	0.0014
7	Ethnic	0.00	0.02	0.00	0.001	−0.02	0.00	0.001	0.000
8	Annual number of accidents	0.00	0.02	0.00	0.00	−0.02	0.00	0.00	0.00
9	Color	0.00	0.08	0.00	0.006	−0.08	0.00	0.006	0.000
10	Occupational health and safety management system	0.00	0.02	0.00	0.0005	−0.02	0.00	0.001	0.0000
11	Technical training of employee	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Child labour	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	Working hours	0.00	0.01	0.00	0.00	−0.01	0.00	0.00	0.00
14	Social management commitment	0.00	0.03	0.00	0.001	−0.03	0.00	0.001	0.000
15	Social code of conduct	0.00	0.02	0.00	0.0003	−0.02	0.00	0.00	0.00
16	Donation for sustainable projects	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Gender diversity	0.00	0.02	0.00	0.0004	−0.02	0.00	0.00	0.0004
		Sum.		**0.0014**	**0.0132**	**Sum.**		**0.0013**	**0.0014**
		Distance (S + ve)		**0.038**	**0.115**	**Distance (S-ve)**		**0.115**	**0.038**

4.3. Sensitivity analysis

Sensitivity analysis is conducted to study the impact of changing attributes' weights on the selected suppliers and to ensure stability of the results. The first scenario (analyzed before) which is the base case has all three social criteria C1, C2, C3 and attribute A1. In the second scenario, the criterion of the stakeholder involvement with its attributes and the technical training of the employee attribute are excluded from the hierarchy. In third scenario, the attribute of technical training of employee and criterion of health and safety are also eliminated with all attributes. Consequently, any excluded criteria from the hierarchy have been followed by the same exclusion from the proposed computational model. In the fourth scenario, the social strategy criterion is eliminated besides the technical training of the employee. Finally, for the fifth scenario, both of the social strategy and health and safety criteria are reduced. Also, the weights of the attributes in each scenario are determined to satisfy the condition of AHP which is $\sum W = 1$. Table 7 lists the changing of attributes' weights through the normalization process with respect to the changing of social attributes for each scenario.

Table 8 lists the suppliers ranking which is associated with the changing of social indicators for level one in according to each scenario. As a result of this analysis, Supplier 1 has a closeness coefficient value more than Supplier 2 in most scenarios. Moreover, Fig. 4 illustrates the line graph of the five scenarios of the social performance for the two suppliers according to the closeness coe_cient calculations. Overall, in the first four scenarios, Supplier 1 was the highest-ranked social sustainable performance, which was replaced by Supplier 2 in the last scenario. With regards to the social performance of Supplier 1, it began with closeness coefficient equals 0.75 at Scenario 1, then peaked to the value that equals 1 in Scenario 2, before falling dramatically to about 0.63, 0.61, and 0.4 at Scenario 3, 4, and 5, respectively. On the other hand, the social performance of Supplier 2 dropped over the first two scenarios from 0.25 to 0, while it increased to be 0.37, 0.39, and 0.6 at Scenario 3, 4, and 5, respectively.

Table 7
Scenarios weights.

ID	Attributes	Scenario 2	3	4	5
1	Rights of stakeholder	0	0.17	0.32	0.52
2	Safety practices	0.11	0	0.21	0
3	contract labour	0.11	0.11	0	0
4	National origin	0.1	0.1	0	0
5	Wages	0.09	0.09	0	0
6	Stakeholder relation	0	0.09	0.18	0.28
7	Ethnic	0.09	0.09	0	0
8	Annual number of accidents	0.08	0	0.16	0
9	Color	0.07	0.07	0	0
10	Occupational health and safety management system	0.07	0	0.13	0
11	Technical training of employee	0	0	0	0.2
12	Child labour	0.06	0.06	0	0
13	Working hours	0.06	0.06	0	0
14	Social management commitment	0.05	0.05	0	0
15	Social code of conduct	0.05	0.05	0	0
16	Donation for sustainable projects	0.03	0.03	0	0
17	Gender diversity	0.03	0.03	0	0
Sum		1.00	1.00	1.00	1.00

Table 8
Suppliers rank in different scenarios.

