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Analysis of supplier evaluation and selection strategies for sustainable collaboration: A combined approach of best–worst method and TOmada de Decisao Interativa Multicriterio

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Abstract

Sustainable collaboration between manufacturer and supplier has emerged as a crucial supply chain decision for increasing business efficiency. In this study, a theoretical framework is proposed that uses practice-based view to analyze key performance indicators (KPIs) for developing sustainable collaboration. Further, the current study proposes a novel three-phase supplier evaluation–selection model to assess the incumbent suppliers on basis of KPIs for showcasing the applicability of theoretical framework. The model uses best–worst method (BWM) in the first phase for generating weights of KPI, adopts the TODIM approach in the second phase for evaluation of suppliers, and develops a supplier classification grid in the third phase for analyzing the impact of each selection strategy to be adopted. The novelty of the study is in evaluation of suppliers based on the KPIs with consideration of desirability as well as the potentiality metric and in consideration of the selection strategies, namely, supplier retention, supplier development, and supplier switching. A case study of India's leading home appliances company is taken to demonstrate the application of the current study. The result of BWM reveals that in terms of supplier's potentiality, "quality" emerges as a strong KPI while KPI "information disclosure" gains more importance while considering supplier's desirability towards strengthening the sustainable relationship. The TODIM grid analysis result suggests that suppliers with high performance in both metrics clearly qualify as the best suppliers and must be retained, while the suppliers performing low in both areas must be switched. For suppliers with metric values in conflict with each other, a trade-off analysis is needed. Important research and managerial implications are drawn from the validation of the proposed framework, which can be useful for researchers and practitioners.

KEYWORDS
BWM, practice-based view, selection strategy, supplier performance evaluation, supplier-manufacturer relationship, sustainable collaboration, TODIM

1 | INTRODUCTION

Given excessive global competition, it is imperative for companies to relentlessly try to improve their supply chain processes. Some of these efforts are made to improve their ability to respond to customer demands quickly despite limited resources (Mathiyazhagan et al., 2014). Apart from achieving their profit objectives, companies also need to meet the standards set by the government authorities to achieve a sustainable supply chain (SC). To develop a sustainable SC, each partner has a role to play. Therefore, it becomes necessary for companies to ensure that each stakeholder functions to its fullest capabilities so the satisfactory sustainable performance of the entire SC may be achieved (Carballo-Penela et al., 2018; Flynn et al., 2015).

In the current customer-oriented market, suppliers play a critical role in enhancing the sustainable performance of the manufacturing companies (Fallahpour et al., 2021; Tansakul et al., 2022). Thus, a strong and trustworthy manufacturer–supplier relationship emerges as a focal point for many companies to enhance sustainable performance in the procurement process, optimize purchasing effectiveness, maintain a competitive advantage, and increase customer value (Rezaei et al., 2015; Shah & Soomro, 2021). A successful sustainable manufacturer–supplier relationship depends on long-term commitment, coordination of business activities, and collaborative efforts (Govindan et al., 2021; Hofman et al., 2020; Yen, 2018). It has also been proven that performance measurement of suppliers is a fundamental method of synchronizing the partnership with the operational, strategic, and sustainable objectives of the buying firm (Ghadimi et al., 2016; Stål et al., 2021). However, a task for the manufacturer is how to periodically monitor the sustainable performance of the existing suppliers. Although the potentiality/capability of a supplier is a pertinent gauge that manufacturers employ when choosing a supplier (Zimmer et al., 2016), the desirability/keenness of the suppliers towards a sustainable collaboration must also be considered (Rezaei & Fallah, 2019). Hence, the performance of suppliers should be evaluated in terms of potentiality or the ability of the supplier to contribute to the sustainable collaboration, and the desirability, intention, or willingness to be part of the sustainable collaboration with the manufacturer. The choice of performance indicators on which the potentiality and desirability metrics of supplier can be measured is still a critical challenge for the buying firm in local or global supply chains. These statements raise the research question: "What are the appropriate KPIs of incumbent suppliers for a potentiality metric and a desirability different order of importance of alternatives. Therefore, the appropriate choice of KPIs and their evaluation are critically important to synchronizing the purchasing decisions of manufacturers with long-term goals and performance objectives of the buying firm (Govindan et al., 2021; Lima-Junior & Carpinetti, 2016). Many researchers have developed performance measurement systems for evaluating suppliers (Govindan et al., 2015; Viswanadham & Samvedi, 2013) and identifying the KPIs used by manufacturers to select their suppliers (Abdel-Basset et al., 2018). No comprehensive systematic framework exists that is developed for evaluation and selection of suppliers based on their potentiality and desirability for working towards a sustainable manufacturer–supplier relationship. These statements drive the research question: "What should be the method of assessment of the performance of the incumbent suppliers and their selection strategy based on the identified sustainable KPIs regarding their potentiality and desirability?"

For answering the above-mentioned questions, a novel three-phase conceptual framework is proposed for performance evaluation and selection of suppliers for sustainable collaboration. The novelty of this framework is in evaluation of suppliers based on the KPIs with consideration of desirability as well as the potentiality metric and in consideration of the selection strategies, namely, supplier retention, supplier development, and supplier switching. First, the KPIs are identified through an extensive literature survey and with the deliberation of decision makers. Thereafter, in Phase I of the proposed model, the best–worst method (BWM) is applied to calculate the weights of KPIs for suppliers' capability as well as desirability. Next, for an evaluation of suppliers based on the weighted KPIs, the TOmada de Decisao Interativa Multicriterio (TODIM) method is used in Phase II to comprehensively reflect the existing supplier's importance as well as to deal with subjectivity inherent in the decision-making environment. Based on the evaluation scores of the suppliers in Phase II, a supplier classification grid is formed in Phase III that uses a scatter plot to suggest the best selection strategy for suppliers. The implications drawn from the study will provide insights in making key decisions for supplier selection and in making periodic timely interventions for supplier development and supplier switching if/when required.

Thus, the present study contributes to the area of sustainable manufacturer–supplier relationship by developing an effective, sustainable, performance-based supplier selection model for evaluating existing/incumbent suppliers based on sustainable key performance indicators (KPIs) with regard to two metrics of evaluation:

a. While existing studies on supplier evaluation and selection focus solely on the potentiality metric of the suppliers, this study also considers the desirability metric of suppliers regarding sustainability.
b. While existing literature provides models for performance evaluation of suppliers regarding manufacturer's economic gains, this study presents the suppliers' performance evaluation and selection model for building sustainable collaboration between manufacturer and supplier.
c. While most supplier evaluation models do not provide practical tools the manufacturer may use to classify incumbent suppliers and to provide selection strategies for each of them, this study provides an efficient multi-criteria group decision approach for performance evaluation of existing suppliers and for timely interventions.

The rest of the paper is structured as follows: Section 2 provides a literature review on manufacturer–supplier collaboration, sustainable performance criteria, and supplier evaluation modelling. In Section 3, the theoretical framework of this study is presented. In Section 4, the problem description is discussed. Section 5 describes the importance and the steps of solution methods. Further, a framework for supplier selection for sustainable collaboration is discussed in Section 6. Section 7 describes a case study of a real-life application of the proposed model. In Section 8, discussions on results and implications of the study are presented. Finally, Section 9 concludes the paper.

2 | LITERATURE REVIEW

Given that the focus of the paper is on sustainable collaboration for enhanced improvement in the supply chain, the extant literature in that direction is presented. We have divided the literature review section in three sections: Section 2.1 discusses performance evaluation of suppliers for sustainable collaboration; Section 2.2 discusses the supplier performance evaluation and selection models; Section 2.3 provides the research gap of the study.

