Annals of Operations Research
https://doi.org/10.1007/s10479-023-05767-8

ORIGINAL RESEARCH

Integrating social sustainability into supplier evaluation using data envelopment analysis

Sharma Aashi[1] · **R. Rajesh**[2]

Received: 2 January 2023 / Accepted: 28 November 2023

Abstract
Multiple approaches are available for supplier selection and long term supplier development of any company. Data Envelopment Analysis (DEA) serves as a tool to measure maximum supplier efficiency based on any set of considered aspects. This study proposes a DEA model by integrating best possible criteria to the coherent framework for social sustainability based supplier selection. To this end, we analyse different Decision Making Units (DMUs) and compare the efficiency of each DMU with only the best one, so as to determine the most efficient one. This will eventually help in identifying the best supplier according to the aspects of social sustainability. A case evaluation of the proposed methodology has been conducted in the fast food supply chains and the best supplier was selected. Managers can use the proposed framework for supplier selection considering social sustainability for enhancing the overall sustainability capabilities of their supply chains. This research also points towards the importance of considering social sustainability and the related issues, right from the upstream of the supply chain. Considerations for the same can improve the capabilities of supply chain and can directly enhance the environmental, social, and governance performances of firms.

Keywords Data envelopment analysis (DEA) · Decision-making · ESG performance · Social sustainability · Supplier selection

1 Introduction

Sustainability has turned into a significant focal point of organizations, as consumers are mostly aware about the environmental and social aspects of businesses. Most of the assessment work concerning sustainability has been focused on the financial and environmental impact estimations and less thought has been paid to the social sections of sustainability

✉ R. Rajesh
rajeshambzha@gmail.com; rajesh@iimtrichy.ac.in

Sharma Aashi
aashisharma.adm@gmail.com

[1] Management Division, ABV- Indian Institute of Information Technology and Management (ABV-IIITM), Gwalior 474015, India

[2] Operations Management and Decision Sciences, Indian Institute of Management (IIM) Tiruchirappalli, Tiruchirappalli 620024, India

Published online: 16 December 2023

across the supply chains (Dai et al., 2021; Moktadir et al., 2021). The social part of sustainability in this assessment is fundamentally stressed over ensuring organizations to manage their businesses in a way that advances: prosperity and security, a consistent work area, normal freedoms standards, work opportunities, and measures that highlight the use of moral practices at the workplace (Govindan et al., 2021). Seeing the decreased focus of assessment on the social side of sustainability across organizations, we observe the need for assessment of the same, right from the supplier selection processes.

Considering a basic supply chain, the relationship between an organization and its suppliers is very important. The elements in a regular supply chain can connect the manufacturers, logistics, warehouses, and retailers. Supply chain managers seek to achieve for lower costs and quicker conception cycles for products (Jessin et al., 2023). For the case of developing economies, child labour can be a critical issue (Khan et al., 2021). The well-being and the security of the workers, along with managing issues related to child and bonded labour are essential for any global supply chains. Hence, organizations are supposed to upkeep the social sustainability standards of their suppliers at their operational levels (Bubicz et al., 2021; Walker et al., 2021). Assume, for instance, that an end customer for an item has identified that the manufacturer has sourced items from a supplier who has employed child labourers, then the customer may choose for an alternative possible option. Also, imagine that the end consumer for the product may be reluctant to buy a product, if children were employed as labourers in the assembly or in the parts handling of a product. Hence, manufactures are at the risk of global sourcing, particularly sourcing to low income economies (Toussaint et al., 2021). Accordingly, the manufacturer would need to guarantee that their supplier is consistent with this forbid utilization of children at work. These examples are portrayed to project the need for consideration of social sustainability into supplier selection problems.

Although the economic and environmental dimensions of sustainability are widely discussed in the literature on supplier selection. Supplier selection models considering social sustainability as the primary concern is rarely seen in the literature. Considering some works in the literature, Mani et al., (2014) focussed on the socially sustainable supplier selection and using the method of Analytic Hierarchy Process (AHP) to solve the same. They have considered several factors for including the social aspects of sustainability; including equity, safety, wages, health, education, philanthropy, child and bonded labour. Alternatively, Xu et al. (2013) considered the aspects of corporate social responsibility (CSR) into the supplier selection process. They have included several criteria, such as; issues related to human rights, child labor, female labor, hours of working, pollution, safeguard mechanisms, and other legal responsibilities of organizations.

Further to this, Govindan et al. (2018) considered the CSR practices in supplier selection. They have considered the key actors; such as shareholders, governments, customers, and community and their perspectives in to supplier selection processes and pointed the importance of considering CSR practices, while selecting vendors or suppliers. Thomas et al. (2021) in their studies observed the investments in philanthropy and social welfare measures. Based on signalling theory, they observed that buyers have typical preferences to trust, select, and collaborate with suppliers with significant investments in employee welfare, philanthropy, and pricing. They have also pointed based on different effect sizes that the conclusions on relations and the practical significances might vary. In a recent study by Rajesh and Aljabhan (2023), a sustainability framework for the selection of suppliers based on social sustainability aspects was proposed. They have proposed a two layered model for supplier selection using grey theory, where the primary performance attributes were also considered along with considerations for attributes of social sustainability.

Considering the major prior studies in literature depicting on the social aspects of sustainability into supplier selection processes, we understand the increasing need of consideration for social sustainability, right from the selection of suppliers so that the sustainability performances of the firms and its supply chain can be improved. This is the motivations for the study. Also, a supplier selection model that only considers the social aspects of sustainability can understand, evaluate and rank the suppliers based on their capabilities for social sustainability performances. Later, other performance attributes such as, quality, reliability, cost, responsiveness, and flexibility can be added into the supplier selection process to understand the best performing suppliers. The study objectives are to help managers in quantitatively selecting those suppliers that are good at social sustainability, along with considerations for other factors of supplier performances. Moreover, the use of non-parametric methods, such as; the Data Envelopment Analysis (DEA) for the supplier selection processes can help to determine the efficient frontiers so that the exactitude of decision-making can be enhanced.

We consider the problem of supplier selection for social sustainability and use the Data Envelopment Analysis (DEA) technique to measure the relative efficiency of Decision Making Units (DMUs) with multiple inputs and outputs. The methodology can enable managers to select the best suppliers based on their social sustainability performances. And the paper is further arranged as follows. Section 2 discusses the literature on aspects of social sustainability, importance of the problem. The social sustainability indicators of performance are shown in Section 3 and the methodology, and the implementation of the case are shown in Section 4. Section 5 presents the results and discussions, followed by the implications of the study in Section 6. Sections 7 presents the conclusions and future scope of the study.