Scenario	Social Indicator	Suppliers Rank
1	**C1, C2, C3, A1**	**S1 > S2**
2	**C1, C2**	**S1 > S2**
3	**C1, C3**	**S1 > S2**
4	**C2, C3**	**S1 > S2**
5	**C3, A1**	**S2 > S1**

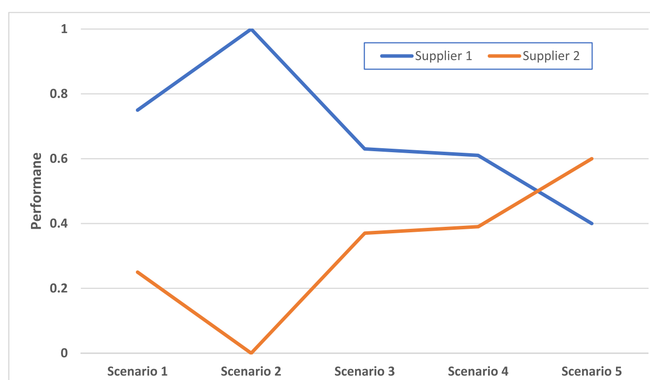

Fig. 4. Sensitivity analysis for the social performance of suppliers.

5. Conclusions

This research identified social sustainability indicators for supplier selection and clustered them into criteria, sub-criteria, and attributes. Through the literature, this objective was achieved during the previous studies' reviews where the research was for the most important and top ten social sustainability indicators for supplier selection. Then, during the unstructured interviews which have been conducted through the study phases, the experts added other social indicators to become 23 indicators. Moreover, the literature is reviewed to present previous studies for social sustainability indicators in different countries as well as social sustainability indicators in the supply chain. Supplier assessment models in the construction supply chain were reviewed in the previous studies to select the appropriate tools which could be used in the research model. Based on literature findings, four main groups are effective enough to be the main criteria of socially sustainable supplier assessment in the construction supply chain. Additionally, three sub-criteria and 17 attributes were categorized under these groups which were clustered through the unstructured interviews in a generic hierarchy of social sustainability metrics in order to facilitate the criteria weight calculations.

A list of social metrics as a social sustainability qualification to support the decision-making process in the construction supply chain. This was achieved by conducting structured interviews with professional experts in order to obtain the criteria weight. Further, developing the questionnaire survey was introduced to facilitate the judgement of professional experts through structured interviews which were conducted with professional experts. Hence, a computational model consists of two techniques which are AHP and TOPSIS. AHP was utilized to obtain the social criteria weights taking into consideration the check of consistency that is required to validate the AHP model. Also, conducting several rounds to check the consistency for all professional experts to test the results and produce perfect consistency as well. Whereas TOPSIS model is developed to rank the alternatives according to the distance from the positive ideal solution and the negative ideal solution. As a result, multi-criteria decision-making model is performed to get the optimum socially sustainable supplier who has the most positive impact on society. A case study was worked out to illustrate the use of the proposed model, considering two suppliers. Sensitivity analysis was conducted to study the impact of changing attributes' weights on the selected suppliers and to ensure stability of the results. Five scenarios were considered in the study and the results revealed that Supplier 1 was the highest-ranked social sustainable performance in four scenarios.

This research can be extended in the future to incorporate the uncertainty that might be associated with the attributes by using Fuzzy-TOPSIS and Fuzzy-AHP. Also, the social sustainability qualification aspects can be further investigated in the different types of construction projects to identify the list of social metrics that suit each type of the project.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Accord, B., 2005. Conclusions of Ministerial Informal on Sustainable Communities in Europe. Office of the Deputy PrimeMinister, UK Presidency.

Bai, C., Sarkis, J., 2010. Integrating sustainability into supplier selection with grey system and rough set methodologies. Int. J. Prod. Econ. 124 (1), 252–264.

Baskaran, V., Nachiappan, S., Rahman, S., 2012. Indian textile suppliers' sustainability evaluation using the grey approach. Int. J. Prod. Econ. 135 (2), 647–658.