2.1 | Performance evaluation of suppliers for sustainable collaboration

Manufacturer–supplier relationships have gained a significant amount of attention in academic literature. In most of the earlier 1990s' research work, the primary focus of manufacturers was only on self-gain and the relationship with suppliers was transactional (Goffin et al., 1997), adversarial (O'Toole & Donaldson, 2002), contractual (Kim & Michell, 1999), or arms-length (Metcalf et al., 1992). Humphreys et al. (2001) proved in their study that manufacturers evaluate the suppliers only based on the purchasing cost of suppliers and manufacturer supplier relationships. Dabhilkar et al. (2009) present an empirical study to understand the importance of collaborative participation of suppliers in a manufacturing context. Because scholars recognize that suppliers can make long-term contributions and help manufacturers achieve a competitive advantage, a stream of literature began to recommend the development of relationships with suppliers to enhance performance of the SC. Shamsuzzoha et al. (2013) prove through their study that collaborative participation with suppliers leads to a competitive advantage for manufacturers. Alimardani et al. (2013) present a study for supplier evaluation to improve the performance of the manufacturing company and to maintain financial gain. Further, growing concerns over resource scarcity, waste management, and environmental protection has driven manufacturers towards incorporating sustainability aspects in their business (Gaziulusoy, 2015). This concern has generated more studies on sustainable supplier evaluation and selection. Recent works include a significant study by Awan et al. (2017) who emphasize on the importance of continuous performance measurement of suppliers for meeting rapidly changing customer requirements and for balancing economic, environmental, and social objectives. In another study by Sancha et al. (2019), the authors stress that manufacturers should work with sustainable suppliers for long-term benefits and competitive advantage. Nonetheless, there are very few studies that focus on developing relationships between manufacturers and suppliers in the context of sustainability, which is mutually beneficial to both. Recent works also emphasize that supplier evaluation is considered one of the subsequent endeavors of building buyer/supplier relationships and of enhancing supplier capabilities (Kashyap & Lakhanpal, 2022; Melander, 2018; Mina et al., 2021). Further, there is substantial growth in supplier evaluation and selection studies related to the potentiality of the suppliers in terms of environmental and social aspects for improving manufacturer's performance and profitability (Bai et al., 2019; Demiralay & Paksoy, 2022; Tavana et al., 2017). Lintukangas et al. (2019) show empirically that supplier orientation towards sustainability has a positive impact on the overall performance of the manufacturer. Nevertheless, supplier evaluation should not only rest on their capabilities but also on their willingness to collaborate. However, there are comparatively few studies that consider desirability for supplier evaluation (He & Chen, 2022). For a sustainable collaboration, it is crucial that both parties establish mutually identified sustainable objectives and that they are equally inclined towards achieving them. Shah and Soomro (2021) prove in their study that environmental collaboration with suppliers has a positive impact on environmental performance of the manufacturing company. The present study bridges this gap by assessing suppliers based on KPIs reflecting their potential as well as their desire to be sustainable, which can aid in achieving sustainable manufacturer–supplier collaboration.

various aspects (Razmi et al., 2009). Due to a growing concern towards environmental and social issues, most practitioners focus on incorporating sustainability-related aspects in the supplier evaluation and selection process (Aditi & Aggarwal, 2021; Azadnia et al., 2015; Govindan et al., 2013; Singh, 2014; Walker et al., 2012). Therefore, sustainable supplier evaluation has received much attention during the last decade (Azadi et al., 2015; Bai & Sarkis, 2014; Li et al., 2019; Sarkis & Dhavale, 2015; Winter & Lasch, 2016). Effective evaluation calls for the development of modeling techniques that deal with conflicting objectives and different opinions of decision makers in the sustainable supplier evaluation process. Because all performance measures do not have similar significance for the company and their importance is based on the objectives of the company, the evaluation of performance measures is equally important as the evaluation of suppliers in sustainable supplier selection problem. In short, an integrated MCDM technique is needed. In this regard, integrated multi-criteria decision-making techniques are applied by many researchers for developing sustainable supplier selection models. Hsu et al. (2012) adopted decision making trial and Evaluation Laboratory (DEMATEL)-based analytic network process (ANP) (called DANP), with VIsekriterijumskaoptimizacijaiKOmpromisnoResenje (VIKOR) to evaluate the performance of suppliers for environmentally conscious green manufacturers in aluminum composite panel industry of Taiwan. DANP with VIKOR is applied to solve the problem of multiple interdependent dimensions and criteria instead of independent assumption of AHP but it cannot handle the large number of criteria. Dai and Blackhurst (2012) evaluated and selected suppliers with respect to triple bottom line aspects by combining analytic hierarchy process (AHP) and quality function deployment techniques. Sivakumar et al. (2015) proposed the combined approach of AHP and Taguchi loss functions for analyzing the performance of supplier and identifying the best one. Luthra et al. (2017) proposed an integrated framework for sustainable supplier evaluation and selection using AHP-VIKOR based approach and considered various potentiality measures such as price, quality, environmental costs, and environmental competencies. Azimifard et al. (2018) generated the weights of sustainable performance indicators through AHP, and TOPSIS was utilized for ranking of suppliers. Abdel-Baset et al. (2019) proposed a two-phase integrated model, ANP-VIKOR, for resolving the problem of supplier selection in sustainable supply chain management. The strengths of above discussed methodologies are easy implementation and the capacity to handle the measurement of qualitative or intangible attributes, but the main drawback is taking the assumption of independent criteria and dimension that removes the study from real-world scenario. In the above discussed literature, the researchers have taken the triple bottom line approach for performance evaluation in terms of capability of the suppliers. None of the studies considers the performance measures in terms of the desirability of the suppliers weights of criteria with fewer pairwise comparisons and more consistent results. BWM has one additional advantage; it can be integrated very easily with other MCDM methods. In this study, we combined BWM with TODIM. TODIM is a MCDM method that captures the human perception in terms of gain and loss as well as reflects the limited rationality character of the decision maker efficiently based on the prospect theory. In the current work, TODIM is applied to select suppliers based both on their potentiality and desirability in terms of sustainable collaboration. Additionally, the novelty of the study is also in the classification of suppliers based on the results analysis of BWM-TODIM technique.

2.3 | Research gap

It is clear from the above discussion that there exists extant research by researchers worldwide on sustainable supplier performance evaluation and selection problems. Based on the conducted literature review, a summary of the recent work in the field is presented in the paragraph that follows. The comparative analysis presented is based on parameters such as the focus of the manufacturer on strengthening the relationship, consideration of sustainable performance measures, assessing the potentiality as well as the desirability of the suppliers towards collaboration, and lastly the integrated MCDM techniques used. This helps to highlight the research gap of the current study. The identified gaps are summarized as follows:

- As discussed, there are lots of studies in literature that consider the potentiality metric in the area of supplier performance evaluation. But no comprehensive study exists in which potentiality and desirability of the supplier regarding supplier selection is taken with the aim of building sustainable collaboration. Hence, in the current study, these two metrics are considered for supplier performance evaluation.
- The previous literature considered supplier evaluation and supplier selection strategies aspects independently. But there is no work under consideration that provides supplier evaluation as well as selection strategies. Therefore, the current study results supplier selection strategies based on supplier performance evaluation with respect to potentiality and desirability metric, which facilitates successful collaboration between manufacturer and supplier.
- Previously proposed assessment models have failed to provide a complete framework that can analyze the supplier performance on potentiality and desirability metric and suggest the potential supplier selection strategy. Hence, the current study makes a contribution by developing a three-phase framework to identify KPIs of