2 Literature review

2.1 Social sustainability

Numerous researchers through their studies have attempted to characterize social maintainability. To give some examples; Langhelle (1999), Blanchet and Girois (2013). Sharma and Ruud (2003) portrayed social maintainability as human implied rules, which should be achieved in an unbiased, exhaustive and sensible way. Siche et al. (2008) described the meaning of social sensibility by saying: *"human health aspects are essential for the well-being of a society, but they should not be confused with environmental sustainability"*. In a layman language, social sustainability includes common freedoms, sensible work culture, living conditions, prosperity, security, wellbeing, group benefits, esteem, balance, etc. Anyways, well-disposed impact, or social legitimacy, issues are not actually quantifiable or genuinely quantifiable; they are less complex to perceive (Hearit, 1995).

Social sustainability is a frequently neglected part of sustainability; as practical advancement conversations frequently centre on the ecological or financial aspects of sustainability. Each of the three elements of sustainability should be addressed to achieve the sustainable competitive advantages (Barbosa-Póvoa et al., 2018). Social sustainability is achieved when the formal and casual cycles; frameworks; designs; and connections effectively support the people and families to build robust and resilient networks. Socially manageable networks must give a decent personal satisfaction. WACOSS, Western Australia Council of Social Services define social sustainability as a cycle for making manageable effective changes that advance prosperity, by figuring out what individuals need from the areas they live and work (McKenzie, 2004). Social sustainability consolidates the plan of the actual domain

with plan of the social world, including foundation to help society and social life, social conveniences, frameworks for resident commitment, and space for individuals and spots to develop (Eizenberg & Jabareen, 2017).

According to a business point of view, social sustainability is tied in with figuring out the effects of companies on individuals and society. In the triple bottom-line (TBL) model, social sustainability is considered as the most un-quantifiable piece of sustainability (Vallance et al., 2011). The TBL is a bookkeeping system of three sections: social, environmental and economic. The three viewpoints can interrelate to decide a company's exhibition. In enterprises, social sustainability execution issues can incorporate common freedoms, fair wages, day to day working environments, wellbeing, security, health, variety, value, balance between work and life, strengthening local area commitment, altruism, volunteerism, etc. (Dempsey et al., 2011). However social effect, or social sustainability, issues are not effectively quantifiable, as they are simpler to distinguish among themselves.

In one way, social sustainability is a proactive way of managing and identifying business impacts on employees, workers in the value chain, customers, and local communities (Missimer et al., 2017). Companies that raise the importance of social sustainability may recognize the significance of their relationships with people, communities and society. Social responsibility becomes a part of their core business strategy and they consider how their activities affect people (Magis, 2010). There is always a human cost to doing business. A socially sustainable business will consider the safety of its workers in a particular location (Woodcraft, 2015). Say for example, it will not allow its workers' safety to be compromised by forcing them to work in a building that has been deemed unsafe.

2.2 Social sustainability in the supply chain

Social sustainability looks for reformed methods of coordinating the human and social perspectives into the supply chain. This suggests shielding individuals from the impacts of objects and sequences that adversely sway a person's security, wellbeing and prosperity. With respect to the issues that should be tended to; numerous prominent researchers distinguished different social issues in the supply chain networks. Examples of which are, Emmelhainz and Adams (1999) portrayed the significance of common freedoms and work conditions in the supply networks. Carter and Jennings (2002) emphasized on wellbeing and security, variety, generosity, basic liberties, and morals. Pagell and Wu (2009) tended to the models and cases for sustainability and social sustainability and considered issues like, reasonable and impartial treatment, common liberties, and child and bonded labour, etc. Hutchins and Sutherland (2008) through their review distinguished different social boundaries and pointers like; wellbeing, security, generosity and value to quantify social indicators.

Comparative examination done by numerous different scientists demanded different social issues that included security, wellbeing, variety, working conditions, work practices, child and bonded labour, and its neediness in the supply chain. According to Nobel Laureate Amartya Sen, social sustainability has diverse dimensions (Sen, 2008). Although, several theories including the ecological economics focuses on the environmental and the economic aspects of sustainability, the social dimensions of the same are treated with lower priorities. But, sustainability in general is a balance between economy, environment, and the society. From the literature, we can see the representations of these dimensions in concentric circles to show the interdependence or by overlapping circles to show equal importance and interdependencies.

The major dimensions needed to be considered in determining, if a business or a project is socially sustainable are elaborated as follows.

2.2.1 Equity

Equity refers to the equitable opportunities and outcomes expected even for the employees at the lowest levels. Equity can be regarded as one of the most important components and which can be seen as a part of many other components. Equity ensures that there is least disparity among employees and workers in terms of living standards and prospects. The following sample questions can be answered to understand the level of importance for equity that a firm ascertains to their employees.

- Will firms distinguish the reasons for disservice and imbalance and search for ways of decreasing them?
- Will firms distinguish and intend to address the issues of especially distraught and underestimated individuals?
- Will firms ensure justice and right information be conveyed without inclination and advance reasonableness?

2.2.2 Diversity

Diversity is another major feature of sustainable communities, where firms are expected to perform focussing on diversity and diversification of resources. Diversity is closely associated to equity and inclusion and are values held by many organizations that are working to support individuals or groups of people including different religions, ethnicities, races culture, abilities, gender, and different sexual orientations. Some of the sample questions that can be answered to understand the level of diversity that a firm offer may include the following.

- Will firms perceive variety in recruitment and selection considering social, ethnic, racial, and sexual identities?
- Will firms take into consideration of assorted perspectives, convictions and values to be thought about?
- Will firms advance comprehension and acknowledgment of all communities and their inclusion in decision-making environments?

2.2.3 Social cohesion

In the context of development, social cohesion comes into picture, where this allows people to work together and respond to challenging situations by avoiding conflicts and promoting sustainable compromises. As such, social cohesion can be defined as the sense of shared purpose, trust, and willingness to cooperate among members of the same, as well as different groups and among the people for common good. A glimpse of the test questions that can be answered to understand the level of social cohesion that a firm offer may include the following.

- Will firms help the employees to develop a sense of belongingness in the broader community?

- Will firms encourage participation in social activities by individuals in the larger community?
- Will firms build links between their employees and other groups in the broader community?

2.2.4 Quality of life

Firms and organizations need to ensure that the fundamental needs of the individuals including the employees are met. This also focuses on providing quality of life to individuals, as well as groups considering a community level. Firms need to ensure that minimum wages and benefits to their employees, including health insurance, stock options, or any other welfare measures, time to time. The firms can also ensure fair and performance based wage compensation plans, along with employee benefits, such as life insurance, medical reimbursements, retirement plans, insurance for disabled, etc. are implemented and are included in the policy norms of the firms. The following sample questions can be answered to justify the level of importance for quality of life that a firm make certain to their employees.

- Will firms execute plans for developing the health and wellbeing of their employees and family?
- Will firms develop plans for emotional wellness among employees and workers?
- Will firms develop schooling and conduct other ability improvement programs for their employees and family?

