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Abstract - In today's competitive business environment, corporations attempt to achieve sustainability through innovation. Innovation is considered by researchers and scholars to be a key driver for achieving sustainability. One of the key parts in any sustainable supply chains is sustainable supplier evaluation and selection. However, few sustainable supply chain management (SSCM) studies have focused on sustainable supplier evaluation and selection, particularly in the context of sustainable innovation management. Thus, supplier evaluation and selection studies that consider overall sustainability (social, environmental, and economic) innovation criteria are nearly non-existent. To deal with this issue, this paper proposes a decision framework to assess sustainable innovative suppliers. A combination of best worst method (BWM) and modified Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) is employed as an integrated model in the analysis. The BWM is initially applied to identify the sustainable innovation criteria weights, and then the modified PROMETHEE is used to analyze the suppliers' performance. A manufacturing case example is employed to verify the utility and applicability of the proposed methodology. This paper can assist industrial managers, researchers, and decision-makers in understanding and focusing on sustainable innovation, particularly when selecting suppliers, and enhancing their supply chains' sustainability to make progress toward sustainable development.

Keywords: sustainable innovation; sustainable supply chain management; supplier selection; BWM; PROMETHEE

1. Introduction

Industrialization has serious adverse impact on natural environment and to human life. There is a critical requirement for firms to work together in sustainable supply chains considering social, economic and environmental factors (Mangla et al., 2014; Pieroni et al., 2019). With the advent of rapid growth in manufacturing industries globally and particularly in developing countries, managing resources for the future is a major concern and challenge for humankind (Gupta and Barua, 2018). Sustainable innovation can be described as innovation that improves the performance of sustainability, which consists of social, environmental, and economic factors (Boons et al., 2013). Implementing sustainable innovation is one of the requirements for obtaining sustainable development. Sustainable innovation, green technology, and the incorporation of sustainability in the supply chain are several models that have a proven ability to leverage the effects of these challenges (Boons et al., 2013). Sustainable innovation is a major impetus for achieving sustainable development, because it involves technological, product, process, and social innovation that is necessary for energy conservation, pollution prevention, and waste management initiatives within the supply chain (El-Kassar and Singh, 2019). Sustainable development is portrayed as a tool to achieve competitive advantage over others by incorporating both environmental and social dimensions into the profitability (Sroufe, 2017). Several researchers have tried to investigate sustainable innovation by focusing on variety of issues. For example, Iles and Martin (2013) investigated sustainable business innovation in the chemical industry using bio plastics as case. Veronica et al. (2019) investigated stakeholder involvement in promoting sustainable business innovation in Italian small and medium-sized enterprises (SMEs). Calik and Bardudeen (2016) in their study, evaluated supply chains sustainable innovation performance in manufacturing corporations. Zhou et al. (2020) evaluated the impact of fairness, embeddedness and knowledge sharing on green innovation in the sustainable supply chains. To the best of our knowledge, researchers have not tried to assess suppliers by focusing on sustainability (economic, social, and environmental) innovation factors.

Since initial substances and components are supplied to companies by suppliers, supplier's performance plays a key part in any sustainable supply chain. In addition, it has a considerable effect on customer's performance (Bai et al., 2019). Corporations should consider external sustainability capabilities, practices, and strategies, particularly from their suppliers or upstream supply chain (Kusi-Sarpong et al., 2019). Recently, several companies have switched toward

sustainability-oriented innovation by adopting sustainable practices (Jones and Zubielqui, 2017). Corporations must innovate, by modifying their organizational structures, incorporate some strategies to tackle the challenges and focus on sustainability, for example, when selecting suppliers (Kennedy et al., 2017).

Although several studies have investigated sustainable processes and product innovation, empirical analysis in emerging economies are still lacking, particularly in the context of supplier evaluation and selection based on their innovativeness (Del Río et al., 2016). Nevertheless, many researchers have investigated supplier selection decision, among which several authors have considered economic sustainability criteria (e.g. Pitchipoo et al., 2013), many have investigated supplier selection with environmental sustainability criteria (e.g. Haeri and Rezaei, 2019). Few papers have focused on social sustainable supplier evaluation and selection, taking into consideration only social sustainability criteria (e.g. Bai et al., 2019), whereas many studies have focused on supplier selection with broader sustainability criteria (e.g. Khan et al., 2018; Amindoust, 2018; Azadnia et al., 2015; Ahmadi et al., 2017a).

Up to now, no study in the literature has investigated supplier evaluation and selection based on their sustainable innovation performance. To close this gap, this study evaluates and selects a set of potential suppliers on the basis of their sustainable innovation performance. Supplier evaluation and selection is a problem addressed by multi-criteria decision-making (MCDM), which can be divided into three work procedures: establishment of the evaluation framework, determination of the weight of criteria, and calculation of supplier performance. Common methods based on pairwise comparison include analytic hierarchy process (AHP) (Ahmadi et al., 2017a; Azimifard et al., 2018; Guarnieri and Trojan, 2019), and decision-making trial and evaluation laboratory (DEMATEL) (Li and Mathiyazhagan, 2018). However, as the number of criteria increases, consistency of the questionnaire decreases. The best worst method (BWM) (Rezaei, 2015, 2016) can significantly reduce pairwise comparison times and achieve better consistency. Many articles have pointed out that BWM can obtain expert opinions more accurately than other pairwise comparison methods such as AHP (Rezaei, 2015, 2016; Lo et al., 2018; Yadav et al., 2019). Moreover, the "preference ranking organization method for enrichment of evaluations" (PROMETHEE) is an effective and reliable soft computing tool for supplier performance appraisal (Krishankumar et al., 2017; Govindan et al., 2017; Wu et al., 2019). The PROMETHEE technique assesses the degree of relative advantage among alternatives to prioritize. This study improves the

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PROMETHEE to meet standards for industry applications and employs aspiration level concept to introduce a modified version of PROMETHEE. Compared with conventional PROMETHEE, the modified version of PROMETHEE not only is easy to operate but also provides gap to aspiration level for improvement. This integrated model is proposed in this paper for the first time. We combined BWM and a modified version of PROMETHEE technique to integrate supplier performance and generate a ranking index, which contains more potential information than original PROMETHEE.

In summary, this paper adopts a sustainability innovation criteria decision framework from literature, and integrates it into the supplier selection decision, using a hybrid BWM– modified PROMETHEE methodology. This paper offers two main contributions: (1) introduces a sustainability innovation evaluation framework for guiding general decision-making in sustainable supply chain management (SSCM) and (2) introduces a hybrid MCDM model that integrates BWM with modified PROMETHEE in the supplier selection decision.

2. Theoretical backgrounds

This section begins with an overview of sustainable supply chain management. Next, we focus on sustainable supplier evaluation and selection. In the third sub-section, sustainability and innovation is discussed, and finally a sustainable innovation evaluation framework is introduced.

2.1. Sustainable supply chain management

Supply chain management can be described as employing a set of practices to obtain efficient coordination within and between companies, with the target of enhancing customer service, increasing profit, and reducing the cost (Croxton et al., 2001). In supply chain networks, various decision-makers as well as experts handle processes and information that might not be under their control (Hassini et al., 2012). Corporations need to incorporate their operations and work together to build operations of their supply chain more sustainable (Luthra et al., 2017). Sustainable supply chain management (SSCM) can be defined as a traditional supply chain management that incorporates social and environmental development. SSCM is the management of supply chain operations, information, resources, and funds while considering the economic, environmental, and social dimensions of sustainable development (Seuring and Müller, 2008), with the aim of increasing the supply chains profitability, and social well-being (e.g. the influence of the supply

chains on its personnel, clients and society), and also reducing any adverse environmental impact (Hassini et al., 2012; Shi et al., 2017). Sustainable supply chain improves the performance of corporations, influences a firm's competitiveness and the performance of its supply chains (Seuring et al., 2008). Supply chain operations with negative environmental, social, and economic impacts can be considerably diminished through SSCM implementation (Yadav et al., 2019). Traditional supply chains consider supply chain relationships and material flows to only maximize profitability and operational performance, whereas SSCM assesses additional social and environmental factors for achieving sustainable development (Papetti et al., 2019; Li et al., 2006). Many studies have investigated SSCM from various contexts (Reefke and Sundaram, 2018; Sauer and Seuring, 2017; Rebs et al., 2019; Li et al., 2019; Roy et al., 2020; Kumar et al., 2020; Yadav et al., 2020; Hussain and Malik, 2020; Mardani et al., 2020; Jia et al., 2020).