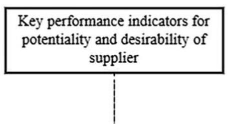
3 | THEORETICAL FRAMEWORK

Manufacturers spend a large amount of money purchasing raw materials, semi-finished goods, finished goods and services from suppliers. Traditionally, manufacturing firms emphasize operational performance measures of suppliers: cost, quality, delivery, and flexibility (Humphreys et al., 2001). Due to media involvement, non-governmental organizations (NGOs) and activists for sustainability-oriented violations hold manufacturing companies responsible for such violations. Hence, manufacturing companies focus more on sustainability aspects (Al-Odeh et al., 2021). But sustainability cannot be achieved by manufacturers alone, because in most cases, these sustainability related issues are due to the suppliers' violations. It can be established that these suppliers' violations occur due to the lack of potentiality and desirability for sustainability. A long-term relationship between supplier and manufacturer can be an effective remedy for these sustainability violations. To achieve this, a proper supplier performance evaluation framework is needed that can measure supplier's potentiality and desirability for sustainable collaboration. Hence, an effective supplier performance evaluation is an important tool for sustainable manufacturer–supplier collaboration implementation in current global scenarios. Due to the significant levels of the manufacturer's investment and the importance of sustainability-oriented violations, a theoretical support is much needed. This support should be established before a practical implementation of supplier performance evaluation and selection for sustainable collaboration practices. This theoretical framework can be a foundational pillar for research as well as for practitioners of sustainable collaboration. Hence, this study proposes a theoretical framework to investigate sustainable collaboration between manufacturer and supplier. A schematic of the theoretical framework is shown in Figure 1. This theoretical framework is comprised of four blocks: supplier's potentiality and desirability for sustainable collaboration, sustainable manufacturer–supplier collaboration, supplier's performance, and KPIs for potentiality and desirability of supplier. These blocks are interrelated. Supplier's potentiality and desirability for sustainable collaboration are essential for implementation of sustainable collaboration between supplier and manufacturer. Regardless of any application, the performance measures are required for evaluating supplier's performance on their capability and willingness for sustainable collaboration. Hence, this practice can influence the performance of supplier. In a nutshell, key performance indicators of supplier's potentiality and desirability for sustainable collaboration are key drivers to convert sustainable manufacturer- supplier collaboration practice into supplier's performance. Thus, the proposed theoretical framework supports the practice-based view (PBV) theory.

The PBV is proposed by Bromiley and Rau (2014). This view is a comparatively new perspective and treated as alternative theory to the resource-based view (RBV). The PBV supports the concept that day to day activities (even small) of any company or organization have an impact on their performance (Shaw et al., 2021). As discussed, sustainability-oriented violations by suppliers can cause huge losses in terms of reputational damage and economic losses to manufacturing companies. Hence, it is required to investigate performance measures thoroughly for sustainable collaboration. Thus, PBV is the most applicable theory as it focuses on common practices and performance. Hence, PBV is utilized as a theoretical lens to assess sustainable collaboration practice as it has significant impact on supplier's performance. There is a common belief among scholars that a range of performances and practices should be included in PBV to enhance and represent the scalability of a company in the industry (Silva et al., 2018). Yet, the practitioners are not able to identify the potential practices and performance dimensions due to lack of knowledge. To overcome this, the PBV helps practitioners to understand these practices and performance dimensions (Bromiley & Rau, 2014).

4 | PROBLEM DESCRIPTION

The problem under consideration is that of XYZ Pvt. Ltd., an Indian home appliances company (name not disclosed due to reasons of confidentiality). The company manufactures various electronic appliances: air conditioners, refrigerators, mixer juicers, microwave ovens, and washing machines. The annual sales turnover of the company has been recorded as approximately Rs. 4500 crores in the financial year 2018–2019. With 2500 employees, it has an extensive distribution network and a robust manufacturing process to cater to market demand. Due to ever increasing competition, government regulations, customer specifications, and changing market conditions, the company is relentlessly facing pressure to further improve upon their sustainable SC performance. Within this context, the company has started to identify the SC stages with scope of improvement for establishing a sustainable SC. To understand the SC stages of the company, a schematic view of the SC network involving suppliers, manufacturing plant, distribution nodes, retail stores, and end customers is shown in Figure 2. The suppliers supply raw material and



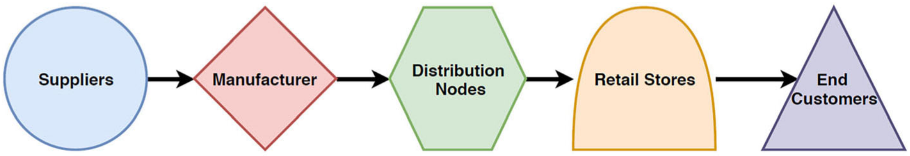


FIGURE 2 The schematic view of supply chain network of the company

components to the manufacturing plants. Products are manufactured in the plant by utilizing the raw material and components sent by suppliers. Subsequently, it is shipped to the retail stores via distribution nodes. Finally, it is moved to the end customers from retail stores.

One initial finding suggests that the procurement process regarding the washing machine segment needs to be improved. Hence, this problem is taken into consideration in the present study. The company manufactures various models of washing machines (semi-automatic and fully automatic with top loading/front loading options). The bill of material of washing machines is made by approximately 210 components which is a complex structure in terms of SC. Further details about the classes of components can be found in Romano et al. (2009). Based on his classification, these components are classified into eight classes according to the similarity in their characteristics as follows: (1) cabinet, (2) drum, (3) timer with harness, (4) motor, (5) PP tub, (6) rubber tub, (7) electrical parts, and (8) aesthetical and small auxiliary parts. Each class of component is supplied by a different supplier. After many deliberations and investigations, the management has established that due to the low performance of a few suppliers of different components regarding on-time delivery and responsiveness, the company has had to maintain high inventory levels, bear high transportation and warehousing costs, and face out-of-stock situations and longer lead times. Further, a few suppliers were found to be not adhering to the environmental management standards in their SC activities, while a few others were found to be lacking in regard to employment. These checks have revealed the need for continuous monitoring of the suppliers and for implementing timely remedial measures, or it will lead to the company's failure. Thus, to develop a SC which has reliable performance, it is imperative that the performance of the existing suppliers is promptly assessed based on the goals set by the company; the result is that suppliers will be retained or switched accordingly. Moreover, the company is inclined towards investing in supplier development process for better performing suppliers so that a sustainable relationship is maintained between the manufacturer and supplier to reap long-term benefits. Hence, the main aim of the study is to develop a supplier selection framework for the company which can be useful for them to achieve a successful sustainable collaboration with suppliers. It aims to provide insights to the decision makers so they understand the suitable selection strategy for each supplier based on its performance and attitude so that the company can significantly enhance its sustainable

5 | PRELIMINARIES

Consider the set of criteria (KPIs) $K = \{KPI_h : h = 1,2,\ldots,H\}$ where H is number of KPIs, the set of alternatives (suppliers) $S = \{S_g : g = 1,2,\ldots,G\}$ where G is the number of suppliers and the set of decision makers $D = \{\{DM_n : n = 1,2,\ldots,N\}\}$ where N is the number of decision makers. Sections 5.1 and 5.2 illustrate BWM and TODIM methods, respectively.

5.1 | BWM

BWM, developed by Rezaei et al. (2015), has been successfully applied in real case applications such as supplier selection (Gupta & Barua, 2017), in firms' R&D performance evaluation (Salimi & Rezaei, 2018), and in biomass thermochemical conversion technology selection (van de Kaa et al., 2017). Other subjective methods need "$h(h-1)/2$" number of comparisons for calculating weights but this method reduces requires only "h" number of comparisons (Stević et al., 2017). Hence, BWM is applied for computing the weights of the KPIs in this study.