2.3 Socially sustainable supplier selection

Supplier selection, evaluation, and reviewing are definitely more significant activity in any supply chains (Sarkis & Talluri, 2002). It is likewise clear that emphasis on responsive measurements for social sustainability in the supply chains has been in suppression for quite a while and much should be done in this direction (Thomas et al., 2021). As we see, increased global relations, adhering to their exchanging power, combined with control on inventory and supply chains competitiveness can make suppliers a vital element in a supply chain.

Because of the untrustworthy practices that have arisen across the different supply chains during the most recent couple of years, it isn't actually to be expected that different partner groups stand out to checking supply chains' activities all the more intently. Customer pressure has been perceived as a significant main thrust for the reception of social measures of sustainability across the supply chain (Mani et al., 2014). A great area of worry for customers has been the significance of laying out a legitimate workplace and fair work regulations across the activities of supply chain partners. Customers' fulfilment rouses associations to take on and expand the various parts of social sustainability and its considerations across their supply chains, including the supplier selection processes (Ehrgott et al., 2011a, 2011b). Extended customer awareness can impact the reliability and validity of the whole supply chain processes and the entire business. Subsequently, there is a developing need to plan a sustainability proposal that adjusts the tasks of departments (purchasing, operations, and so on), while incorporating customers' and partners' assumptions with the organization's sustainability plan.

Albeit governmental guidelines definitely stand out enough to be noticed in the writing, most developed countries as of now have all around settled in regulations and guideline to help the points of the social component of sustainability. The UN Global Compact was created to energize and uphold financial, social and ecological sustainability, particularly among

emerging countries (Williams, 2004). The paper recommends that there is an absence of regulation and guidelines to help the execution of the social component of sustainability idea in its more extensive sense across emerging countries. In such manner, Najjar et al. (2020) recommend that while governments in emerging nations might come up short on capacity and drive to authorize such guidelines on neighbourhood suppliers, there is additionally the likelihood that there might be an absence of tension and requirement from supply chain allies in the more evolved nations.

Non-governmental associations (NGOs) like the Fair Labour Association (FLA) have likewise arisen during the most recent couple of years. They screen denials of basic liberties across the tasks of supply chain partners and can go about as a guardian, invigorating organizations to take on the social parts of sustainability across their total supply chains. One of the significant outcomes of the worldwide scattering of suppliers is that numerous associations view these NGOs as an essential source to act as autonomous bodies for observing the social sustainability practices and execution of their supply chain accomplices (Davidson, 2009). Since revelations in NGO reports can impact a business organization's existence, numerous suppliers will help out the NGOs and make any proffered changes in accordance with their practices.

Koberg and Longoni (2019) featured that organizational connection and coordinated effort with NGOs can prompt positive sustainability results across worldwide supply chains. Investors may likewise assume a rudimentary part in an organization's choice to take on the various parts of the social component of sustainability. Investors might influence the focus of the organization, and accordingly they have huge ability to impact an organization's choice to embrace the different social components of sustainability. Also, investors these days accept the quest for sustainability as a significant essentiality of interest in an organization (Weingaertner & Moberg, 2014). Moreover, they seem, by all accounts, to be abler to put resources into an organization, whose sustainability pointers have key significance.

Considering social sustainability and supplier selection, many factors have been considered and discussed in literature, where human rights, affordable housing, disparities in wages, child labour, bonded labour, gender equality, equity, discriminations, quality education, health care, working hours, and disciplinary actions are among the major factors considered. The indicators of social sustainability and the related works in literature are discussed in detail in the forthcoming section. A table of literature on the recent works in the related area of social sustainability based supplier selection are discussed in Table 1. Although, the social side of sustainability was being considered in supplier selection problems, a sole focus on the same is rarely seen in literature.

3 Social sustainability indicators

Reviewing the literature on social sustainability is important for the identification of the factors considered for supplier selection and evaluation. Najjar et al. (2020) focused on the social side of sustainability in the supply chain and pointed the dyadic manufacturer, supplier connections, and considered the degree to which consecutive upstream and downstream supply chain partners, and social parts of sustainability that a system should focus on. They concluded that sustainability endeavours the supply chains to progress and develop a dyadic purchaser supplier relationship to deal with the social side of sustainability. Mani et al., (2014) centres on socially responsible supplier selection and utilized the Analytic Hierarchy Process (AHP) method for supplier selection and evaluation. This selection was made based on several

Table 1 Literature on social sustainability based supplier selection

Sl. No	Author(s)	Area	Findings
1	Mani et al., (2014)	Addressed socially sustainable supplier selection problem using AHP	Provided guidelines for manufacturers in emerging economies for selection of suppliers
2	Xu et al. (2013)	Analysed the criteria for selection of suppliers considering corporate social responsibility	Using AHP, the seven considered criteria were ranked based on their relative importance to practitioners
3	Govindan et al. (2018)	Proposed methodology for selection of suppliers based on corporate social responsibility practices and identified key actors	Provided guidelines for effective integration of corporate social responsibility in supply chains, particularly for supplier selection
4	Rajesh and Aljabhan (2023)	Proposed a sustainability based framework to identify the factors of supplier selection considering social sustainability	Provided a stratified approach for supplier selection considering social factors of sustainability along with other factors for selection
5	Thomas et al. (2021)	Decomposed dimensions of social sustainability into employee welfare and philanthropy for supplier selection	Observed that trusting relations are developed among partners, who have desired levels of employee welfare, philanthropy, and pricing
6	Zimmer et al. (2016)	Analysed the decision-making models for sustainable supplier selection, monitoring, and development	Pointed on the predominance of Analytic Hierarchy Process, Analytic Network Process, and other fuzzy based approaches in supplier selection
7	Marzouk et al. (2021)	Identified the critical prequalification criteria for supplier selection in construction, considering social sustainability	Developed and evaluated a computational model for the construction industry for prequalification of suppliers
8	Ehrgott and et al., (2011a, 2011b)	Used stakeholder theory to analyse how pressures from various stakeholders' can influence firms to consider the social aspects of sustainability in supplier selection	Analysed how the process of socially sustainable supplier selection can relate to firm capabilities, market reputation, and learning of organizations

Table 1 (continued)

Sl. No	Author(s)	Area	Findings
9	Bai et al. (2019)	Proposed an attribute decision framework considering social sustainability for supplier evaluation and selection	Used a grey based best worst method and TODIM for ranking suppliers of manufacturing firms
10	Jain and Singh (2020)	Developed a two stage fuzzy interface system for selection of sustainable suppliers in large scale industries	The proposed fuzzy interface system was practically employed for the selection of suppliers in iron and steel industry
11	Wu et al. (2021)	Proposed a model for evaluating the selection of sustainable suppliers considering each triple bottom-line dimensions	Argued that though their implemented model in chemical industry, managers could select sustainable suppliers, quickly respond to marker demands, and improve market competitiveness
12	Fallahpour et al. (2021)	Developed an integrated model for considering the criteria of sustainability and Industry 4.0 into supplier selection process	Tested the developed fuzzy interface system for evaluating suppliers' performance, considering the criteria of Industry 4.0 and sustainability

social sustainability indictors, including value, wellbeing, security, compensation, training, altruism, child and bonded labour, etc. They pointed that except if the top management are able to create social boundaries in the supply chain, accomplishing social sustainability and building sustainable societies will be extremely challenging.