Sustainability can be considered a key to acquiring a competitive advantage (Yu et al., 2019). Applying sustainable initiatives and programs such as supplier selection can increase collaboration between partners by enhancing and strengthening their environmental performance, diminishing waste and cost saving (Linton et al., 2007). The goal of SSCM is to maintain and protect the environment and improve the socio-economic aspect for achieving long-term sustainable development (Linton et al., 2007; Formentini and Taticchi, 2016; Fahimnia et al., 2017). SSCM decreases supply chain operations adverse effects and enhances corporation effectiveness with respect to economic, social, and environmental dimensions, which can improve supply chain management, with a considerable influence on a firm's competitiveness and supply chain operations, the target being to develop required capabilities in order to reinforce corporation's sustainable competitive and collaborative advantage (Wong et al., 2014).

Companies should manage their business operations, with a long-term target of society well-being, the environment and economy, if they aim to increase their sustainability level (Hassini et al., 2012). That is why many firms have begun to employ sustainability indicators including safety, environmental, and social factors for evaluating their sustainability level (Tseng, 2013; Kusi-Sarpong et al., 2019). Many authors have proposed sustainability decision frameworks for evaluating and selecting suppliers. For example, Bai et al. (2019) proposed a social sustainability criteria decision framework for evaluating and selecting some potential suppliers in an emerging economy nation manufacturing firm. Their framework only included social sustainability criteria; It did not contain clear sustainability innovation factors. Ahmadi et al. (2017a) developed a

decision framework for evaluating several sustainable suppliers in a telecom industry context. Although they developed a sustainability framework, their framework covered sustainability (social, economic, and environmental) factors, the operational criteria did not clearly include sustainability innovation factors. A decision framework was developed by Azadnia et al. (2015) based on social, environmental, and economic sustainability criteria, for assessing suppliers in an emerging economy context. Their framework did not clearly consider sustainability innovation factors, and sustainability innovation was not discussed in their study. Gupta and Barua, (2017) developed a framework for selecting suppliers based on their green innovation ability. Their framework for supplier selection only covered environmental sustainability innovation criteria. Additional social and economic innovation criteria were not clearly taken into consideration or discussed in their study. Gao et al. (2020) proposed a criteria decision framework for selecting some potential green suppliers for an electronic manufacturing firm. Only environmental sustainability criteria were considered in that framework, and sustainability innovation factors were not well discussed. According to existing literature review, there are many studies that have focused on supplier selection problem, considering sustainability criteria, But there is not any study that evaluates suppliers based on broader sustainability innovation (economic, social and environmental) criteria. This paper attempts to address this gap of SSCM, and evaluates and selects a set of potential suppliers, considering sustainability innovation criteria, in an emerging economy context.

2.2. Sustainable supplier evaluation and selection

In supply chain networks, suppliers provide both products and services to the consumers as well as the information regarding the products and goods. Suppliers, who are a critical element to supply chain operations, considerably affect firms' sustainability performance and should be carefully evaluated and selected (Ageron et al., 2012). With the sustainable supply chain management arrival, researchers have emphasized the importance of environmental and social criteria incorporation into the conventional economic-based supplier selection problem (Bai and Sarkis, 2010; Song et al., 2017). Sustainable supplier selection can be defined as a traditional economic-based supplier selection which considers additional environmental and social evaluation criteria (Song et al., 2017). Many studies have investigated sustainable supplier selection problem (e.g. Ahmadi et al., 2017a; Bai et al., 2019; Azadnia et al., 2015; Amindoust, 2018; Azimifard et

al., 2018; Bai and Sarkis, 2010). Literature reviews (e.g. Ansari and Kant, 2017; Govindan et al., 2015) have pointed that integrating traditional economic-based supplier selection with environmental and social sustainability criteria has gained considerable attention. Sarkis and Dhavale (2015) argued that a critical element of sustainable supply chain partnership development is supplier selection, and that complexity arises when assessing multiple suppliers. Studies on sustainable innovation supplier selection from an emerging economy are nearly non-existent. This paper expands on previous research in this area by introducing a new typology for investigating sustainability innovation through supplier evaluation and selection in an emerging economy context.

2.3. Sustainability and innovation

Sustainable development requires immediate action from the industry, government, and society. In order to achieving this important global agenda, sustainable innovation must occur. Sustainable innovation includes new or modified products, processes, practices, services, techniques, and systems that reduce adverse social and environmental effects and enhance quality of life (Chen et al., 2019). Studies have suggested that sustainability should address with innovation-centered approaches. SSCM research has highlighted the role of sustainable innovation for achieving sustainable development. Corporations, supply chains, communities, and nations can achieve sustainability through innovation (Silvestre and Ţîrcă, 2019). Innovation is the implementation of new or improved products, processes, marketing methods, or organizational methods in business practices or supplier selection (Rauter et al., 2019; Doyle et al., 2019). Social issues such as poverty, social exclusion, corruption, human rights, safety, and equity are serious challenges that negatively affect organizational supply chains and prevent firms from achieving sustainable development (Silvestre et al., 2018; Silvestre and Ţîrcă, 2019). These social issues as well as several environmental problems should be considered in organizational sustainable innovation (Albareda and Hajikhani, 2019). Ayuso et al. (2011) argued that stakeholder engagement plays a considerable role in promoting sustainable innovation. Vasilenko and Arbaˇciauskas (2012) argued that, organizations motive to achieving sustainable innovation include creating competitive advantage, support for their R&D, saving in costs, compliance with rules and consumer needs. One of the significant sustainable innovation aspects in chemical sector is risk management. Firms that do not take into consideration social criteria into their process

innovation are at more risk than other companies (Iles and Martin, 2013). Knowledge management and learning are key elements for promoting sustainable innovation. Other attributes of sustainability innovation include organizational, social, ethical, technological, and cultural factors which lead to economic, market, financial and environmental performance outcome (Tariq et al., 2017). There are number of ways for improving and adjusting sustainability innovation capabilities of organizations including entrepreneurial abilities for gathering knowledge associated with environmental policies and technologies; changing opportunities into innovative processes and products; and reconfiguration to obtain strategic fit through resources rearrangement based on requirements (Mousavi and Bossink, 2017). Integrating sustainable innovation factors into supplier evaluation and selection can significantly help companies to increase their sustainability level and achieve sustainable development.

2.4. Sustainable innovation evaluation framework

Sustainable innovation has received relatively little attention and investigation (Mousavi and Bossink, 2017). Gupta and Barua (2018) addressed this issue by proposing a framework for selecting suppliers between small and medium-sized enterprises according to their innovativeness. Although this framework assesses innovation ability, the operational criteria do not clearly cover sustainability innovation. This study is the first attempt to introduce and employ a sustainable innovation evaluation framework for evaluating and selecting suppliers. Referring Kusi-Sarpong et al. (2019) work and other references, this study constructed the evaluating framework with 3 main dimensions and 20 criteria as shown in Table 1.

Table 1. Sustainable innovation criteria decision framework

Dimension	Criteria	Explanation	Authors
Economic (P)	Sustainable product cost reduction (P1)	Ability of firms to decrease the product costs	Bai and Sarkis (2010); Sarkis and Dhavale (2015); Zhu et al. (2018)
	Financial availability for innovation (P2)	Availability of efficient ideas and solutions in order to ensure financial support for implementing sustainability innovation	Jenkins and Yakovleva (2006); Mathiyazhagan and Haq (2013)
	Finance resumption of products (P3)	Application of different activities such as reuse and recycle in order to recover the financial resources.	Mathivathanan et al. (2018)
	Increased sustainability value to customers (P4)	Higher value preparation to customers through decreasing the price or increasing the products functions.	Gupta and Barua (2017)
	Finance in R&D (P5)	Availability of financial resources to conduct research for supporting manufacturing of sustainable products.	Ansari and Kant (2017)
	Producing sustainable products in order to decrease material utilization (P6)	Manufacturing products taking into account sustainability aspects in order to diminish the usage of materials	Calik and Bardudeen (2016); Zhu et al. (2018)
Environmental (G)	Inter- and Intra-organization collaboration (G1)	Collaboration among diverse functions of firms, with the target of producing sustainable products.	Messeni Petruzzelli et al. (2011); Mathivathanan et al. (2018)
	Availability of technical proficiency (G2)	Development of technical expertise and research focus to achieve sustainable practices in corporations.	Kammerer (2009); Li and Mathiyazhagan (2018)
	Green logistics abilities development (G3)	Firms ability to manufacture products considering environmental sustainability standards	Hashemi et al. (2015); Jabbour et al. (2015); Mathivathanan et al. (2018); Golini et al. (2017)
	Development of environmentally sustainable production (G4)	Utilization of innovative production methods in order to reduce energy and waste in manufacturing	Somsuk and Laosirihongthong (2017); Ansari and Kant (2017)