The steps of BWM are as follows:

Step a Determine the best and worst KPI:

First, set of KPIs, $K = \{KPI_1, KPI_2, \ldots, KPI_H\}$ is identified based on extant literature review and extensive discussions with decision makers. Then, the best KPI (viz., most important KPI to evaluate the alternatives) and the worst KPI (viz., least important KPI to evaluate the alternatives) are identified by decision makers.

Step b Calculate the preference of best KPI over all the other KPIs:

In this step, the preference of best KPI over the others is calculated, using a score of 1–9. The result is a best-to-others (BO) vector and is given as

$$A_B = (a_{B1}, a_{B2}, \ldots, a_{BH})$$

where a_{Bh} is the preference of the best KPI over h^{th} KPI and $a_{BB} = 1$.

$$A_w = (a_{1W}, a_{2W}, \dots, a_{HW})$$

where a_{hW} is the preference of the h^{th} KPI over worst KPI and $a_{WW} = 1$.

Step d Obtain the optimal weights of each KPI.

Rezaei et al. (2015) have proposed a mathematical model for BWM, which gives multiple optimal solutions. Later, Rezaei (2016) gave a linear model which leads to unique weights. In this study, the linear model is used for determining the unique optimal weights $(u_1, u_2, \dots, u_H)$ of KPIs such that the following maximum absolute difference is minimized:

$$\max\{|u_B - a_{Bh}u_h|, |u_h - a_{hW}u_W|; h = 1, 2, \dots, H\}$$

The fractional programming model is as follows:

$$\min \max_h \left\{ \left|\frac{u_B}{u_h} - a_{Bh}\right|, \left|\frac{u_h}{u_W} - a_{hW}\right| \right\} \quad \text{(P1)}$$

Subject to

$$\sum_h u_h = 1$$

$$u_h \geq 0, \quad \forall h \in \{1, 2, \dots, H\}$$

This model is transformed into the following linear programming problem (Rezaei, 2016):

$$\min \varepsilon \quad \text{(P2)}$$

Subject to

$$\{|u_B - a_{Bh}u_h|\} \leq \varepsilon \quad \forall h \in \{1, 2, \dots, H\}$$
$$\{|u_h - a_{hW}u_W|\} \leq \varepsilon \quad \forall h \in \{1, 2, \dots, H\}$$

$$\sum_h u_h = 1$$

$$u_h \geq 0, \quad \forall h \in \{1, 2, \dots, H\}$$

The above problem generates the optimal weights $(u_1, u_2, \dots, u_H)$ and optimal value ε^*. The value of ε^* close to zero indicates a high consistency and high reliability.

5.2 | TODIM

Tversky, 1979). Based on the prospect theory, this method computes the dominance of each alternative over others for determining the ranking of alternatives (Xu et al., 2017).

TODIM is applied to evaluate the set of G suppliers $S = \{S_g : g = 1, 2, \dots, G\}$ based on the set of H criteria (KPIs), $K = \{KPI_h : h = 1, 2, \dots, H\}$. In this method, the decision makers need to indicate the reference KPI for calculation of relative weights of KPIs. Usually, the reference KPI is the KPI with the highest weight according to its importance. In this case, the reference KPI is taken from the results of BWM. Let the KPI with the highest weight be denoted by KPI_r. Next, the value of evaluation of the suppliers in relation to the KPIs is required to be numerical and normalized. As a result, the qualitative KPIs are evaluated in a verbal scale and converted into a cardinal scale. The evaluation of suppliers in relation to all the KPIs produces the performance matrix, where all the values are numerical.

The evaluation weights of suppliers are obtained using the following steps:

Step a Calculate the relative weight of each KPI with respect to reference KPI_r using the following expression:

$$u_h^r = \frac{u_h}{u_r} \forall h \in \{1, 2, \dots, H\} \quad (1)$$

And the weight of reference KPI, $u_r = \max\{u_h | h \in \{1, 2, \dots, H\}\}$

Step b Obtain the performance matrix

$$X = [x_{gh}]_{GXH} \quad (2)$$

Step c Obtain the normalized performance matrix

$$Y = [y_{gh}]_{GXH} \text{where } y_{gh} = \frac{x_{gh}}{\sum_{g=1}^{G} x_{gh}} \quad (3)$$

Step d For each KPI, calculate the pairwise dominance degree of each supplier over other suppliers using the following expression:

$$\phi_h(S_f, S_g) = \begin{cases} \sqrt{\frac{u_h^r}{\sum_{h=1}^{H} u_h^r}(y_{fh} - y_{gh})} & \text{if } (y_{fh} - y_{gh}) \geq 0 \\ -\frac{1}{\theta}\sqrt{\frac{\sum_{j=1}^{p} u_h^r}{u_h^r}(y_{gh} - y_{fh})} & \text{if } (y_{fh} - y_{gh}) < 0 \end{cases} \quad \forall f, g \in \{1, 2, \dots, G\} \quad (4)$$

where θ is the attenuation factor of the losses. If θ > 1, then the

Step e Calculate the pairwise overall dominance degree of suppliers using the following expression:

$$\delta(S_f, S_g) = \sum_{h=1}^{H} \phi_h(S_f, S_g) \quad \forall f, g \in \{1, 2, ..., G\} \tag{5}$$

Step f Obtain the global value of each supplier using the following expression:

$$v_g = \frac{\sum_{g=1}^{G} \delta(S_f, S_g) - \min_g \sum_{g=1}^{G} \delta(S_f, S_g)}{\max_g \sum_{g=1}^{G} \delta(S_f, S_g) - \min_g \sum_{g=1}^{G} \delta(S_f, S_g)} \quad g \in 1, 2, ..., G \tag{6}$$

Finally, the suppliers are ranked according to their global values. The supplier having the minimum global value becomes the last choice and the supplier having the maximum global value becomes the first choice.

6 | FRAMEWORK FOR SUPPLIER SELECTION FOR SUSTAINABLE COLLABORATION

As per our discussion in Section 4, a framework for evaluation of incumbent suppliers is designed for an Indian home appliances company. The uniqueness of this conceptual model is that it evaluates the performance of suppliers with respect to desirability along with potentiality metric.

It also depicts supplier selection strategies that include supplier retention, supplier development, or supplier switching.

The steps are as follows:

- Formation of a decision-making team for supplier evaluation

Initially, a decision-making team with experts from different functional areas within the company (the case company) is formed for an evaluation of their incumbent suppliers. Experienced and knowledgeable representatives of the company who are familiar with this area of work and can provide reliable judgments for this study are purposefully chosen. This team consists of 11 decision makers, denoted by $D = \{DM_n : n = 1, 2, ..., 11\}$. The team has the following members with their years of experience: Strategic planning manager (15 years), Sourcing manager (22 years), Production manager (20 years), Purchasing manager (18 years), Product development manager (26 years), Research and Development (R&D) manager (17 years), General manager (13 years), IT manager (10 years), Logistics and deliv-

Further, with the help of an exhaustive literature survey and deliberation among the 11 decision makers, KPIs for supplier evaluation with regard to the potentiality metric and desirability metric (as defined below) are identified. The exhaustive list of KPIs for both metrics is discussed below.

1. Potentiality metric: measures the abilities, knowledge, and skills of the supplier. Let the set of KPIs for potentiality be denoted by $K^P = \{KPI_h^P, h = 1, 2, ..., H_1\}$.
2. Desirability metric: measures the willingness and motivation towards sustainable collaboration with company under consideration. Let the set of KPIs for desirability be denoted by $K^D = \{KPI_h^D, h = 1, 2, ..., H_2\}$.