The present study incorporates a supplier selection problem considering the interaction by which firms distinguish, assess, and contract with suppliers. We incorporate a Data Envelopment Analysis (DEA) model for the integration and evaluation supplier performance for social sustainability. Also, we develop a pragmatic approach for firms to use the methodology for including supplier evaluation, selection, monitoring, and improvement processes. Expansion of the tool to include other decision criteria of environmental and economic aspects into decision-making can be easily completed. We have compared each Decision Making Unit (DMU) with only the best one, so as to determine the most efficient supplier considering social sustainability performances. The indicators of social sustainability into supplier selection process are identified form the vast literature and it includes equity, health, safety, wages, education, philanthropy, child and bonded labour, which are detailed as follows.

- Equity: It suggests fair admittance to job, instruction, and assets; full cooperation in the political and social existence of the local area; and self-assurance in addressing principal needs.
- Health: For advancement to be sustainable, it should meet fundamental human necessities like positions, food, energy, water and sterilization. The essential human necessities are named as: lodging, water supply, sterilization and medical care.

- Safety: This implies that organizations can't be supportable without safeguarding the security, wellbeing, and government assistance of their most imperative asset, the labourers.
- Wages: Every single person who works has the honour of fair pay, ensuring for him as well as his beneficiaries a standard living environment and also various beneficial plans including for retirement. Collective dealing, employment security, working time, work and family balance completely go under this part.
- Education: Sustainability training incorporates all areas of work and training and stretches out a long way past the study hall. It gives alternate genuine abilities and trainings, so as they can use to work in the real world.
- Philanthropy: Philanthropy is portrayed as lifting and attempting to accomplish social change by fundamentally committing substantial investments and related responsibilities.
- Child and bonded labour: Child labour alludes to the peculiarity of youngsters working in states of subjugation to take care of an obligation. Under any circumstances, child labour is a culpable offense for the business.

A pictorial view of the attributes of social sustainability considered for supplier selection is indicated in Fig. 1.

4 Research methodology and case implementation

We use the Data Envelopment Analysis (DEA) for finding the best suppliers for a case supply chain considering the fast food industry. DEA enjoys several benefits, of which some of them are as per the following: DEA is a basic and simple methodology utilizing the information and prior data to calculate the efficiency of decision-making units (DMUs) (Boussofiane et al., 1991; Wei, 2001). Although several methods are available for performance evaluations and prediction (Mahmoudi & Javed, 2022; Rajesh, 2023a, 2023b, 2023c, 2023d), popular methodologies like regression analysis, neural networks and multi-criteria decision-making techniques were frequently used in prior literature. This methodology (DEA) utilizes genuine and reasonable information collection of the decision-making units (Kohl et al., 2019; Xu et al., 2020). The classical DEA model and the revised DEA model used in this study are detailed. The methodologies for the selection of suppliers considering the attributes of social sustainability using the DEA based approach are indicated in Fig. 2.

In the DEA model, the non-beneficial attributes form the inputs and the beneficial attributes can form the output. For our study, we have two non-beneficial attributes known as inputs and rest are beneficial attributes, known as output. Inputs in this case are the cost and the quality rating, and outputs can be the social sustainability indicators including equity, health, safety, wages, education, philanthropy, child and bonded labour, which are having positive impacts.

- Equity: Is the employer providing fair access to livelihood, education, and resources?
- Health: Is the employer meeting essential human needs such as food, energy, water and sanitation?
- Safety: Is the employer ensuring physical safety, which includes physical & mental well-being of employees?
- Wages: Is the employer providing favourable remuneration and nor exploiting in terms of working hours?
- Education: Is the employer giving proper training to employees with machinery, technical systems etc.?
- Philanthropy: Is the employer providing any financial aid to those in need?

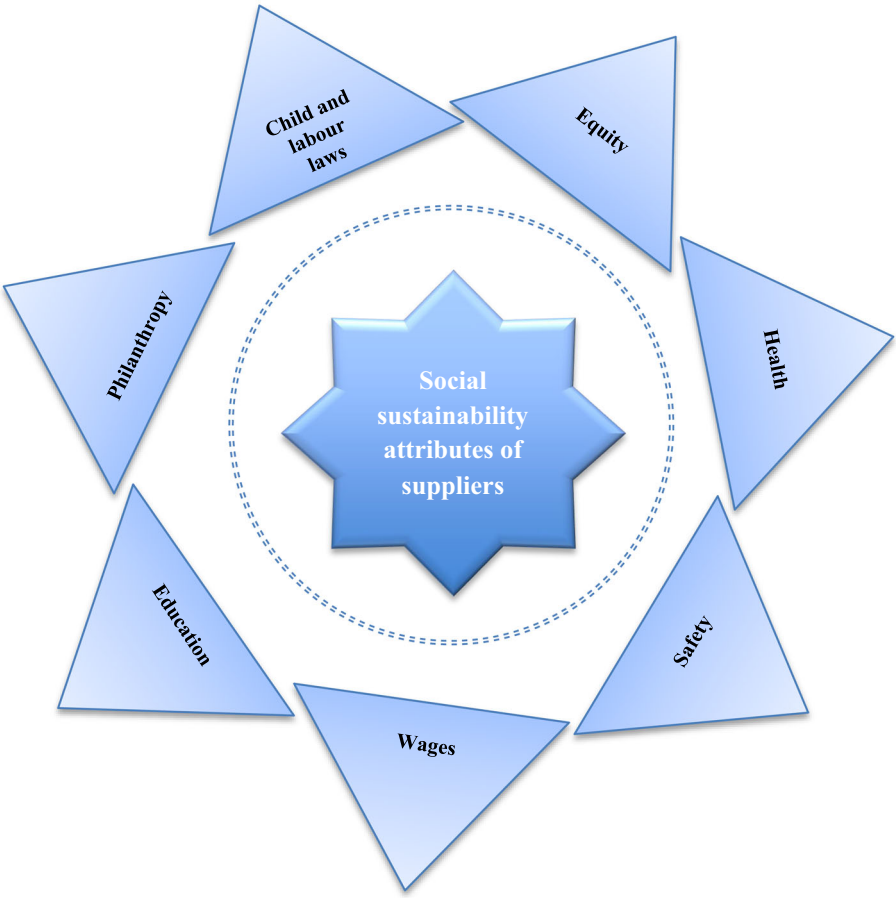

Fig. 1 Attributes of social sustainability considered for supplier selection

- Child and bonded labour: Is the employer following child and bonded labour norms and laws?