	Environment management commitment and initiatives (G5)	Employment and implementation of different environmental standards in firms.	Das (2018); Hashemi et al. (2015)
	Designing products to decrease their impact on environment (G6)	Designing products in order to diminish their environmental impacts	Hashemi et al. (2015); Ansari and Kant (2017)
	Conducting regular environmental audits (G7)	Carrying out audits in companies	Mathivathanan et al. (2018); Somsuk and Laosirihongthong (2017); Kannan et al. (2014)
Social (S)	Application of efficient policies considering social and environmental factors (S1)	Application of efficient policies considering social and environmental dimensions of sustainability	Demirel and Kesidou (2011); Horbach et al. (2012); Tariq et al. (2017); Govindan et al. (2016)
	Fast response and responsibility of firms to customers and market demand (S2)	Responsibility of organizations to response to customers and market request	Tariq et al. (2017); Golini et al. (2017); Kammerer (2009); Zhu et al. (2012)
	Enhancing social image of the organization (S3)	Companies try to increase their social image through manufacturing sustainable products	Kammerer (2009); Tariq et al. (2017); Zhu et al. (2018)
	Reaction on pressure of stakeholders (S4)	Means reaction of firms and their response to stakeholders' pressure for manufacturing sustainable products	Tariq et al. (2017); Demirel and Kesidou (2011); Amore and Bennedsen (2016)
	Corporate social responsibility initiatives (S5)	Application of social and environmental initiatives.	Ansari and Kant (2017); Tariq et al. (2017)
	Cultural, social values and norms (S6)	Cultural and social beliefs and standards of companies	Rothenberg and Zyglidopoulos (2007); Jia et al. (2018)
	Health, safety and rights of suppliers (S7)	Means health, safety and rights of suppliers at their workplace and endeavor of companies to make progress towards these conditions	Bai and Sarkis (2010); Zhu et al. (2018); Ahmadi et al. (2017a); Jia et al. (2018)

3. Methodology

The BWM combined with a modified version of PROMETHEE, as a hybrid MCDM tool, is employed to evaluate and select suppliers based on their sustainable innovation performance. Detailed definitions of these tools are introduced in this section. Moreover, the research solution methodology can be seen in Fig. 1.
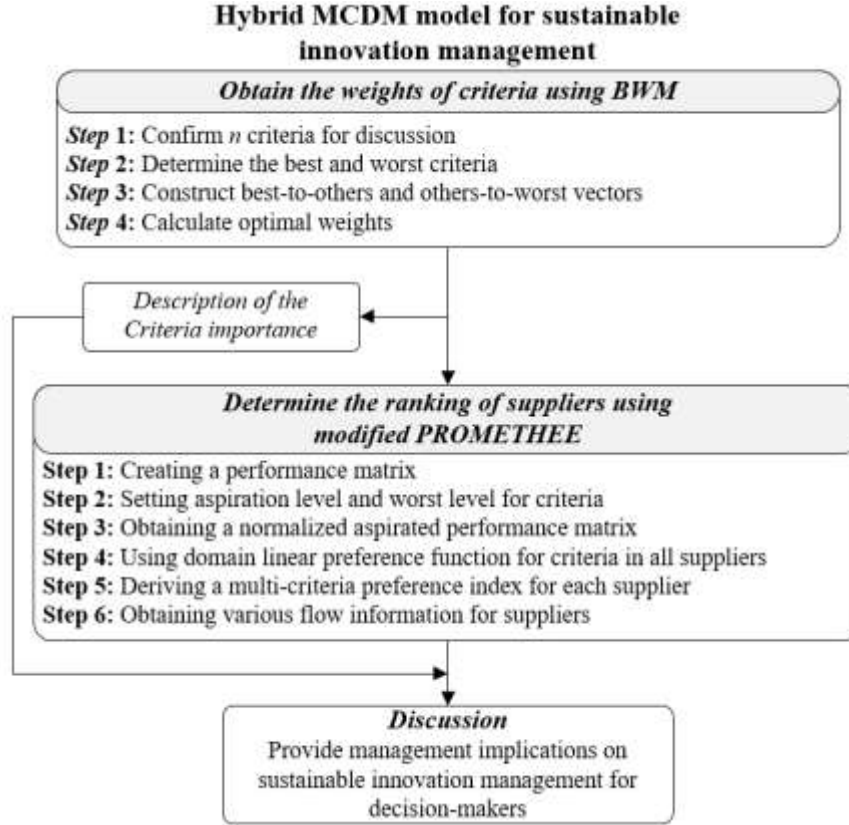
Hybrid MCDM model for sustainable innovation management

Obtain the weights of criteria using BWM
Step 1: Confirm n criteria for discussion
Step 2: Determine the best and worst criteria
Step 3: Construct best-to-others and others-to-worst vectors
Step 4: Calculate optimal weights

Description of the Criteria importance

Determine the ranking of suppliers using modified PROMETHEE
Step 1: Creating a performance matrix
Step 2: Setting aspiration level and worst level for criteria
Step 3: Obtaining a normalized aspirated performance matrix
Step 4: Using domain linear preference function for criteria in all suppliers
Step 5: Deriving a multi-criteria preference index for each supplier
Step 6: Obtaining various flow information for suppliers

Discussion
Provide management implications on sustainable innovation management for decision-makers

Fig 1. Research solution methodology steps

3.1. Best worst method

BWM is a recently popular MCDM technique, proposed by Rezaei (2015). The BWM is widely used for various problems addressed by MCDM, because it is easy to operate and effectively reflects the opinions of decision-makers (Lo and Liou, 2018; Yadav et al., 2019; Moktadir et al., 2020; Gupta et al., 2020). Detailed steps of the BWM are as follows:

Step 1. *Confirm n criteria for discussion*

Decision-makers identify n criteria $\{c_1,\ c_2,...,\ c_n\}$ to use in decision-making.

Step 2. *Determine the best (B) and worst (W) criteria*

Each decision-maker selects the best (most important) and worst (least important) criteria, from the criteria set identified in Step 1.

Step 3. Construct best-to-others (BO) and others-to-worst (OW) vectors

Each decision-maker is asked to rate the preference of the best criterion over other criteria and all other criteria over the worst criterion, employing a 9-point measurement scale, where score 1 means equal preference and score 9 shows extreme preference. The best-to-others (BO) and others-to-worst (OW) vectors (A_{Bj} and A_{jW}) are formulated as follows:

$$A_{Bj} = \left(a_{B1}, \ a_{B2}, \ldots, \ a_{Bn} \right),$$

$$A_{jW} = \left(a_{1W}, \ a_{1W}, \ldots, \ a_{nW} \right)^{T}.$$

The relative importance of each criterion to itself is equal to 1, that is, $A_{BB} = 1$ and $A_{WW} = 1$.

Step 4. Calculate the optimal weights

The weights of criteria are calculated so that the maximum absolute differences for all *j* can be minimized for $\left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_W \right| \right\}$. The following minimax model will be obtained:

$$\min \max \left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jW} w_W \right| \right\},$$

s.t.

$$\sum_j w_j = 1,$$

$$w_j \geq 0, \text{ for all } j. \tag{1}$$

Model (1) is transformed to a linear model and is shown as:

$$\min \xi^L$$

s.t.

$$\left| w_B - a_{Bj} w_j \right| \leq \xi^L, \text{ for all } j,$$

$$\left| w_j - a_{jW} w_W \right| \leq \xi^L, \text{ for all } j,$$

$$\sum_j w_j = 1,$$

$$w_j \geq 0, \text{ for all } j. \tag{2}$$

Model (2) can be solved to obtain optimal weights $\left\{ w_1^*, \ w_2^*, \ldots, \ w_n^* \right\}$ and optimal value ξ^L .

Consistency (ξ^L) of attribute comparisons close to "0" is desired (Rezaei, 2016).

3.2. Preference ranking organization method for enrichment of evaluations based on aspiration level concept (PROMETHEE – AL)

PROMETHEE method is currently a popular MCDM method for integrating performance of alternatives. The idea of PROMETHEE is based on the comparison between two suppliers under each criterion. The initial decision data is divided into two sets of matrices, which are the inflow and outflow matrices of the suppliers on a specific criterion. At the same time, the initial data is replaced by inflow and outflow information, the comprehensiveness of decision data and accuracy of outcomes have been endorsed by PROMETHEE. In this paper, after computing the criteria weights using BWM, a modified version of PROMETHEE is applied to rank the suppliers. The steps of the modified PROMETHEE are as follows:

Step 1*. Creating a performance matrix*

For MCDM problem, a performance questionnaire is typically completed by decision-makers who evaluate the performance of i suppliers under the j criteria, where $i = 1,2,\ldots, m$; and $j = 1, 2,\ldots, n$. Suppliers with multiple criteria are listed in column and row of a performance matrix. The matrix shows the performance of different alternatives under various criteria (Eq. (3)).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mj} & \cdots & a_{mn} \end{bmatrix}_{m \times n} \tag{3}$$

Step 2*. Setting aspiration level and worst level for criteria*

This step is the most critical part of the modified PROMEETHEE. Conventionally, positive and negative ideal points are defined by max-min values of criteria from a number of suppliers (i.e., Eqs. (4) and (5)). Although this approach can be easily used to rank suppliers, it cannot reflect the gaps of criteria in each supplier. Traditional PROMETHEE can help decision-makers to just solve the selection problem but does not improve it. In a MCDM problem, the measurement scale of each indicator is generally within a known range. In this situation, the absolutely good can replace the relatively good concept. Therefore, we apply the concept of aspiration level for setting positive and negative ideal points, using Eqs. (6) and (7).