With the help of literature review, the exhaustive list of KPIs for potentiality metric and desirability metric is prepared. The KPIs for potentiality metric (K^P) are as follows: cost, quality, delivery, technical capability, resource consumption, financial position, innovativeness, geographical location, flexibility, technological compatibility, facility and infrastructure, reputation, and position in the industry. The KPIs for desirability metric (K^D) are as follows: pollution prevention, waste material treatment capability, environmental competencies, training education and community influence, interests and rights of employees, environmental management system, returns handling capabilities, recycling, information disclosure, employment practices, pollution controls, green image, environmental costs, occupational health and safety management system, as well as work health and safety.

Further, due to deliberation with the decision-making team, the exhaustive list of identified KPIs for potentiality metric and desirability metric is scrutinized for shortlisting KPIs that have critical impact on supplier selection process with respect to sustainable collaboration, specifically to those related to the requirements of the case company as discussed in case study. Members of the decision-making team are asked to choose the most relevant KPIs without any constraint in the number of KPIs to be selected. Also, they were asked to propose other KPIs that were not present in the exhaustive list. A round of meetings is held and the list of KPIs for both metrics is finalized by the decision-making team as discussed below.

For the potentiality metric, 12 KPIs are identified from the literature survey. Upon further discussion with the decision-making team members, nine KPIs $K^P = \{KPI_h^P, h = 1, 2, ..., 9\}$ are shortlisted from the exhaustive list of KPIs for the potentiality metric as presented in Table 1. Similarly, for the desirability metric, 15 KPIs are identified with the help of exhaustive literature review. Next, following discussion with the decision makers, some relevant KPIs from the exhaustive list are included, some of the KPIs are removed, and some KPIs

TABLE 1 Shortlisted key performance indicators for potentiality metric

KPIs	Notation	Description	References
Cost	KPI_1^P	The final price of the components that includes the processing cost, maintenance cost, and warranty cost incurred by supplier.	Aditi et al. (2022), Memari et al. (2019), Ghadimi et al. (2018), Luthra et al. (2017), Fallahpour et al. (2017), Nourmohamadi Shalke et al. (2018), Song et al. (2017), Zimmer et al. (2016), Azadnia et al. (2015), Azadi et al. (2015), Ghadimi and Heavey (2014), Chaharsooghi and Ashrafi (2014), Azadnia et al. (2013), Amindoust et al. (2012), Chiou et al. (2011), Bai and Sarkis (2010), Kannan, Solanki, et al., (2022)
Quality	KPI_2^P	The ability to deliver components that are free from defects in accordance with supplier quality agreement.	Gören (2018), Ghadimi et al. (2018), Nourmohamadi Shalke et al. (2018), Fallahpour et al. (2017), Song et al. (2017), Tavana et al. (2017), Luthra et al. (2017), Zimmer et al. (2016), Azadnia et al. (2015), Azadi et al. (2015), Ghadimi and Heavey (2014), Chaharsooghi and Ashrafi (2014), Nielsen et al. (2014), Amindoust et al. (2012), Chiou et al. (2011), Bai and Sarkis (2010)
Delivery	KPI_3^P	The ability to follow the predefined delivery schedule and on-time delivery reliability.	Tavana et al. (2021), Ghadimi et al. (2018), Nourmohamadi Shalke et al. (2018), Fallahpour et al. (2017), Tavana et al. (2017), Luthra et al. (2017), Song et al. (2017), Azadnia et al. (2015), Ghadimi and Heavey (2014), Nielsen et al. (2014), Chaharsooghi and Ashrafi (2014), Amindoust et al. (2012)
Technical capability	KPI_4^P	The technology development, capability of R&D, and capability of new product design of the supplier to meet current and future demand of the firm.	Memari et al. (2019), Ghadimi et al. (2018), Nourmohamadi Shalke et al. (2018), Luthra et al. (2017), Azadnia et al. (2015), Azadi et al. (2015), Ghadimi and Heavey (2014), Chaharsooghi and Ashrafi (2014), Nielsen et al. (2014), Amindoust et al. (2012), Chiou et al. (2011), Kannan (2021)
Flexibility	KPI_5^P	Level of responsiveness that allows the supplier to react in case of changes, whether predicted or unpredicted.	Luthra et al. (2017), Fallahpour et al. (2017), Azadi et al. (2015), Nielsen et al. (2014), Chaharsooghi and Ashrafi (2014), Amindoust et al. (2012), Chiou et al. (2011), Bai and Sarkis (2010)
Resource consumption	KPI_6^P	Extent of efforts made to minimize wastage of resources.	Song et al. (2017), Azadi et al. (2015), Nielsen et al. (2014), Chaharsooghi and Ashrafi (2014), Shen et al. (2013), Torng and Tseng (2013), Bai and Sarkis (2010)
Financial position	KPI_7^P	Level of financial stability and profitability of a supplier in market.	Tavana et al. (2017), Zimmer et al. (2016), Nielsen et al. (2014), Amindoust et al. (2012)
Geographical location	KPI_8^P	The distance between their facilities and their suppliers.	Memari et al. (2019), Nielsen et al. (2014)
Reputation and position in the industry	KPI_9^P	How well supplier is reputed in the industry and what kind of customer feedback and business references is the supplier getting.	Nielsen et al. (2014)

A three-phase methodology is proposed further for the assessment of the incumbent suppliers with the following purpose: (a) to phase is given below, and the conceptual model is illustrated through Figure 3. BWM-TODIM methodology is adapted in this framework for

TABLE 2 Key performance indicators for desirability metric

KPIs	Notation	Description	References
Environmental management system	KPI_1^D	Joint planning for implementation of processes and practices that enable simultaneous reduction of negative impact on environment and increase operating efficiency for supplier and manufacturer.	Gören (2018), Tavana et al. (2017), Nourmohamadi Shalke et al. (2018), Song et al. (2017), Luthra et al. (2017), Rabbani et al. (2019), Fallahpour et al. (2017), Azadnia et al. (2015), Azadi et al. (2015), Nielsen et al. (2014), Chaharsooghi and Ashrafi (2014), Amindoust et al. (2012), Chiou et al. (2011), Bai and Sarkis (2010), Kannan, Shankar, et al., (2022)
Pollution controls	KPI_2^D	Synchronization of rules for controlling the amount of pollution releases to the environment by the supplier and the manufacturer.	Ghadimi et al. (2018), Tavana et al. (2017), Azadi et al. (2015), Ghadimi and Heavey (2014), Nielsen et al. (2014), Amindoust et al. (2012), Bai and Sarkis (2010)
Environmental competencies	KPI_3^D	Synchronization in standards to be followed for development of competencies related to the environment. This enables the whole network to better manage risk while sharing benefits.	Luthra et al. (2017), Azadi et al. (2015), Amindoust et al. (2012)
Recycling	KPI_4^D	Allied planning for recycling of used products, components, and materials.	Azadi et al. (2015), Yeh and Chuang (2011), Amin and Zhang (2012)
Information disclosure	KPI_5^D	Level at which information is shared about the material being used during the manufacturing process and carbon emission.	Luthra et al. (2017), Rabbani et al. (2019), Azadi et al. (2015), Chiou et al. (2011)
Training education and community influence	KPI_6^D	Collective planning for transferring of knowledge from employer to its employees and impact on the community within which they operate.	Vahidi et al. (2018), Song et al. (2017), Nourmohamadi Shalke et al. (2018), Azadnia et al. (2015)
Interests and rights of employees	KPI_7^D	Joint efforts that promote employee concerns related to sustainable employment issues.	Luthra et al. (2017), Azadi et al. (2015)
Incentive alignment	KPI_8^D	The degree of sharing costs, risks, and benefits among firm and supplier.	Cao and Zhang (2011)
Resource sharing	KPI_9^D	Level of leveraging capabilities and assets and investing in capabilities and assets with each other (manufacturer and supplier). Resources include physical resources, such as manufacturing equipment, facility, and technology.	Um and Kim (2019)

At the end of Phase I the following weights of importance are generated:

For $K^P = \{KPI_h^P, h = 1,2,...,9\}$, we get the weights $\{u_h^P \mid h = 1,2,...,9\}$ and

For $K^D = \{KPI_h^D, h = 1,2,...,9\}$, we get the weights $\{u_h^D \mid h = 1,2,...,9\}$.