Brent, A., Labuschagne, C., 2006. Social indicators for sustainable project and technology life cycle management in the process industry (13 pp+ 4). Int. J. Life Cycle Assess. 11 (1), 3–15.

Chaharsooghi, S.K., Ashrafi, M., 2014. Sustainable supplier performance evaluation and selection with neofuzzy TOPSIS method. International scholarly research notices, 2014.

Ciliberti, F., Pontrandolfo, P., Scozzi, B., 2008. Logistics social responsibility: standard adoption and practices in Italian companies. Int. J. Prod. Econ. 113 (1), 88–106.

Cousins, P.D., Lawson, B., Squire, B., 2006. Supply chain management: theory and practice–the emergence of an academic discipline? Int. J. Oper. Prod. Manag. 26 (7), 697–702.

Dempsey, N., Bramley, G., Power, S., Brown, C., 2011. The social dimension of sustainable development: defining urban social sustainability. Sustain. Dev. 19 (5), 289–300.

Dowlatshahi, S., 2000. Designer–buyer–supplier interface: theory versus practice. Int. J. Prod. Econ. 63 (2), 111–130.

Esfahbodi, A., Zhang, Y., Watson, G., 2016. Sustainable supply chain management in emerging economies: trade-offs between environmental and cost performance. Int. J. Prod. Econ. 181, 350–366.

Fichtner, J., 1986. On deriving priority vectors from matrices of pairwise comparisons. Soc. Econ. Plann. Sci. 20 (6), 341–345.

Forsman, L., Jonsson, S., 2016. Addressing Social Sustainability in Residential Development-An Analysis of a Residential Developer and Two Municipalities in Sweden.

Greenhouse, S., 2013. Retailers Are Pressed on Safety at Factories. The New York Times available at: www.nytimes.com/2013/05/11/business/global/clothing-retailers-pressed-on-bangladesh-factory-safety. html (Accessed June 14, 2019).

Griessler, E., Littig, B., 2005. Social sustainability: a catchword between political pragmatism and social theory. Int. J. Sustain. Dev. 8 (1/2), 65–79.

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E.K., Turskis, Z., Antucheviciene, J., 2021. Determination of objective weights using a new method based on the removal effects of criteria (MEREC). Symmetry 13 (4), 525.

Kochkina, M.V., Karamyshev, A.N., Isavnin, A.G., Makhmutov, I.I., Rozencvajg, A.K., 2017. Modified multi-criteria decision making method development based on" AHP" and" TOPSIS" methods using probabilistic interval estimates. Turkish Online Journal of Design Art and Communication 7, 1663–1674.

Köksal, D., Strähle, J., Müller, M., 2018. Social sustainability in apparel supply chains—the role of the sourcing intermediary in a developing country. Sustainability 10 (4), 1039.

Koufteros, X., Vickery, S.K., Dröge, C., 2012. The effects of strategic supplier selection on buyer competitive perfor- mance in matched domains: does supplier integration mediate the relationships? J. Supply Chain Manag. 48 (2), 93–115.

Krause, D.R., Scannell, T.V., Calantone, R.J., 2000. A structural analysis of the effectiveness of buying firms' strategies to improve supplier performance. Decis. Sci. J. 31 (1), 33–55.

Kwong, C., Ip, W., Chan, J., 2002. Combining scoring method and fuzzy expert systems approach to supplier assessment: a case studies. Integrated Manuf. Syst. 13 (7), 512–519.

Labuschagne, C., Brent, A.C., Van Erck, R.P., 2005. Assessing the sustainability performances of industries. J. Clean. Prod. 13 (4), 373–385.

Leire, C., Mont, O., 2010. The implementation of socially responsible purchasing. Corp. Soc. Responsib. Environ. Manag. 17 (1), 27–39.

Liu, S., Kasturiratne, D., Moizer, J., 2012. A hub-and-spoke model for multi-dimensional integration of green marketing and sustainable supply chain management. Ind. Market. Manag. 41 (4), 581–588.

Mani, V., Gunasekaran, A., Papadopoulos, T., Hazen, B., Dubey, R., 2016. Supply chain social sustainability for developing nations: evidence from India. Resour. Conserv. Recycl. 111, 42–52.