Positive ideal: $f_i^* = \max_p f_{ij} \big| i = 1,\ 2,\ldots,\ m;\ j = 1,\ 2,\ldots,\ n.$ \hfill (4)

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Negative ideal: $f_i^- = \min_p f_{ij} \big| i = 1, 2, \dots, m; j = 1, 2, \dots, n.$ (5)

According to aspiration level concept, we can rewrite Eqs. (4) and (5), as Eqs. (6) and (7), respectively.

The aspiration levels: $f_j^{aspried} = \left(f_1^{aspried}, f_2^{aspried}, \dots, f_n^{aspried} \right)$ (6)

The worst levels: $f_j^{worst} = \left(f_1^{worst}, f_2^{worst}, \dots, f_n^{worst} \right)$ (7)

The auditing data of the case company were scored on a scale from 0 to 10 to evaluate the performance of each supplier. Therefore, for each criteria, the aspiration level can be set to 10 and the worst value to 0 ($f_j^{aspired} = 10$ and $f_j^{worst} = 0$). It is worth noting that aspiration and worst levels are included as alternatives. In this way, the gap between the supplier and the aspiration level can be obtained.

Step 3. *Obtaining a normalized aspirated performance matrix*

Eq. (8) can be used in order to obtain a normalized aspirated performance matrix $\mathbf{F}^\varphi = \left[f_{ij}^\varphi \right]_{m \times n}$.

$$f_{ij}^\varphi = f_{ij} \big/ \left(f_j^{aspired} - f^{worst} \right)$$ (8)

Step 4. *Using domain linear preference function for criteria in all suppliers*

Brans and Vincke (1985) proposed six basic types of preference functions. This study employs the preference function of "Type V: Criterion with Linear Preference and Indifference Area" to compute the function for the preference degree for criteria in all suppliers. The performance matrix can be obtained by using a measurement scale from 0 to 10; hence, a domain relationship exists between performance criteria in all suppliers. Therefore, we can redefine a function in which supplier (u) outranks supplier (v) for the jth criterion, as shown in Eq. (9).

$$S_j(u, v) = \begin{cases} 0 & , f_{uj}^\varphi - f_{vj}^\varphi \leq f_j^{\varphi worst} \\ f_{uj}^\varphi - f_{vj}^\varphi & , f_j^{\varphi worst} < f_{uj}^\varphi - f_{vj}^\varphi \leq f_j^{\varphi aspired} \\ 1 & , \text{otherwise} \end{cases}$$ (9)

where $S_j(u, v)$ shows higher rank of supplier u over supplier v on the jth criterion, $f_{pj}^{\Phi aspirted} = 1$, $f_{pj}^{\Phi worst} = 0$, f_{uj} is the assessment score of the jth criterion in the uth supplier, and f_{vj} is the assessment score of the jth criterion in the vth supplier.

Step 5. *Deriving a multi-criteria preference index for each supplier*

For each criterion, the preference scores can be combined with the criteria weights (obtained from BWM) to obtain the preference index (named multi-criteria preference index), where the π (u, v) index indicates the advantage of supplier u over supplier v, as shown in Eq. (10):

$$\pi(u, v) = \sum_{j=1}^{n} w_j \pi_j(u, v) \tag{10}$$

where w_j is the importance weight on the jth criterion.

Step 6. Obtaining various flow information for suppliers

Based on the multi-criteria preference index concept and framework, we can compute three flows for each supplier: "leaving flow", "entering flow", and "net flow". The amount by which supplier u outperforms other suppliers is indicated by leaving flow, similarly entering flow is an indication of how other suppliers outperforms supplier u, final score of supplier u is represented by net flow, as shown in Eqs. (11), (12), and (13), respectively:

The leaving flow: $\theta^+(u) = \sum_{v=1}^{z} \pi(u, v)$ (11)

The entering flow: $\theta^-(u) = \sum_{v=1}^{z} \pi(v, u)$ (12)

The net flow: $\theta(u) = \theta^+(u) - \theta^-(u)$ (13)

where $\theta(u)$ represents the supplier that is closest to the aspiration level; a greater $\theta(u)$ value is preferred.

4. Real case demonstration

Iran, case country of this study, is a developing nation in southwestern Asia. Sustainability initiatives and manufacturing practices are still in the early implementation phases (Ahmadi et al., 2017b; Bai et al., 2019). Selecting suppliers based on their sustainable innovation performance significantly helps firms increase their overall sustainability level and shift towards sustainable development. "Company T," a buying firm, is used in this study to verify the usefulness of the proposed decision framework and methodology. Company T is located in eastern Iran. It is one of the largest tile corporations, operating at a capacity of 5 million square meters. Company T was established in 1983 and has since designed and produced various wall and floor tiles and ceramics in various sizes. Company T was interested to participate in this study and evaluates the sustainable innovation performance of its suppliers.

A committee of nine managers (experts) from logistics, marketing, production planning, maintenance, supply chain, research and development, IT, purchasing, and finance departments was formed. These managers are really expert and professional in their respective field. Each expert had at least more than 10 years of working experience and was specially selected for the assessment process. Corporation T had contracts with several suppliers for supplying various parts and materials. Six suppliers were shortlisted by the management. These six suppliers are assessed on the basis of their sustainable innovation implementation levels.

4.1. Applying the BWM and modified PROMETHEE methodology

The BWM and the modified PROMETHEE methodology are employed to analyze the framework proposed in subsection 2.4, weight the sustainability innovation criteria and rank the 6 suppliers. Table 2 presents the most and least important criteria determined by nine managers. For example, "Economic (P)" is the best dimension for most experts, indicating that the economic dimension is relatively important for sustainable innovation. Furthermore, experts use 1 to 9 scale to elicit the relative importance among criteria ("best to others and others to worst"). Tables 3 and 4 respectively present the BO and OW vectors of dimensions. The criteria weights are calculated using Eq. (2), and the final optimal weights are computed from integrating the nine experts' BWM results, by using the arithmetic average method.

Table 2. Best and worst criteria determined by nine experts

Dimension	Best	Worst	Criteria	Best	Worst
Economic (P)	XXXXXX	XX	P1	XX	
			P2	XX	XX
			P3		X
			P4	XX	
			P5	XXX	XXXX
			P6		XX
Social (S)	XX	XXXX	S1	X	XX
			S2	X	X
			S3	XXX	
			S4	X	XX
			S5	X	
			S6	X	XXX
			S7	X	X
Environmental (G)	X	XXX	G1		
			G2		XXXXX
			G3	XX	X
			G4	X	X
			G5	XX	X
			G6	XXX	X
			G7	X	

Table 3. Dimensions' BO vectors determined by nine experts

Expert no.	Best	P	S	G
1	P	1	8	6
2	P	1	4	6
3	P	1	7	3
4	P	1	7	5
5	S	7	1	6
6	G	2	4	1
7	P	1	3	8
8	P	1	3	7
9	S	3	1	2

Table 4. Dimensions' OW vectors determined by nine experts

Expert no.	1	2	3	4	5	6	7	8	9
Worst	S	G	S	S	P	S	S	G	P
P	8	6	7	7	1	3	8	7	1
S	1	2	1	1	7	1	3	3	3
G	5	1	4	5	5	4	1	1	2

The *CR* represents the system consistency. The *CR* of each BWM questionnaire is less than 0.1, indicating high reliability (Rezaei, 2015, 2016). Final weights of dimensions and criteria can be seen in Table 5. According to Table 5, top five criteria are sustainable product cost reduction (P1), financial availability for innovation (P2), Finance in R&D (P5), increased sustainability value to customers (P4), and finance resumption of products (P3). The experts clearly believe that the economic dimension is the most important factor for sustainable innovation, so these criteria have a higher weight than other criteria. Although other criteria are not included in top five, they still affect overall evaluation system results. Next, we apply the modified PROMETHEE to aggregate the performance data and criteria weights.