For our study, we have taken into account of the food venture, *McDonald's*. We select 4 particular suppliers for the case and rate their performances in the chosen attributes, through expert opinion and brainstorming. For this, five managers of leading fast food providers, the McDonalds were selected. These managers of the *McDonald's* were engaged to rate the available four suppliers on the basis of social sustainability domains considering Likert scales of 1—5. The scale is indicated below.

1. Very poor
2. Poor
3. Average
4. Good
5. Very good

We have selected the suppliers of cheese and vegetables, where they supply their products to all major food ventures in India including McDonald's and Burger King. These suppliers

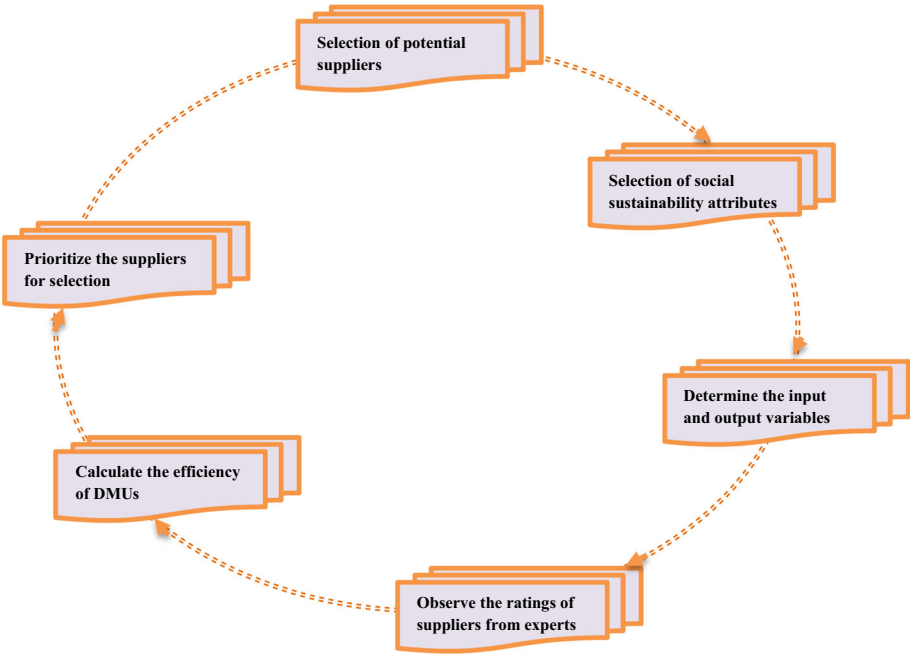

Fig. 2 Methodology for selection of suppliers for social sustainability

are the Dairy Craft, Delhi; Schreiber Dynamix, Fazilka; Finns Frozen Foods, Nasik; and the Jain Foods, Jalgaon. The selected managers were required to rate the performances of these suppliers in terms of their social sustainability performances and the cost was measured based on the actual cost by which these suppliers deliver their products. Through aggregate regularization of the responses, the authors observe the matrix comprising of the initial feedback of the suppliers. This is indicated in Table 2. The ratings for the benefit and cost attributes are graphically shown in Fig. 3.

DEA models can analyse the information and process the results through enhancing computation and through optimization. In view of that, units can be categorized as efficient and

Table 2 Suppliers' ratings on social sustainability attributes

Indicator	Dairy craft, Delhi	Schreiber dynamix, Fazilka	Finns frozen foods, Nasik	Jain foods, Jalgaon
Equity	3	4	4	3
Health	2	4	4	3
Safety	3	4	3	2
Wages	5	3	4	4
Education	4	4	4	3
Philanthropy	3	3	4	3
Child and Labour Laws	5	5	5	2

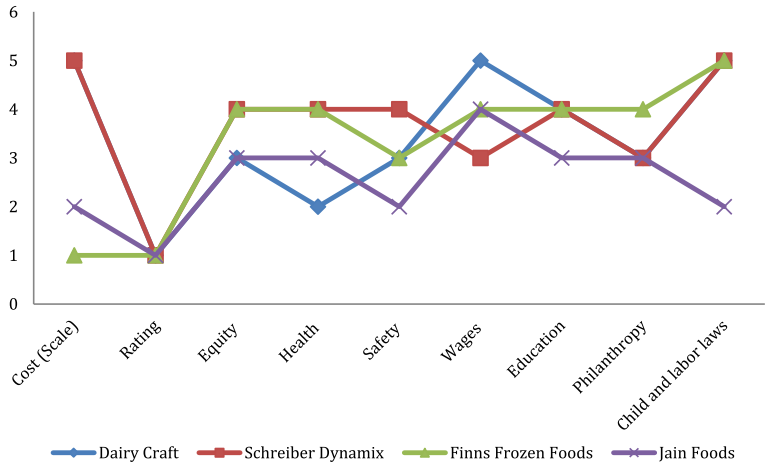

Fig. 3 Trends in the attribute ratings of four suppliers

inefficient based on their relative efficiencies. As the two products, cheese and vegetables cannot be compared price-wise, we take rating as the measure. Also the actual prices of items are included as criteria in relative scales into the evaluation process. Based on the feedback from the five select managers, we observe the suppliers into 5 categories, indicated below, based on their cost considerations.

1. Economical
2. Can be economical
3. Moderate
4. Expensive
5. Very expensive

We calculate the efficiency of the Decision Making Units (DMUs) using Eqs. (1)–(5).

$$\text{Efficiency} = \text{Weighted Output/Weighted Input, where} \tag{1}$$

$$\text{Weighted Output} = \Sigma(\text{output}) * (\text{weight}), \text{ and} \tag{2}$$

$$\text{Weighted Input} = \Sigma(\text{input}) * (\text{weight}). \tag{3}$$

The relative efficiency of DMUs can be calculated using the following formula, where

$$\text{Relative Efficiency} = \text{Efficiency/Base, where} \tag{4}$$

$$\text{Base} = \text{DMU with highest efficiency.} \tag{5}$$

For the considered case, K = number of DMUs (suppliers) = 4; the responses are aggregated and the input and output parameters are also noted, where; m = number of output = 7, n = number of input criteria = 1. A general output oriented DEA model can be represented in the following form, the efficiency of the j^{th} DMU can be calculated as follows.

$$\max \phi_j = \frac{\sum_{m=1}^{M} y_m^j u_m^j}{\sum_{n=1}^{N} x_n^j v_n^j}, \text{ where} \tag{6}$$

$$\frac{\sum_{m=1}^{M} y_m^k u_m^j}{\sum_{n=1}^{N} x_n^k v_n^j} \leq 1; k = 1, 2, \ldots, K.$$

We construct a maximization of output based DEA model, indicated as.

$$g(k) = \max(\phi) \tag{7}$$

5 Results and discussion

We have implemented the DEA model and the best supplier was selected based on their performances in social sustainability. Firstly, the objective function and the constraints are constructed for DMU 1 as follows. This is as per Eq. (6).

$$MaxZ = \frac{3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7}{5v_1 + 1v_2}$$