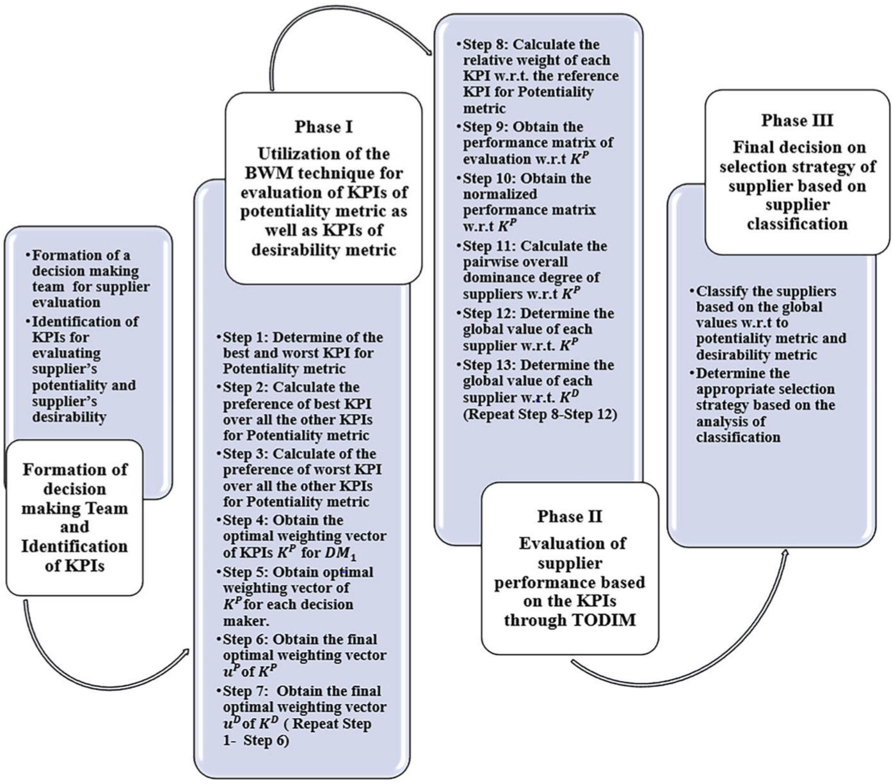
Phase II Evaluation of supplier performance based on the KPIs through TODIM

desirability respectively are obtained: $\{v_g^P, g = 1,2,...,G\}$ and $\{v_g^D, g = 1,2,...,G\}$.

Phase III Final decision on selection strategy of supplier based on supplier classification

The suppliers are classified into four classes based on their potentiality metric and desirability metric for sustainable collaboration; these classes are divided into three zones (red, yellow, and green). Based on these classes and zones, a selection strategy for each sup-

FIGURE 3 Framework for supplier selection for sustainable collaboration



ii. Supplier development: Proceed with existing suppliers and help them to improve their potentiality and desirability.

iii. Supplier retention: Continue with the existing supplier.

7 | APPLICATION OF PROPOSED FRAMEWORK

The framework as proposed in Section 6 is applied to the case problem (as described in Section 4) to develop a successful collaborative supplier-manufacturer relationship. Here, a set of 11 incumbent suppliers $S = \{S_g : g = 1,2,...,11\}$ is considered from the pool of existing suppliers who are appropriate to provide the components of three classes of washing machine (from the eight total components, specifically: timer with harness, motor, and electrical parts). In order to evaluate them on the potentiality metric and desirability metric for sustainable collaboration of these 11 suppliers, the proposed framework developed in Section 6 is applied. This model consists of three phases for the evaluation of the incumbent suppliers. Subsequently, it provides help in understanding the suitable selection strategy for the pool of the incumbent suppliers.

Before implementing the phases of the proposed model, the formation of the decision-making team and identification of KPIs was

For each decision maker, the importance of weight for KPIs are generated using the steps of BWM (refer Section 5.1). The steps of BWM for finding weights of KPIs of potentiality metric for strategic planning manager (DM_1) are explained below.

Step 1: Determine of the best and worst KPI

DM_1 is asked to decide the best and the worst KPIs for potentiality metric of supplier. The best KPI as KPI_1^P and worst KPI as KPI_4^P w.r.t. potentiality metric is selected.

Step 2: Calculate the preference of best KPI over all the other KPIs

In this step, DM_1 is asked the preference of best KPI over all other KPIs is determined based on potentiality metric of supplier. This preference is stated using a linguistic measurement scale from 1 (equal importance) to 9 (extreme importance) for K^P, resulting in a vector of best-to-others (BO). The vector of BO filled by DM_1 is $A_B^1(P) = \left\{a_{Bh}^{1^P} \mid h = 1,2,...,9\right\} = \{1,8,2,9,3,7,6,4,5\}$.

Step 3: Calculate the preference of worst KPI over all the other KPIs

TABLE 3 Optimal KPI weights of K^P (DM_1 – DM_{11})

KPI	DM_1 u^{1^P}	DM_2 u^{2^P}	DM_3 u^{3^P}	DM_4 u^{4^P}	DM_5 u^{5^P}	DM_6 u^{6^P}	DM_7 u^{7^P}	DM_8 u^{8^P}	DM_9 u^{9^P}	DM_{10} u^{10^P}	DM_{11} u^{11^P}
KPI_1^P	0.342	0.192	0.064	0.064	0.096	0.315	0.083	0.086	0.026	0.177	0.192
KPI_2^P	0.069	0.315	0.128	0.315	0.128	0.192	0.083	0.115	0.183	0.291	0.128
KPI_3^P	0.059	0.096	0.315	0.192	0.192	0.128	0.166	0.172	0.122	0.118	0.096
KPI_4^P	0.030	0.055	0.077	0.128	0.077	0.077	0.272	0.172	0.122	0.025	0.077
KPI_5^P	0.083	0.064	0.192	0.096	0.027	0.055	0.110	0.057	0.092	0.089	0.064
KPI_6^P	0.104	0.048	0.096	0.077	0.315	0.096	0.055	0.049	0.301	0.071	0.315
KPI_7^P	0.104	0.128	0.027	0.027	0.064	0.027	0.041	0.043	0.061	0.089	0.048
KPI_8^P	0.069	0.027	0.055	0.048	0.055	0.048	0.024	0.025	0.046	0.051	0.027
KPI_9^P	0.139	0.077	0.048	0.055	0.048	0.064	0.166	0.282	0.046	0.089	0.055
ε^*	0.074	0.068	0.068	0.068	0.068	0.068	0.059	0.061	0.066	0.063	0.068

The vector of OW filled by DM_1 is $A_W^1(P) = \left\{a_{hW}^{1^P} \mid h = 1,2,...,9\right\}^T = \{9,2,8,1,\ 7,\ 3,\ 4,\ 6,\ 5\}^T$.