Table 5. BWM results

Dimension	weight	Criteria	local weight	global weight	Ranking
P	0.532	P1	0.215	0.114	1
		P2	0.210	0.112	2
		P3	0.150	0.080	5
		P4	0.154	0.082	4
		P5	0.182	0.097	3
		P6	0.089	0.048	7
S	0.257	S1	0.158	0.041	8
		S2	0.151	0.039	10
		S3	0.233	0.060	6
		S4	0.102	0.026	17
		S5	0.129	0.033	13
		S6	0.101	0.026	18
		S7	0.127	0.033	14
G	0.211	G1	0.185	0.039	9
		G2	0.064	0.014	20
		G3	0.178	0.038	11
		G4	0.154	0.032	15
		G5	0.138	0.029	16
		G6	0.170	0.036	12
		G7	0.112	0.024	19

Evaluating and selecting sustainable innovation suppliers is complex and cumbersome. The modified PROMETHEE is a useful method to solve such problem, because of its speed and simplicity in helping decision-makers to develop improvement strategies. The modified PROMETHEE analysis can be performed as outlined in Section 3.3. The nine experts evaluate the performance of six suppliers according to the performance score ranging from 0 to 10 (0 means extremely poor, 10 means excellent performance, and a larger value means better performance). The average performance matrix that integrates the nine experts is shown in Table 6. Using Eqs. (6) to (8), the aspiration levels, the worst levels and the normalized aspired performance matrix can be obtained. The company formulates a business target every cycle (e.g., every season or year) to develop an aspiration level (or benchmark). Supplier evaluation is a crucial task for every supply chain. Companies should list requirements and conditions to encourage and improve supplier cooperation.

Table 6. Average performance matrix

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
P1	6.111	6.778	5.222	5.000	5.000	5.000
P2	5.222	5.222	5.000	6.333	4.333	4.556
P3	3.444	4.333	5.222	3.889	5.444	5.889
P4	6.333	6.556	5.000	5.889	3.889	4.333
P5	4.778	5.222	5.889	5.000	5.667	7.000
P6	6.111	5.889	4.556	5.222	5.444	4.778
S1	6.778	5.444	5.667	5.000	4.778	6.778
S2	3.667	3.444	6.333	6.333	4.556	5.222
S3	5.667	4.111	3.667	4.111	7.000	5.667
S4	4.778	4.333	6.556	7.000	3.889	4.556
S5	6.111	6.778	6.111	5.667	5.000	3.222
S6	3.222	4.556	5.667	5.444	6.111	5.444
S7	5.222	6.333	5.222	7.444	6.111	5.222
G1	4.556	4.778	5.000	6.111	5.000	7.000
G2	4.778	5.444	5.667	5.000	6.556	4.111
G3	6.333	5.667	6.111	6.556	4.333	5.889
G4	5.889	5.000	4.111	5.444	4.111	4.333
G5	6.333	6.556	5.222	5.000	4.556	6.333
G6	3.889	3.222	5.000	5.222	6.111	4.778
G7	3.667	5.000	5.000	4.778	6.556	5.667

Eqs. (9) and (10) can be used to compute a multi-criteria preference index for each supplier (Table 7). This step has transformed the raw data into a set of informative, through pairwise comparison among suppliers to understand their performance. The leaving, entering and net flows can be obtained using Eqs. (11−13). Table 8 displays the result of the modified PROMETHEE approach. Based on the results obtained in Table 8, Supplier 4 ranks first.

Table 7. Multi-criteria preference index

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	*Sum*
Supplier 1	-	0.026	0.057	0.044	0.078	0.061	0.266
Supplier 2	0.036	-	0.055	0.046	0.078	0.071	0.286
Supplier 3	0.056	0.044	-	0.029	0.051	0.036	0.216
Supplier 4	0.062	0.054	0.048	-	0.080	0.070	0.312
Supplier 5	0.065	0.055	0.039	0.048	-	0.032	0.240
Supplier 6	0.070	0.071	0.047	0.061	0.055	-	0.304
Sum	0.289	0.249	0.245	0.228	0.342	0.270	

Table 8. Results of the BWM–modified PROMETHEE methodology

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6
Leaving flow	0.266	0.286	0.216	0.312	0.240	0.304
Entering flow	0.289	0.249	0.245	0.228	0.342	0.270
Net flow	-0.024	0.037	-0.029	0.084	-0.102	0.034
Rank	4	2	5	1	6	3

4.2. Sensitivity analysis

Many researchers including Gupta and Barua (2017) propose a sensitivity analysis to verify the robustness of the model. Sensitivity analysis helps in determining whether final ranking of the supplier is changed due to variation in weights of the criteria. Because of the large number of criteria, adjusting the dimension level is more suitable for explaining the effectiveness of the sensitivity analysis. When the weight of the highest ranked dimension, Economic (P), changes from 0.1 to 0.9, the other criteria weights are adjusted proportionally (Table 9). For example, the sum of the weights accumulated from P1 to P6 is 0.1 (Run 1). The other run operations use the same method.

Table 9. All the criteria weights change according to dimension "Economic (P)"

Criteria	P1	P2	P3	P4	P5	P6	S1	S2	S3	S4	S5	S6	S7	G1	G2	G3	G4	G5	G6	G7
Run 1	0.021	0.021	0.015	0.015	0.018	0.009	0.078	0.074	0.115	0.050	0.064	0.050	0.063	0.075	0.026	0.072	0.062	0.056	0.069	0.045
Run 2	0.043	0.042	0.030	0.031	0.036	0.018	0.069	0.066	0.102	0.045	0.057	0.044	0.056	0.067	0.023	0.064	0.055	0.050	0.061	0.040
Run 3	0.064	0.063	0.045	0.046	0.055	0.027	0.061	0.058	0.089	0.039	0.050	0.039	0.049	0.058	0.020	0.056	0.049	0.043	0.054	0.035
Run 4	0.086	0.084	0.060	0.062	0.073	0.036	0.052	0.050	0.077	0.034	0.042	0.033	0.042	0.050	0.017	0.048	0.042	0.037	0.046	0.030
Run 5	0.107	0.105	0.075	0.077	0.091	0.045	0.043	0.041	0.064	0.028	0.035	0.028	0.035	0.042	0.014	0.040	0.035	0.031	0.038	0.025
Run 6	0.129	0.126	0.090	0.092	0.109	0.054	0.035	0.033	0.051	0.022	0.028	0.022	0.028	0.033	0.012	0.032	0.028	0.025	0.031	0.020
Run 7	0.150	0.147	0.105	0.108	0.127	0.063	0.026	0.025	0.038	0.017	0.021	0.017	0.021	0.025	0.009	0.024	0.021	0.019	0.023	0.015
Run 8	0.172	0.168	0.120	0.123	0.146	0.071	0.017	0.017	0.026	0.011	0.014	0.011	0.014	0.017	0.006	0.016	0.014	0.012	0.015	0.010
Run 9	0.193	0.189	0.135	0.139	0.164	0.080	0.009	0.008	0.013	0.006	0.007	0.006	0.007	0.008	0.003	0.008	0.007	0.006	0.008	0.005

By integrating supplier performance with the modified PROMETHEE, we can observe the differences in supplier ranking. The sensitivity analysis results can be seen in Fig. 2. The supplier ranking results display significant changes after performing nine runs. In particular, supplier 2 ranking, changes between the last and first run. Obviously, the proposed model is subject to weight changes that affect supplier ranking. This result echoes a practical situation that various business policies and management practices can affect operational performance.
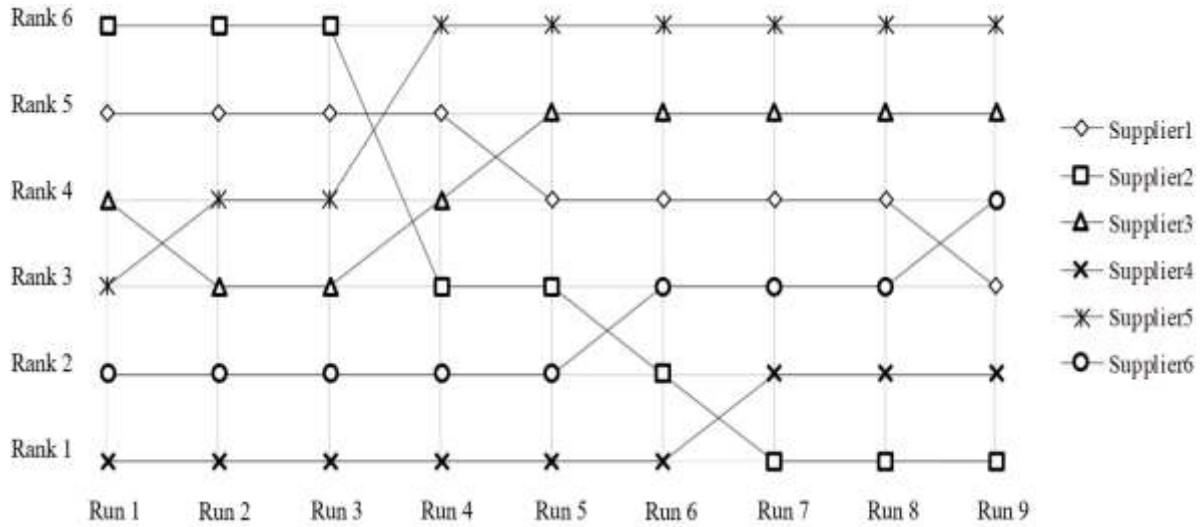