Subject to;

$$\frac{3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7}{5v_1 + 1v_2} \leq 1;$$
$$\frac{4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7}{5v_1 + 1v_2} \leq 1;$$
$$\frac{4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7}{1v_1 + 1v_2} \leq 1;$$
$$\frac{3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7}{2v_1 + 1v_2} \leq 1;$$

A fraction with decision variables in the numerator and denominator is nonlinear. Since we are using a linear programming technique, we need to linearize the formulation, such that the denominator of the objective function is 1, and then maximize the numerator. The new formulation would be:

$$MaxZ = 3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7$$

Denominator of nonlinear $5v_1 + 1v_2 = 1$

$$3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7 - 1v_1 - 1v_2 \leq 0;$$

$3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7 - 2v_1 - 1v_2 \leq 0$; and

$$u, v \geq 0$$

We obtain the solution as follows;

$$u_1 = 0; u_2 = 0; u_3 = 0; u_4 = 0.2; u_5 = 0; u_6 = 0; u_7 = 0; v_1 = 0.49; v_2 = 0.75.$$

Similarly, the objective functions and constraints are defined for DMU 2, DMU 3 and DMU 4, successively as follows.

For DMU 2;

$$MaxZ = 4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7$$

Denominator of nonlinear $5v_1 + 1v_2 = 1$

$$3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7 - 1v_1 - 1v_2 \leq 0;$$

$3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7 - 2v_1 - 1v_2 \leq 0$; and

$$u,\ v \geq 0$$

We obtain the solution as follows;

$$u_1 = 0; u_2 = 0; u_3 = 0.25; u_4 = 0; u_5 = 0; u_6 = 0; u_7 = 0; v_1 = 0.62; v_2 = 0.69$$

For DMU 3;

$$MaxZ = 4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7$$

Denominator of nonlinear $5v_1 + 1v_2 = 1$

$$3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7 - 1v_1 - 1v_2 \leq 0;$$

$3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7 - 2v_1 - 1v_2 \leq 0$; and

$$u,\ v \geq 0$$

We obtain the solution as follows;

$$u_1 = 0; u_2 = 0; u_3 = 0; u_4 = 0; u_5 = 0; u_6 = 0; u_7 = 0.2; v_1 = 1; v_2 = 0.$$

For DMU 4;

$$MaxZ = 3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7$$

Denominator of nonlinear $5v_1 + 1v_2 = 1$

$$3u_1 + 2u_2 + 3u_3 + 5u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 4u_3 + 3u_4 + 4u_5 + 3u_6 + 5u_7 - 5v_1 - 1v_2 \leq 0;$$

$$4u_1 + 4u_2 + 3u_3 + 4u_4 + 4u_5 + 4u_6 + 5u_7 - 1v_1 - 1v_2 \leq 0;$$

$3u_1 + 3u_2 + 2u_3 + 4u_4 + 3u_5 + 3u_6 + 2u_7 - 2v_1 - 1v_2 \leq 0$; and

$$u,\ v \geq 0$$

We obtain the solution as follows;

$$u_1 = 0; u_2 = 0; u_3 = 0; u_4 = 0.24; u_5 = 0; u_6 = 0; u_7 = 0; v_1 = 0.06; v_2 = 0.88.$$

Table 3 Efficiency calculation of the suppliers (DMUs)

Supplier	Cost (scale)	Rating	Equity	Health	Safety	Wages	Education	Philanthropy	Child and labour laws
Dairy craft	5	1	3	2	3	5	4	3	5
Schreiber dynamix	5	1	4	4	4	3	4	3	5
Finns frozen foods	1	1	4	4	3	4	4	4	5
Jain foods	2	1	3	3	2	4	3	3	2

Supplier	v1	v2	u1	u2	u3	u4	u5	u6	u7
Dairy craft	0.49	0.75	0	0	0	0.2	0	0	0
Schreiber dynamix	0.62	0.69	0	0	0.25	0	0	0	0
Finns Frozen foods	1	0	0	0	0	0	0	0	0.2
Jain foods	0.06	0.88	0	0	0	0.24	0	0	0

Weighted input–output	Cost (Scale)	Rating	Equity	Health	Safety	Wages	Education	Philanthropy	Child and labour laws	Efficiency
Dairy craft	2.45	0.75	0	0	0	1	0	0	0	0.313
Schreiber dynamix	3.1	0.69	0	0	1	0	0	0	0	0.264
Finns frozen foods	1	0	0	0	0	0	0	0	1	1
Jain foods	0.12	0.88	0	0	0	0.96	0	0	0	0.96

Table 4 Relative efficiency

Suppliers	Relative efficiency
Dairy craft	0.313
Schreiber dynamix	0.264
Finns frozen foods	1
Jain foods	0.96

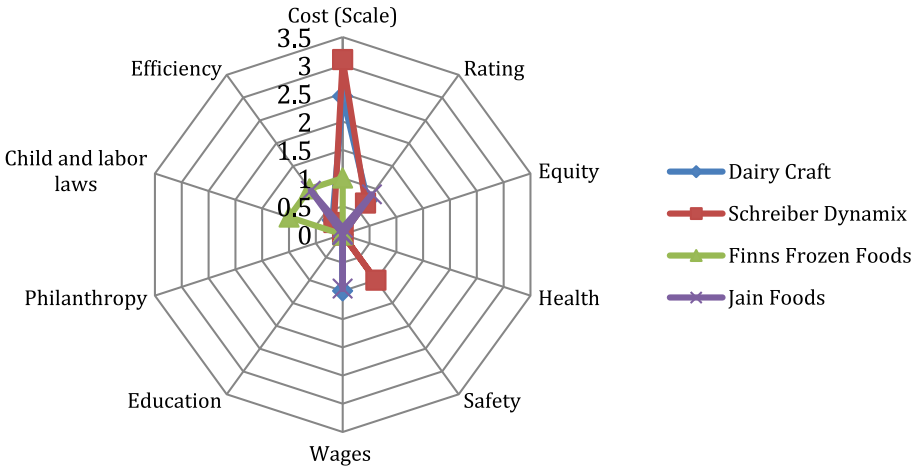

Fig. 4 Weighted input—output value of attributes and the efficiency of suppliers

Table 3 indicates the efficiency calculation for the suppliers (DMUs) considered in the model. As we see, Finns Frozen Foods appear to have a better cost to benefit ratio considering the results of the DES model. From the implementation of DEA, we can see that supplier 3 i.e. Finns Frozen Foods, Nasik has the highest efficiency, taking this as base; we have calculated the relative efficiency. As we can see the relative efficiency of the other suppliers in comparison to Finns Frozen Foods is indicated in Table 4. The weighted input—output, and the efficiency comparisons are graphically shown in Fig. 4.

Also, we can observe that the Finns Frozen Foods excels in most of the domains of social sustainability i.e., Equity, Health, Wages, Education, Philanthropy, Child and Labour Laws. Hence the selection is justified.