Step 4: Obtain the optimal weighting vector of KPIs K^P for DM_1

The optimal weighting vector $u^{1^P} = \left(u_1^{1^P} u_2^{1^P},...,u_9^{1^P}\right)$ of $K^P = \{KPI_h^P, h = 1,2,...,9\}$ is calculated for DM_1 by utilizing step (d) of Section 5.1. The obtained optimal weighting vector of K^P for DM_1 is (0.342, 0.069, 0.059, 0.030, 0.083, 0.104, 0.104, 0.069, 0.139).

Step 5: Obtain optimal weighting vector of K^P for each decision maker

Repeat Steps 1–4 to obtain the optimal weighting vectors of $K^P = \{KPI_h^P, h = 1,2,...,9\}$ for each of the remaining 10 decision makers by taking their individual judgments.

Columns of Table 3 present the optimal weighting vectors corresponding the judgments of 11 decision makers, and the last row depicts the consistency of each of the BWM model solved.

It is observed that the value of consistency ratio is small, confirming that comparisons are highly reliable and consistent (Rezaei, 2015).

Step 6: Obtain the final optimal weighting vector u^P of K^P

The final optimal weighting vector u_h^P is calculated by taking average of weighting vectors calculated using judgments of all 11 decision makers by using the following expression.

$$u^P = \frac{1}{\ }\left[u^{1^P} + u^{2^P} + \dots + u^{11^P}\right]$$

Step 7: Obtain the final optimal weighting vector u^D of K^D

Steps 1–6 are repeated to compute the evaluation weights for KPIs of desirability metric (K^D) by considering and aggregating all decision makers' judgments.

The final evaluation weighting vector u^D for KPIs of desirability metric (K^D) obtained using BWM methodology is (0.176, 0.047, 0.133, 0.036, 0.189, 0.069, 0.072, 0.131, 0.148).

Phase II Evaluation of supplier performance based on the KPIs through TODIM

In Phase II, each incumbent supplier is evaluated with respect to potentiality metric KPIs (K^P) and desirability metric KPIs (K^D), taking into account the evaluation weights of KPIs obtained in Phase I. The evaluation of suppliers is done by using TODIM as discussed in Section 5.2. The steps of TODIM for potentiality metric are discussed below.

Step 8: Calculate the relative weight of each KPI w.r.t. the reference KPI for potentiality metric

The relative weight u_h^{rP} of h^{th} KPI w.r.t. the r^{th} reference KPI_r of potentiality metric of supplier is determined by using the step (a) of Section 5.2. In this particular case, the reference KPI is taken as KPI_2^P (Quality). The relative weights of all KPIs in K^P are shown in Table 4.

Step 9: Obtain the performance matrix of evaluation w.r.t K^P

TABLE 4 Relative weights of K^P to the reference KPI (KPI_2^P)

KPI	KPI_1^P	KPI_2^P	KPI_3^P	KPI_4^P	KPI_5^P	KPI_6^P	KPI_7^P	KPI_8^P	KPI_9^P
Relative weights	0.841	1.000	0.850	0.571	0.477	0.784	0.339	0.244	0.548

TABLE 5 Evaluation matrix of suppliers for KPI^P (DM_1)

Suppliers	KPI_1^P	KPI_2^P	KPI_3^P	KPI_4^P	KPI_5^P	KPI_6^P	KPI_7^P	KPI_8^P	KPI_9^P
S_1	4	4	4	4	1	0	3	3	0
S_2	4	3	4	3	1	1	0	0	4
S_3	3	1	0	4	0	1	2	4	4
S_4	4	5	3	2	2	4	4	2	4
S_5	1	2	1	1	0	3	0	3	2
S_6	1	0	4	0	2	2	1	2	2
S_7	4	3	3	3	3	4	3	4	3
S_8	2	1	2	0	0	0	3	4	1
S_9	3	1	1	2	1	3	3	4	3
S_{10}	1	2	0	0	1	0	1	2	3
S_{11}	3	2	3	4	4	2	1	0	2

TABLE 6 Normalized performance matrix of suppliers for K^P

Suppliers	KPI_1^P	KPI_2^P	KPI_3^P	KPI_4^P	KPI_5^P	KPI_6^P	KPI_7^P	KPI_8^P	KPI_9^P
S_1	0.133	0.167	0.160	0.174	0.067	0.000	0.143	0.107	0.000
S_2	0.133	0.125	0.160	0.130	0.067	0.050	0.000	0.000	0.143
S_3	0.100	0.042	0.000	0.174	0.000	0.050	0.095	0.143	0.143
S_4	0.133	0.208	0.120	0.087	0.133	0.200	0.190	0.071	0.143
S_5	0.033	0.083	0.040	0.043	0.000	0.150	0.000	0.107	0.071
S_6	0.033	0.000	0.160	0.000	0.133	0.100	0.048	0.071	0.071
S_7	0.133	0.125	0.120	0.130	0.200	0.200	0.143	0.143	0.107
S_8	0.067	0.042	0.080	0.000	0.000	0.000	0.143	0.143	0.036
S_9	0.100	0.042	0.040	0.087	0.067	0.150	0.143	0.143	0.107
S_{10}	0.033	0.083	0.000	0.000	0.067	0.000	0.048	0.071	0.107
S_{11}	0.100	0.083	0.120	0.174	0.267	0.100	0.048	0.000	0.071

For each decision maker, the evaluation of suppliers for each metric generates 11 matrices. Here, only one such evaluation matrix of suppliers w.r.t. K^P, $X^{1^P} = \left[x_{gh}^{1^P}\right]_{11X9}$, as given by DM_1 is presented in Table 5. The remaining matrices w.r.t to other decision makers are not shown for reasons of brevity.

In Table 5, as per DM_1, supplier S_1 is at "Very Good" level on the KPI_1^P. Therefore, value 4 is assigned by using above mentioned linguistic scale.

Then, the final performance matrix X^P of suppliers for potentiality metric is achieved by aggregating the performance matrices as follows:

The overall aggregated KPI values of potentiality metric for each supplier are calculated.

Step 10: Obtain the normalized performance matrix w.r.t. K^P

The performance matrix $X^P = \left[x_{gh}^P\right]_{11X9}$ of suppliers for K^P is normalized using step (c) of Section 5.2. The normalized matrix $Y^P = \left[y_{gh}^P\right]_{11X9}$ is presented in Table 6.

Step 11: Calculate the pairwise overall dominance degree of suppliers w.r.t. K^P

TABLE 7 Pairwise overall dominance measures between suppliers (K^P)

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}
S_1	0.000	−1.501	−2.222	−4.469	−1.238	−2.055	−4.189	−0.952	−2.554	−0.405	−2.834
S_2	−4.061	0.000	−3.315	−5.541	−1.832	−3.199	−5.524	−2.658	−3.762	−2.221	−4.000
S_3	−3.885	−2.860	0.000	−5.745	−1.438	−2.379	−5.398	−1.232	−2.992	−0.891	−3.541
S_4	−1.856	−0.669	−1.513	0.000	−0.084	0.185	−2.599	−0.417	−0.665	0.892	−1.617
S_5	−5.741	−4.688	−4.554	−7.505	0.000	−2.731	−8.163	−3.088	−5.189	−2.059	−5.053
S_6	−4.998	−3.389	−5.160	−6.007	−2.560	0.000	−7.612	−3.114	−5.629	−0.945	−3.793
S_7	−1.244	−0.701	−0.609	−1.988	0.815	1.284	0.000	0.793	0.557	0.861	−1.058
S_8	−4.343	−5.591	−3.275	−7.429	−2.509	−3.155	−6.607	0.000	−4.111	−1.921	−0.200
S_9	−2.850	−3.028	−1.211	−5.105	−0.054	−1.230	−4.403	−0.049	0.000	0.061	−3.386
S_{10}	−5.919	−4.572	−5.207	−7.722	−2.935	−2.707	−8.341	−1.589	−1.560	0.000	0.373
S_{11}	−4.182	−2.000	−3.116	−5.653	−1.650	−1.344	−5.354	−2.388	−3.869	−1.280	0.000

TABLE 8 Global values of suppliers w.r.t. K^P

Suppliers	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}
v^P	0.380	0.581	0.557	0.020	0.889	0.813	0.000	0.865	0.565	1.000	0.658

TABLE 9 Global values of suppliers w.r.t. K^D

Suppliers	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}
v^D	0.758	0.178	1.000	0.000	0.557	0.839	0.278	0.280	0.672	0.120	0.329

Next, the overall dominance measures between suppliers for K^P are calculated by using step (e) of Section 5.2. The entries of 11×11 pairwise overall dominance matrix are shown in Table 7.