Fig 2. Supplier rankings based on the sensitivity analysis result

5. Discussion

Sustainable supply chain management decreases the adverse impacts of supply chains operations and enhances the corporation effectiveness from environmental, social, and economic dimensions. Companies need to balance responsibilities for social, environmental, and economic issues to manage these sustainability initiatives (Bai and Sarkis, 2010). Sustainable supply chain management initiatives provide a pathway for companies in obtaining a 'win-win-win' sustainable outcome. Within this context, supplier evaluation and collaboration play a critical role in contributing to the nation sustainable development. Companies considering these initiatives become more concentrated on promoting sustainable development (Das, 2018). Global organizations face the challenges of managing and maintaining profitability when implementing socially and environmentally sustainable operations. Selecting sustainable suppliers that are innovating methods to manage sustainability for day-to-day operations, is the logical and optimized means of helping organizations to achieve sustainability goals. This study adopts such a sustainability innovation framework to evaluate and select sustainable suppliers for an Iranian manufacturing organization. The findings present several unique results for this organization. The Economic (P) dimension, with a weight of 0.532, is the most significant for supplier selection. Any supply chain, sustainable or not, cannot be maintained without controlling the costs related to its operations. Costs incurred that are related to suppliers are crucial, particularly for suppliers selected on the basis of their green and environmental management abilities (Luthra et al., 2015). Suppliers with strong financial backgrounds are attracted to innovative and new ideas to reduce the harmful environmental effects of their products. Suppliers with sufficient capital establish R&D facilities and invest in the training and development of human resources in terms of sustainable technologies and processes (Gupta and Barua, 2017). Strong economic support helps organizations to invest in new technologies and seek expertise from outside organizations for improving processes and reducing waste. Furthermore, with economic backing, organizations are able to invest in reverse cycling and new energy-efficient materials, thus reducing overall waste and material requirements (Gupta and Barua, 2018).

The Social (S) dimension ranked second with a weight of 0.257. Earth's natural resources are being rapidly depleted, and humans risk extinction if the pool of natural resources is depleted. Society as a whole is affected the most by environmental degradation. Large organizations are constantly seeking association with suppliers that are concerned with social matters (Ahmadi et

al., 2017b). Major concerns within the social criteria are working conditions and the health, and safety of workers. Organizations prefer suppliers that are responsive to the market and customer demand for green products (Tariq et al., 2017). In addition, organizations that are involved in environmental management activities through corporate social initiatives perform well in sustainable supply chains and can implement socioeconomic standards within supply chains (Govindan et al., 2015).

Among the criteria, sustainable product cost reduction (P1) is ranked first, a result supported by various scholars (Zhu et al., 2018). Ability to provide competitive prices as compared to competitors are primary criteria for supplier selection. As resources become scarcer and the costs of raw materials and products increase, sustainable innovation becomes the only option to reduce production cost and harmful effects on the environment (Kusi-Sarpong et al., 2019). The second criterion is financial availability for innovation (P2). Sustainable innovation requires substantial investment in technology and skilled workers who can competently innovate an organization's processes and products for sustainability. The third criterion is Finance in R&D (P5). Greening the organizations and products toward sustainability requires substantial effort for developing new processes, altering current processes, and experimenting with alternate materials to reduce harmful environmental effects. These efforts are supported through R&D activities inside and outside organizations. Organizations require substantial investment in R&D facilities to achieve their sustainability goals and compete with other organizations (Ansari and Kant, 2017).

The aim of this work is to select suppliers based on sustainable innovation criteria. A modified version of PROMETHEE technique is used to evaluate and rank suppliers. Six suppliers are ranked from the importance weights obtained through the BWM. Supplier 4 ranks first, indicating that this supplier performs the best according to the study criteria, particularly in the economic and social dimensions. The proposed methodology is a novel soft computing tool in which the numbers of criteria and alternatives do not affect solution quality. In addition, the methodology does not require any assumptions to perform its calculations. The proposed methodology is more suitable for practical use than statistical methods, and its results are more reliable. The modified PROMETHEE provides helpful information concerning possible improvements for suppliers. Obviously, if a supplier wants to improve its performance, it can start from two aspects: increasing leaving flow and reducing entering flow. In the case of this study, a supplier with a negative net flow value performed relatively poor. For example, leaving flow and entering flow of supplier 5

are 0.240 and 0.342 respectively. The supplier must track which criteria should be improved based on the results of the BWM analysis. We recommend starting with the top five criteria, as their total weight is close to 0.5. Suppliers should pay attention to the performance in sustainable product cost reduction (P1), financial availability for innovation (P2), finance in R&D (P5), increased sustainability value to customers (P4) and finance resumption of products (P3), to establish a set of improvement measures to enhance the company's performance in these indicators. The modified PROMETHEE ranks the importance of the criteria and indicates the number of gaps that must be reduced to achieve the aspiration level for each supplier. The "net flow" generated by the PROMETHEE calculation can identify the relative merits of the supplier. For example, the supplier 4 is the first priority with the highest net flow, indicating that it is a better performing supplier. It is worth mentioning that although supplier 4 has been identified as the best supplier in the current evaluation system, it does not mean that this supplier does not need to improve. Because the value of the entering flow (gap) is 0.228 to reach the aspiration level. This paper provides a framework for managers and decision-makers of manufacturing organizations to select suppliers according to sustainable innovation criteria.

6. Conclusion and remarks

Organizational sustainable innovation can significantly be improved through sustainable innovative supply chains. Supplier evaluation and selection is an important element for building an efficient sustainable innovative supply chains. This manuscript is the first of its kind and an initial attempt for providing a framework of innovation criteria for supplier evaluation and selection on the basis of sustainability innovativeness. The framework contains three main dimensions and 20 criteria (see Table 1), making it a multi-criteria decision-making problem. In evaluating multi-criteria decision problems such as supplier evaluating problems, several models have been employed. Each has its own characteristics and merits. In this paper, after evaluating the characteristics and advantages of several models, we introduced some models in an integrated manner, which has not been employed before in the literature. An integrated BWM and modified version of PROMETHEE was introduced and applied to aid in the evaluation and ranking of six manufacturing company suppliers, with input from nine of their managers (decision-makers). Introducing a sustainability innovation evaluation framework and employing an integrated BWM

- modified version of PROMETHEE (BWM and PROMETHEE-AL) are the two contributions of this work.

This study also has several limitations. Limitations can provide opportunities for further study in this area. One limitation is that each dimension could have several sub-criteria for a deeper analysis and framework extension. Another limitation is that a particular industrial sector was employed for obtaining criteria weights and ranking suppliers. Future studies might apply our evaluation framework to test other industrial sectors, for example for assessing their suppliers in terms of sustainability innovation performance. Other limitation of this research is that sustainability innovation criteria weights and ranking of suppliers were identified using BWM-modified PROMETHEE. Possible future studies could employ fuzzy or grey BWM to address uncertainty issues in the criteria weighting, and then apply other MCDM tools including ANP or VIKOR to evaluate and rank the suppliers. Also, we suggest that future works try to investigate interrelationships and interdependencies among the sustainability innovation criteria, identify their causal relationship and determine which criteria affect others and which factors are affected by other criteria. Finally, potential future works can extend this study' investigation to include suppliers management and supplier development, after evaluating and selecting suppliers.

References

Ageron, B., Gunasekaran, A., Spalanzani, A. 2012. Sustainable supply management: An empirical study. International Journal of Production Economics, 140(1), 168–182.

Ahmadi, H. B., Kusi–Sarpong, S., Rezaei, J. 2017b. Assessing the social sustainability of supply chains using Best Worst Method. Resources, Conservation and Recycling, 126, 99–106.

Ahmadi, H. B., Petrudi, S. H. H., Wang, X. 2017a. Integrating sustainability into supplier selection with analytical hierarchy process and improved grey relational analysis: a case of telecom industry. The International Journal of Advanced Manufacturing Technology, 90(9–12), 2413–2427.

Albareda, L., Hajikhani, A. 2019. Innovation for Sustainability: Literature Review and Bibliometric Analysis Innovation for Sustainability (pp. 35–57): Springer.

Amindoust, A. 2018. A resilient–sustainable based supplier selection model using a hybrid intelligent method. Computers & Industrial Engineering, 126, 122–135.

Amore, M. D., Bennedsen, M. 2016. Corporate governance and green innovation. Journal of Environmental Economics and Management, 75, 54–72.

Ansari, Z. N., Kant, R. 2017. A state–of–art literature review reflecting 15 years of focus on sustainable supply chain management. Journal of Cleaner Production, 142, 2524–2543.