6 Implications of the study

We contribute to the interface of sustainable supply chain management and performance evaluation by executing a problem of supplier evaluation for social sustainability outlining a case. It gives a ground on why organizations should give weightage to not only the cost, quality, communication, expertise, and capabilities; but also to the social sustainability aspects of supplier selection. Managers can use the proposed model for evaluating their suppliers and vendors for their social sustainability performances to achieve long term competitive

advantages for firms. The proposed model for evaluation considers the aspect of social sustainability along with cost and quality rating for the suppliers, as the additional criteria for evaluation. This makes the model practically feasible, as it considers primary attributes of performance along with the attributes contributing to social sustainability. A cost–benefit analysis can be further devised by managers to understand and position the suppliers for their relative costs and relative benefits.

Also, managers can further plan the model into a multi-stage model, where the initial evaluation based on social sustainability can be done as qualifiers for suppliers, and the further evaluation for suppliers can be made for other attributes including flexibility, technical support, responsiveness, agility, risk management capabilities, and performance on other dimensions of sustainability including the economic and the environmental dimensions. This can follow the similar approaches as shown by Marzouk et al. (2021), where an initial prequalification of suppliers can be done for social sustainability and related performances. Also, from the works of Rajesh and Aljabhan (2023), a stratified decision-making framework can be developed and constructed, where multi-stage evaluation of suppliers is recommended for robust selection process. The benefits of the same can be visible with the supply chain performance on a long run, as suppliers are mostly regarded as the core of any supply chain. Also, practitioners can build interface systems considering the developed model and following the work of Fallahpour et al. (2021), where an interface for social sustainability with other technical capabilities of suppliers, such as integration of Industry 4.0 or Industry 5.0 systems can be evaluated, further.

7 Conclusions and further research

Through this research paper, we can conclude that social sustainability needs to be considered as one of the major aspects in supplier selection. It suggests guarding individuals from the impacts of matters and arrangements that adversely sway a person's security, wellbeing and prosperity. Social sustainability initiatives can increase the acceptance of a firm and the industry to a wide range of customers and stakeholders and can protect the firm from the detrimental effects being caught for critical issues like child labour or bonded labour, particularly while you work with global supply chains. As suppliers being the source of external risks in any supply chains, the social sustainability issues need to be addressed with urgent priorities. This research points the importance for considering social sustainability and the related issues, right from the upstream of the supply chain. This can improve the capabilities of supply chain and can directly enhance the environmental, social, and governance (ESG) performances of firms. As more firms are participating in the sustainability ratings provided through ESG, this can directly enhance the sustainable competitive advantages of firms.

The research has some limitations too. The factors of social sustainability considered in this research are inclusive, although not exhaustive. A critical analysis of more factors can be done and is a direction for future research. As the DEA model can overlook some of the exogenous factors of uncertainty, as well as there can be errors in the intuitive information collected, a comparison of the results of study with other multi-criteria decision-making methods can be conducted and this is another direction for future research. The study suggests that supplier selection, is the process by which firms recognize, survey, and agreement with suppliers to lessen their risk, help in improving value creation to customers, and encourage closeness and improve long term associations among buyers, suppliers, and customers. For this, the elements of social sustainability along with the environmental and economic aspects

of sustainability can be considered and included, while contracting with suppliers. This can be a possible direction for future research. This can aid in choosing the most proficient supplier, in consideration of the cost aspects, as well as by considering their performances in social and environmental aspects of sustainability.

Acknowledgements The authors sincerely thank the Editor in Chief, Prof. Endre Boros, the Guest Editor Prof. Malin Song and the two unknown reviewers for their insightful comments to improving the quality of contents to a greater extent.

Funding No funding has been received for this research.

Availability of data and material Data will be made available on request.

Declarations

Ethical approval The paper has not been submitted or considered for submission elsewhere.

Consent for publication The authors transfer the copyrights to the journal and the publisher, if accepted for publication.

Conflict of interest No potential conflicts of interests are reported in this research.

References

Bai, C., Kusi-Sarpong, S., Badri Ahmadi, H., & Sarkis, J. (2019). Social sustainable supplier evaluation and selection: A group decision-support approach. *International Journal of Production Research, 57*(22), 7046–7067.

Barbosa-Póvoa, A. P., da Silva, C., & Carvalho, A. (2018). Opportunities and challenges in sustainable supply chain: An operations research perspective. *European Journal of Operational Research, 268*(2), 399–431.

Blanchet, K., & Girois, S. (2013). Selection of sustainability indicators for health services in challenging environments: Balancing scientific approach with political engagement. *Evaluation and Program Planning, 38*, 28–32.

Boussofiane, A., Dyson, R. G., & Thanassoulis, E. (1991). Applied data envelopment analysis. *European Journal of Operational Research, 52*(1), 1–15.

Bubicz, M. E., Barbosa-Póvoa, A. P. F. D., & Carvalho, A. (2021). Social sustainability management in the apparel supply chains. *Journal of Cleaner Production, 280*, 124214.

Carter, C. R., & Jennings, M. M. (2002). Logistics social responsibility: An integrative framework. *Journal of Business Logistics, 23*(1), 145–180.

Dai, J., Xie, L., & Chu, Z. (2021). Developing sustainable supply chain management: The interplay of institutional pressures and sustainability capabilities. *Sustainable Production and Consumption, 28*, 254–268.

Davidson, M. (2009). Social sustainability: A potential for politics? *Local Environment, 14*(7), 607–619.

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. *Sustainable Development, 19*(5), 289–300.

Ehrgott, M., Reimann, F., Kaufmann, L., & Carter, C. R. (2011a). Social sustainability in selecting emerging economy suppliers. *Journal of Business Ethics, 98*(1), 99–119.

Ehrgott, M., Reimann, F., Kaufmann, L., & Carter, C. R. (2011b). Social sustainability in selecting emerging economy suppliers. *Journal of Business Ethics, 98*, 99–119.

Eizenberg, E., & Jabareen, Y. (2017). Social sustainability: A new conceptual framework. *Sustainability, 9*(1), 68.

Emmelhainz, M. A., & Adams, R. J. (1999). The apparel industry response to "sweatshop" concerns: A review and analysis of codes of conduct. *Journal of Supply Chain Management, 35*(2), 51–57.

Fallahpour, A., Wong, K. Y., Rajoo, S., Fathollahi-Fard, A. M., Antucheviciene, J., & Nayeri, S. (2021). An integrated approach for a sustainable supplier selection based on Industry 4.0 concept. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-17445-y

Govindan, K., Shankar, M., & Kannan, D. (2018). Supplier selection based on corporate social responsibility practices. *International Journal of Production Economics, 200*, 353–379.