Manzini, R., Accorsi, R., 2013. The new conceptual framework for food supply chain assessment. J. Food Eng. 115 (2), 251–263.

Marshall, D., McCarthy, L., Claudy, M., McGrath, P., 2019. Piggy in the middle: how direct customer power affects first-tier suppliers' adoption of socially responsible procurement practices and performance. J. Bus. Ethics 154 (4), 1081–1102.

McKenzie, S., 2004. Social Sustainability: towards Some Definitions.

McWilliams, A., Siegel, D., 2001. Corporate social responsibility: a theory of the firm perspective. Acad. Manag. Rev. 26 (1), 117–127.

O'Riordan, L., Zmuda, P., Heinemann, S., 2015. New Perspectives on Corporate Social Responsibility: Locating the Missing Link. Springer.

Peng, X., Krishankumar, R., Ravichandran, K.S., 2021. A novel interval-valued fuzzy soft decision-making method based on CoCoSo and CRITIC for intelligent healthcare management evaluation. Soft Computing 25 (6), 4213–4241.

Plackett, R.L., 1958. Studies in the history of probability and statistics: VII. The principle of the arithmetic mean. Biometrika 45 (1–2), 130–135.

Ross, A.D., Parker, H., del Mar Benavides-Espinosa, M., Droge, C., 2012. Sustainability and supply chain infrastructure development. Manag. Decis. 50 (10), 1891–1910.

Rossi, P., Krey, N., 2018. Marketing Transformation: Marketing Practice in an Ever-Changing World: Proceedings of The2017 Academy of Marketing Science (AMS) World Marketing Congress (WMC). Springer.

Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 15 (3), 234–281.

Saaty, T.L., 1990. How to make a decision: the analytic hierarchy process. Eur. J. Oper. Res. 48 (1), 9–26.

Sarkis, J., 2012. A boundaries and flows perspective of green supply chain management. Supply Chain Manag.: Int. J. 17 (2), 202–216.

Schaltegger, S., Lüdeke-Freund, F., Hansen, E.G., 2011. Business Cases for Sustainability and the Role of Business Model Innovation: Developing a Conceptual Framework. Centre for Sustainability Management (CSM), Leuphana Universität Lüneburg.

Seuring, S., Müller, M., 2008a. From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16 (15), 1699–1710.

Seuring, S., Müller, M., 2008b. Core issues in sustainable supply chain management–a DELPHI study. Bus. Strat. Environ. 17 (8), 455–466.

Sierra, L.A., Yepes, V., Pellicer, E., 2018. A review of multi-criteria assessment of the social sustainability of infrastruc- tures. J. Clean. Prod. 187, 496–513.

Srivastava, S.K., 2007. Green supply-chain management: a state-of-the-art literature review. Int. J. Manag. Rev. 9 (1), 53–80.

Triantaphyllou, E., Shu, B., Sanchez, S.N., Ray, T., 1998. Multi-criteria decision making: an operations research approach. Encyclopedia of electrical and electronics engineering 15, 175–186, 1998.

Valdes-Vasquez, R., Klotz, L.E., 2012. Social sustainability considerations during planning and design: framework of processes for construction projects. J. Construct. Eng. Manag. 139 (1), 80–89.

Varsei, M., Soosay, C., Fahimnia, B., Sarkis, J., 2014. Framing sustainability performance of supply chains with multi-dimensional indicators. Supply Chain Manag.: Int. J. 19 (3), 242–257.

Yadav, A., Jayswal, S.C., 2013. Using geometric mean method of analytical hierarchy process for decision making in functional layout. Int. J. Eng. Res. Technol. 2, 775–780.

Yusuf, Y.Y., Gunasekaran, A., Musa, A., El-Berishy, N.M., Abubakar, T., Ambursa, H.M., 2013. The UK oil and gas supply chains: an empirical analysis of adoption of sustainable measures and performance outcomes. Int. J. Prod. Econ. 146 (2), 501–514.

Zuo, J., Zillante, G., Wilson, L., Davidson, K., Pullen, S., 2012. Sustainability policy of construction contractors: a review. Renew. Sustain. Energy Rev. 16 (6), 3910–3916.