Ayuso, S., M. Ángel Rodríguez., R. García-Castro., M. Ángel Ariño. 2011. Does Stakeholder Engagement Promote Sustainable Innovation Orientation? Industrial Management & Data Systems, 111 (9), 1399–1417.

Azadnia, A. H., Saman, M. Z. M., Wong, K. Y. 2015. Sustainable supplier selection and order lot-sizing: an integrated multi-objective decision-making process. International Journal of Production Research, 53(2), 383-408.

Azimifard, A., Moosavirad, S. H., Ariafar, S. 2018. Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. Resources Policy, 57, 30–44.

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, 1–22.

Bai, C., Sarkis, J. 2010. Integrating sustainability into supplier selection with grey system and rough set methodologies. International Journal of Production Economics, 124(1), 252–264.

Boons, F., Montalvo, C., Quist, J., Wagner, M. 2013. Sustainable innovation, business models and economic performance: an overview. Journal of Cleaner Production, 45, 1–8.

Brans, J.–P., Vincke, P. 1985. Note–A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision–Making). Management science, 31(6), 647–656.

Calik, E., Bardudeen, F. 2016. A measurement scale to evaluate sustainable innovation performance in manufacturing organizations. Procedia Cirp, 40, 449–454.

Chen, J.–Y., Dimitrov, S., Pun, H. 2019. The impact of government subsidy on supply Chains' sustainability innovation. Omega, 86, 42–58.

Croxton, K. L., García‐Dastugue, S. J., Lambert, D. M., Rogers, D. S. 2001. The Supply Chain Management Processes. The International Journal of Logistics Management, 12(2), 13-36.

Das, D. 2018. Sustainable supply chain management in Indian organisations: an empirical investigation. International Journal of Production Research, 56(17), 5776–5794.

Del Río, P., Peñasco, C., Romero–Jordán, D. 2016. What drives eco–innovators? A critical review of the empirical literature based on econometric methods. Journal of Cleaner Production, 112, 2158–2170.

Demirel, P., Kesidou, E. 2011. Stimulating different types of eco–innovation in the UK: Government policies and firm motivations. Ecological Economics, 70(8), 1546–1557.

Doyle, E., McGovern, D., McCarthy, S., Perez–Alaniz, M. 2019. Compliance–innovation: A quality–based route to sustainability. Journal of Cleaner Production, 210, 266–275.

Dyllick, T., Hockerts, K. 2002. Beyond the business case for corporate sustainability. Business strategy and the environment, 11(2), 130–141.

El–Kassar, A.–N., Singh, S. K. 2019. Green innovation and organizational performance: the influence of big data and the moderating role of management commitment and HR practices. Technological Forecasting and Social Change, 144, 483–498.

Fahimnia, B., Sarkis, J., Gunasekaran, A., Farahani, R. 2017. Decision models for sustainable supply chain design and management. Annals of Operations Research, 250(2), 277-278.

Formentini, M., Taticchi, P. 2016. Corporate sustainability approaches and governance mechanisms in sustainable supply chain management. Journal of Cleaner Production, 112, Part 3, 1920-1933.

Gao, H., Ju, Y., Gonzalez, E.D.S. Zhang, W. 2020. Green supplier selection in electronics manufacturing: An approach based on consensus decision making. Journal of Cleaner Production, 245, p.118781.

Golini, R., Moretto, A., Caniato, F., Caridi, M., Kalchschmidt, M. 2017. Developing sustainability in the Italian meat supply chain: an empirical investigation. International Journal of Production Research, 55(4), 1183–1209.

Govindan, K., Kadziński, M., Sivakumar, R. 2017. Application of a novel PROMETHEE–based method for construction of a group compromise ranking to prioritization of green suppliers in food supply chain. Omega, 71, 129–145.

Govindan, K., Muduli, K., Devika, K., Barve, A. 2016. Investigation of the influential strength of factors on adoption of green supply chain management practices: An Indian mining scenario. Resources, Conservation and Recycling, 107, 185–194.

Govindan, K., Rajendran, S., Sarkis, J., Murugesan, P. 2015. Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. Journal of Cleaner Production, 98, 66–83.

Guarnieri, P., Trojan, F. 2019. Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry. Resources, Conservation and Recycling, 141, 347–361.

Gupta, H., Barua, M. K. 2017. Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. Journal of Cleaner Production, 152, 242–258.

Gupta, H., Barua, M. K. 2018. A novel hybrid multi–criteria method for supplier selection among SMEs on the basis of innovation ability. International Journal of Logistics Research and Applications, 21(3), 201–223.

Gupta, H., Kusi-Sarpong, S., Rezaei, J. 2020. Barriers and overcoming strategies to supply chain sustainability innovation. Resources Conservation and Recycling, 159, DOI: https://doi.org/10.1016/j.resconrec.2020.104819.

Haeri, S. A. S., Rezaei, J. 2019. A grey–based green supplier selection model for uncertain environments. Journal of Cleaner Production, 221, 768–784.

Hashemi, S. H., Karimi, A., Tavana, M. 2015. An integrated green supplier selection approach with analytic network process and improved Grey relational analysis. International Journal of Production Economics, 159, 178–191.

Hassini, E., Surti, C., Searcy, C. 2012. A literature review and a case study of sustainable supply chains with a focus on metrics. International Journal of Production Economics, 140(1), 69-82.

Horbach, J., Rammer, C., Rennings, K. 2012. Determinants of eco–innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. Ecological Economics, 78, 112–122.

Hussain, M., Malik, M. 2020. Organizational enablers for circular economy in the context of sustainable supply chain management. Journal of Cleaner Production, 256, 120375.

Iles, A., Martin, A. N. 2013. Expanding bioplastics production: sustainable business innovation in the chemical industry. Journal of Cleaner Production, 45, 38–49.

Jabbour, C. J. C., Jugend, D., de Sousa Jabbour, A. B. L., Gunasekaran, A., Latan, H. 2015. Green product development and performance of Brazilian firms: measuring the role of human and technical aspects. Journal of Cleaner Production, 87, 442–451.

Jenkins, H., Yakovleva, N. 2006. Corporate social responsibility in the mining industry: Exploring trends in social and environmental disclosure. Journal of Cleaner Production, 14(3–4), 271–284.

Jia, F., Zuluaga–Cardona, L., Bailey, A., Rueda, X. 2018. Sustainable supply chain management in developing countries: An analysis of the literature. Journal of Cleaner Production, 189, 263–278.

Jia, F., Yin, S., Chen, L., Chen, X. 2020. Circular Economy in Textile and Apparel Industry: A systematic Literature review. Journal of Cleaner Production, 120728.

Jones, J., de Zubielqui, G. C. 2017. Doing well by doing good: A study of university–industry interactions, innovationess and firm performance in sustainability–oriented Australian SMEs. Technological Forecasting and Social Change, 123, 262–270.

Kammerer, D. 2009. The effects of customer benefit and regulation on environmental product innovation.: Empirical evidence from appliance manufacturers in Germany. Ecological Economics, 68(8–9), 2285–2295.

Kannan, D., de Sousa Jabbour, A. B. L., Jabbour, C. J. C. 2014. Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. European Journal of Operational Research, 233(2), 432–447.

Kennedy, S., Whiteman, G., van den Ende, J. 2017. Radical innovation for sustainability: The power of strategy and open innovation. Long Range Planning, 50(6), 712–725.

Khan, S. A., Kusi–Sarpong, S., Arhin, F. K., Kusi–Sarpong, H. 2018. Supplier sustainability performance evaluation and selection: A framework and methodology. Journal of Cleaner Production, 205, 964–979.

Krishankumar, R., Ravichandran, K., Saeid, A. B. 2017. A new extension to PROMETHEE under intuitionistic fuzzy environment for solving supplier selection problem with linguistic preferences. Applied Soft Computing, 60, 564–576.

Kumar, A., Moktadir, M.A., Khan, S.A.R., Garza-Reyes, J.A., Tyagi, M., Kazançoğlu, Y. 2020. Behavioural factors on the adoption of sustainable supply chain practices. Resources, Conservation & Recycling: X,100031.

Kusi–Sarpong, S., Bai, C., Sarkis, J., Wang, X. 2015. Green supply chain practices evaluation in the mining industry using a joint rough sets and fuzzy TOPSIS methodology. Resources Policy, 46, 86–100.

Kusi–Sarpong, S., Gupta, H., Sarkis, J. 2019. A supply chain sustainability innovation framework and evaluation methodology. International Journal of Production Research, 57(7), 1990–2008.

Li, S., Ragu–Nathan, B., Ragu–Nathan, T., Rao, S. S. 2006. The impact of supply chain management practices on competitive advantage and organizational performance. Omega, 34(2), 107–124.

Li, Y., Mathiyazhagan, K. 2018. Application of DEMATEL approach to identify the influential indicators towards sustainable supply chain adoption in the auto components manufacturing sector. Journal of Cleaner Production, 172, 2931–2941.