Govindan, K., Shaw, M., & Majumdar, A. (2021). Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development. *Journal of Cleaner Production, 279*, 123075.
Hearit, K. M. (1995). "Mistakes were made": Organizations, apologia, and crises of social legitimacy. *Communication Studies, 46*(1–2), 1–17.
Hutchins, M. J., & Sutherland, J. W. (2008). An exploration of measures of social sustainability and their application to supply chain decisions. *Journal of Cleaner Production, 16*(15), 1688–1698.
Jain, N., & Singh, A. R. (2020). Sustainable supplier selection under must-be criteria through Fuzzy inference system. *Journal of Cleaner Production, 248*, 119275.
Jessin, T. A., Rajeev, A., & Rajesh, R. (2023). Supplier selection framework to evade pseudo-resilience and to achieve sustainability in supply chains. *International Journal of Emerging Markets, 18*(6), 1425–1452.
Khan, S. A. R., Zkik, K., Belhadi, A., & Kamble, S. S. (2021). Evaluating barriers and solutions for social sustainability adoption in multi-tier supply chains. *International Journal of Production Research, 59*(11), 3378–3397.
Koberg, E., & Longoni, A. (2019). A systematic review of sustainable supply chain management in global supply chains. *Journal of Cleaner Production, 207*, 1084–1098.
Kohl, S., Schoenfelder, J., Fügener, A., & Brunner, J. O. (2019). The use of data envelopment analysis (DEA) in healthcare with a focus on hospitals. *Health Care Management Science, 22*(2), 245–286.
Langhelle, O. (1999). *Towards sustainable development: On the goals of development-and the conditions of sustainability*. Macmillan Press Ltd.
Magis, K. (2010). Community resilience: An indicator of social sustainability. *Society and Natural Resources, 23*(5), 401–416.
Mahmoudi, A., & Javed, S. A. (2022). Performance evaluation of construction sub-contractors using ordinal priority approach. *Evaluation and Program Planning, 91*, 102022.
Mani, V., Agrawal, R., & Sharma, V. (2014). Supplier selection using social sustainability: AHP based approach in India. *International Strategic Management Review, 2*(2), 98–112.
Marzouk, M., & Sabbah, M. (2021). AHP-TOPSIS social sustainability approach for selecting supplier in construction supply chain. *Cleaner Environmental Systems, 2*, 100034.
McKenzie, S. (2004). *Social sustainability: towards some definitions*, Hawke Research Institute, 27. Retrieved June 20, 2022 from http://www.hawkecentre.unisa.edu.au/institute/
Missimer, M., Robèrt, K. H., & Broman, G. (2017). A strategic approach to social sustainability–part 1: Exploring the social system. *Journal of Cleaner Production, 140*, 32–41.
Moktadir, M. A., Dwivedi, A., Khan, N. S., Paul, S. K., Khan, S. A., Ahmed, S., & Sultana, R. (2021). Analysis of risk factors in sustainable supply chain management in an emerging economy of leather industry. *Journal of Cleaner Production, 283*, 124641.
Najjar, M., Small, M. H., & Yasin, M. (2020). Social sustainability strategy across the supply chain: A conceptual approach from the organisational perspective. *Sustainability, 12*(24), 10438.
Pagell, M., & Wu, Z. (2009). Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. *Journal of Supply Chain Management, 45*(2), 37–56.
Rajesh, R. (2023a). Industry 5.0: Analyzing the challenges in implementation using grey influence analysis. *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-03-2023-0121
Rajesh, R. (2023b). Performance predictions for sustainability governance of firms: Implications to select Indian firms. *Benchmarking: An International Journal*. https://doi.org/10.1108/BIJ-06-2022-0342
Rajesh, R. (2023c). Grey Markov models for predicting the social sustainability performances of firms. *Social Indicators Research, 168*, 297–351.
Rajesh, R. (2023d). An introduction to grey causal modelling (GCM): Applications to manufacturing, supply chains, resilience, and sustainability. *Artificial Intelligence Review, 56*, 6267–6293.
Rajesh, R., & Aljabhan, B. (2023). A novel grey stratified decision-making (GSDM) model for social sustainability-based supplier selection. *IEEE Transactions on Computational Social Systems*. https://doi.org/10.1109/TCSS.2022.3216814
Sarkis, J., & Talluri, S. (2002). A model for strategic supplier selection. *Journal of Supply Chain Management, 38*(4), 18–28.
Sen, A. (2008). The idea of justice. *Journal of Human Development, 9*(3), 331–342.
Sharma, S., & Ruud, A. (2003). On the path to sustainability: Integrating social dimensions into the research and practice of environmental management. *Business Strategy and the Environment, 12*(4), 205–214.
Siche, J. R., Agostinho, F., Ortega, E., & Romeiro, A. (2008). Sustainability of nations by indices: Comparative study between environmental sustainability index, ecological footprint and the emergy performance indices. *Ecological Economics, 66*(4), 628–637.

Thomas, R., Darby, J. L., Dobrzykowski, D., & van Hoek, R. (2021). Decomposing social sustainability: Signaling theory insights into supplier selection decisions. *Journal of Supply Chain Management, 57*(4), 117–136.

Toussaint, M., Cabanelas, P., & Blanco-González, A. (2021). Social sustainability in the food value chain: An integrative approach beyond corporate social responsibility. *Corporate Social Responsibility and Environmental Management, 28*(1), 103–115.

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum, 42*(3), 342–348.

Walker, A. M., Opferkuch, K., Lindgreen, E. R., Simboli, A., Vermeulen, W. J., & Raggi, A. (2021). Assessing the social sustainability of circular economy practices: Industry perspectives from Italy and the Netherlands. *Sustainable Production and Consumption, 27*, 831–844.

Wei, Q. (2001). Data envelopment analysis. *Chinese Science Bulletin, 46*(16), 1321–1332.

Weingaertner, C., & Moberg, Å. (2014). Exploring social sustainability: Learning from perspectives on urban development and companies and products. *Sustainable Development, 22*(2), 122–133.

Williams, O. F. (2004). The UN global compact: The challenge and the promise. *Business Ethics Quarterly, 14*(4), 755–774.

Woodcraft, S. (2015). Understanding and measuring social sustainability. *Journal of Urban Regeneration and Renewal, 8*(2), 133–144.

Wu, C., Lin, Y., & Barnes, D. (2021). An integrated decision-making approach for sustainable supplier selection in the chemical industry. *Expert Systems with Applications, 184*, 115553.

Xu, L., Kumar, D. T., Shankar, K. M., Kannan, D., & Chen, G. (2013). Analyzing criteria and sub-criteria for the corporate social responsibility-based supplier selection process using AHP. *The International Journal of Advanced Manufacturing Technology, 68*, 907–916.

Xu, T., You, J., Li, H., & Shao, L. (2020). Energy efficiency evaluation based on data envelopment analysis: A literature review. *Energies, 13*(14), 3548.

Zimmer, K., Fröhling, M., & Schultmann, F. (2016). Sustainable supplier management–a review of models supporting sustainable supplier selection, monitoring and development. *International Journal of Production Research, 54*(5), 1412–1442.