Li, J., Fang, H., Song, W. 2019. Sustainable supplier selection based on SSCM practices: A rough cloud TOPSIS approach. Journal of cleaner production, 222, 606–621.

Linton, J. D., Klassen, R., Jayaraman, V. 2007. Sustainable supply chains: An introduction. Journal of Operations Management, 25(6), 1075-1082.

Lo, H.–W., Liou, J. J. 2018. A novel multiple–criteria decision–making–based FMEA model for risk assessment. Applied Soft Computing, 73, 684–696.

Lo, H.–W., Liou, J. J., Wang, H. –S., Tsai, Y. –S. 2018. An integrated model for solving problems in green supplier selection and order allocation. Journal of cleaner production, 190, 339–352.

Luthra, S., Garg, D., Haleem, A. 2015. An analysis of interactions among critical success factors to implement green supply chain management towards sustainability: An Indian perspective. Resources Policy, 46, 37–50.

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., Garg, C. P. 2017. An integrated framework for sustainable supplier selection and evaluation in supply chains. Journal of Cleaner Production, 140, Part 3, 1686-1698.

Mangla, S. K., Kumar, P., Barua, M. K. 2014. Flexible decision approach for analysing performance of sustainable supply chains under risks/uncertainty. Global Journal of Flexible Systems Management, 15(2), 113–130.

Mardani, A., Kannan, D., Hooker, R.E., Ozkul, S., Alrasheedi, M., Tirkolaee, E.B. 2020. Evaluation of green and sustainable supply chain management using structural equation modelling: A systematic review of the state of the art literature and recommendations for future research. Journal of Cleaner Production, 249, 119383.

Mathivathanan, D., Kannan, D., Haq, A. N. 2018. Sustainable supply chain management practices in Indian automotive industry: A multi–stakeholder view. Resources, Conservation and Recycling, 128, 284–305.

Mathiyazhagan, K., Haq, A. N. 2013. Analysis of the influential pressures for green supply chain management adoption—an Indian perspective using interpretive structural modeling. The International Journal of Advanced Manufacturing Technology, 68(1–4), 817–833.

Messeni Petruzzelli, A., Maria Dangelico, R., Rotolo, D., Albino, V. 2011. Organizational factors and technological features in the development of green innovations: Evidence from patent analysis. Innovation, 13(3), 291–310.

Moktadir, M.A., Ahmadi, H.B., Sultana, R., Liou, J.J., Rezaei, J. 2020. Circular economy practices in the leather industry: A practical step towards sustainable development. Journal of Cleaner Production, 251, 119737.

Mousavi, S., Bossink, B. A. 2017. Firms' capabilities for sustainable innovation: The case of biofuel for aviation. Journal of Cleaner Production, 167, 1263–1275.

Papetti, A., Marconi, M., Rossi, M., Germani, M. 2019. Web–based platform for eco–sustainable supply chain management. Sustainable Production and Consumption, 17, 215–228.

Pieroni, M. P., McAloone, T., Pigosso, D. A. 2019. Business model innovation for circular economy and sustainability: A review of approaches. Journal of Cleaner Production.

Pitchipoo, P., Venkumar, P., Rajakarunakaran, S. 2013. Fuzzy hybrid decision model for supplier evaluation and selection. International Journal of Production Research, 51(13), 3903–3919.

Rauter, R., Globocnik, D., Perl–Vorbach, E., Baumgartner, R. J. 2019. Open innovation and its effects on economic and sustainability innovation performance. Journal of Innovation & Knowledge, 4(4), 226–233.

Rebs, T., Brandenburg, M., Seuring, S. 2019. System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach. Journal of Cleaner Production, 208, 1265–1280.

Reefke, H., Sundaram, D. 2018. Sustainable supply chain management: Decision models for transformation and maturity. Decision Support Systems, 113, 56–72.

Rezaei, J. 2015. Best–worst multi–criteria decision–making method. Omega, 53, 49–57.

Rezaei, J. 2016. Best–worst multi–criteria decision–making method: Some properties and a linear model. Omega, 64, 126–130.

Rothenberg, S., Zyglidopoulos, S. C. 2007. Determinants of environmental innovation adoption in the printing industry: the importance of task environment. Business strategy and the environment, 16(1), 39–49.

Roy, V., Schoenherr, T., Charan, P. 2020. Toward an organizational understanding of the transformation needed for sustainable supply chain management: The concepts of force-field and differential efforts. Journal of Purchasing and Supply Management, 100612.

Sarkis, J., Dhavale, D. G. 2015. Supplier selection for sustainable operations: A triple–bottom–line approach using a Bayesian framework. International Journal of Production Economics, 166, 177–191.

Sauer, P. C., Seuring, S. 2017. Sustainable supply chain management for minerals. Journal of Cleaner Production, 151, 235–249.

Seuring, S., Müller, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16(15), 1699–1710.

Seuring, S., Sarkis, J., Muller, M., Rao, P. 2008. Sustainability and supply chain management: an introduction to the special issue. Journal of Cleaner Production, 16 (14), 1545-1551.

Shi, L., Wu, K.J., Tseng, M.L. 2017. Improving corporate sustainable development by using an interdependent closed-loop hierarchical structure. Resources, Conservation and Recycling, 119: p. 24-35.

Silvestre, B. S., Monteiro, M. S., Viana, F. L. E., de Sousa–Filho, J. M. 2018 . Challenges for sustainable supply chain management: When stakeholder collaboration becomes conducive to corruption. Journal of Cleaner Production, 194, 766–776.

Silvestre, B. S., Țîrcă, D. M. 2019. Innovations for sustainable development: Moving toward a sustainable future. Journal of Cleaner Production, 208, 325–332.

Somsuk, N., Laosirihongthong, T. 2017. Prioritization of applicable drivers for green supply chain management implementation toward sustainability in Thailand. International Journal of Sustainable Development & World Ecology, 24(2), 175–191.

Song, W., Xu, Z., Liu, H.–C. 2017. Developing sustainable supplier selection criteria for solar air–conditioner manufacturer: An integrated approach. Renewable and Sustainable Energy Reviews, 79, 1461–1471.

Sroufe, R. 2017. Integration and organizational change towards sustainability. Journal of Cleaner Production, 162, 315–329.

Tariq, A., Badir, Y. F., Tariq, W., Bhutta, U. S. 2017. Drivers and consequences of green product and process innovation: A systematic review, conceptual framework, and future outlook. Technology in Society, 51, 8–23.

Tseng, M.L. 2013. Modeling sustainable production indicators with linguistic preferences. Journal of Cleaner Production, 40, 46–56.

Vasilenko, L., V. Arbačiauskas. 2012. Obstacles and Drivers for Sustainable Innovation Development and Implementation in Small and Medium Sized Enterprises. Environmental Research, Engineering and Management, 60 (2), 58–66.

Veronica, S., Alexeis, G.P., Valentina, C., Elisa. G. 2019. Do stakeholder capabilities promote sustainable business innovation in small and medium-sized enterprises? Evidence from Italy. Journal of Business Research.

Wong, W. P., Tseng, M.-L., Tan, K. H. 2014. A business process management capabilities perspective on organisation performance. Total Quality Management & Business Excellence, 25(5-6), 602-617.

Wu, Y., Zhang, B., Wu, C., Zhang, T., Liu, F. 2019. Optimal site selection for parabolic trough concentrating solar power plant using extended PROMETHEE method: A case in China. Renewable Energy.

Yadav, G., Mangla, S. K., Luthra, S., Rai, D. P. 2019. Developing a sustainable smart city framework for developing economies: An Indian context. Sustainable Cities and Society, 47, 101462.

Yadav, G., Luthra, S., Jakhar, S., Mangla, S.K., Rai, D.P. 2020. A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: An automotive case. Journal of Cleaner Production, 120112.

Yu, C., Shao, Y., Wang, K., Zhang, L. 2019. A group decision making sustainable supplier selection approach using extended TOPSIS under interval–valued Pythagorean fuzzy environment. Expert Systems with Applications, 121, 1–17.

Zhu, Q., Sarkis, J., Lai, K.–h. 2012. Examining the effects of green supply chain management practices and their mediations on performance improvements. International Journal of Production Research, 50(5), 1377–1394.

Zhu, Z., Chu, F., Dolgui, A., Chu, C., Zhou, W., Piramuthu, S. 2018. Recent advances and opportunities in sustainable food supply chain: a model–oriented review. International Journal of Production Research, 56(17), 5700–5722.

Zhou, M., Govindan, K., Xie, X. 2020. How fairness perceptions, embeddedness, and knowledge sharing drive green innovation in sustainable supply chains: An equity theory and network perspective to achieve sustainable development goals. Journal of Cleaner Production, p.120950.