Step 12: Determine the global value of each supplier w.r.t. K^P

The set of global values of supplier $v^P = \left\{v_g^P, g = 1,2,\ldots,11\right\}$ with respect to K^P are calculated using the step (f) of Section 5.2 and presented in Table 8.

Step 13: Determine the global value of each supplier w.r.t. K^D

Similarly, the global values $v^D = \left\{v_g^D, g = 1,2,\ldots,11\right\}$ with respect to KPIs of desirability metric K^D are determined by repeating Steps 8–12 and presented in Table 9.

The global values v^P and v^D of suppliers w.r.t. potentiality metric (shown in Table 8) and desirability metric (shown in Table 9) are utilized in the next phase to classify the suppliers based on their performance.

Phase III Final decision on selection strategy of supplier based on High and Low global values of the supplier as shown in Table 10. For both metrics, global values lower than 0.5 are classified as low, and global values in the range [0.5, 1] are classified as high. Each supplier belongs to one and only Type class. Based on this classification, each supplier is assigned to one of the following three zones: red, yellow, or green. Type I suppliers belong to the Red zone, Types II and III belong to the Yellow zone, and all suppliers of Type IV belong to the Green zone. This is also reflected in Table 10.

To illustrate the classification of suppliers into Types and further zones, a supplier classification grid is drawn as shown in Figure 4. Here, the x-axis represents the level of desirability, and y-axis represents the level of potentiality of the supplier; the values of these axes range between 0 and 1.

Based on the classification into zones, the selection strategy for each supplier from among the following is discussed: (i) Supplier switching, (ii) Supplier development, and (iii) Supplier retention.

The detailed discussion on the classification is carried out in the next section.

8 | DISCUSSION AND IMPLICATIONS

TABLE 10 Classification of supplier as per zones

Supplier's category	Desirability (x-axis)	Potentiality (y-axis)	Supplier
Type I	Low	Low	S_4, S_7
Type II	High	Low	S_1
Type III	Low	High	S_2, S_8, S_{10}, S_{11}
Type IV	High	High	S_3, S_5, S_6, S_9

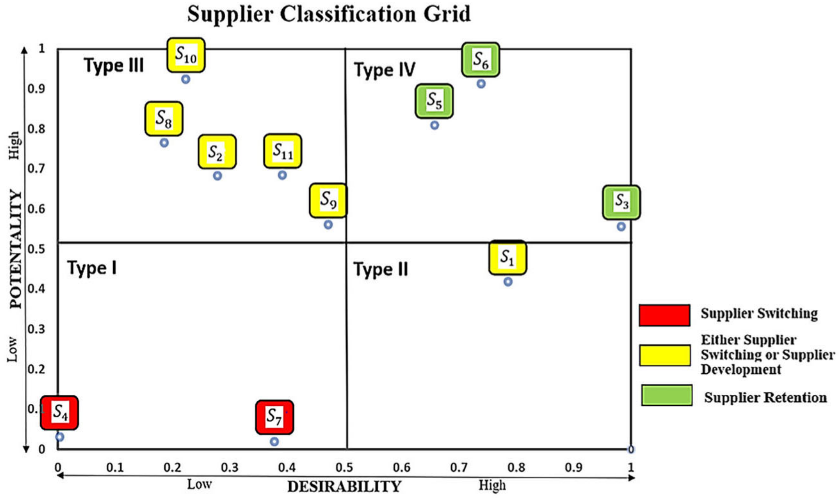


FIGURE 4 Scatter plot for supplier classification and their selection strategy

manufacturing company. There are countless studies available in literature for evaluating the performance of suppliers and various studies that focus only on the manufacturer's perspective on procurement process and in strategy development for sourcing. However, considering the supplier's perspective is also important especially for developing a successful sustainable collaboration. Hence, this study proposes a supplier evaluation model under consideration of manufacturer–supplier relationship development. As a result of the proposed framework and discussion with decision makers, we determined that evaluation only on the capabilities of supplier is not enough. An additional dimension of willingness of supplier for sustainable collaboration with manufacturer should also be considered. Hence, these two aspects are suitably aligned with two dimensions such as potentiality and desirability for supplier evaluation procedure in this study. Based on supplier's potentiality and desirability, KPIs are identified that measure the performance of suppliers. Further, using the three-phase proposed model, these KPIs are prioritized by using BWM and decision makers' opinions in the first phase. Then the output of BWM is combined with TODIM for assessing the performance of existing suppliers in the second phase. In the final phase, suppliers are classified for deciding the appropriate selection strategy for each existing supplier and enhancing the overall performance of the supply chain of the company. In this section, an extensive discussion is presented on results of each phase.

metric, respectively. The results provide some insights to make strategic managerial decisions in the selection of KPIs for evaluation of suppliers for building successful manufacturer–supplier collaborations. It is observed from u^P that "Quality (KPI_2^P)" has the highest weight of 0.177 w.r.t. to potentiality. Quality is the most critical and important KPI when the manufacturer attempts to measure the suppliers' capability. The implications of this result for a home appliances manufacturing company in India and other companies is that the role of quality in supplier's potentiality measurement is considered as a primary KPI. Quality KPI is considered as a major concern while measuring and assessing the performance of suppliers and forming long-term relationships for improving the overall performance of the manufacturer (Gören, 2018; Govindan et al., 2020). The second most important KPI is "Delivery (KPI_3^P)" to measure supplier's potentiality with weight of 0.150. It measures the capability of suppliers in terms of strengthening the manufacturer–supplier relationship. This is in tandem with several studies in extant literature (Fallahpour et al., 2017; Ghadimi et al., 2018; Ghadimi & Heavey, 2014; Osiro et al., 2014), which have highlighted the importance of delivery performance in supplier evaluation process. It helps manufacturers to assess their suppliers' capability to provide the required number of components at the required time. "Cost (KPI_1^P)" is placed third with a weight of 0.149. Earlier, cost was considered as the most important KPI, but with the growing competition and customer's expectations, quality and delivlocation of incumbent suppliers is already fixed and cannot be developed further. Further, weight of "Resource Consumption (KPI_6^P)" is 0.139. This is followed by "Technical Capability (KPI_4^P)," "Reputation and Position in the Industry (KPI_9^P)," "Flexibility (KPI_5^P)," and "Financial Position (KPI_7^P)," with suppliers' potentiality KPI weights of 0.139, 0.101, 0.097, 0.084, and 0.060, respectively.

The weights of the suppliers' desirability KPIs for developing sustainable collaboration with manufacturer are given by u^D. "Information Disclosure (KPI_5^D)" is considered as the most important KPI w.r.t. supplier's desirability with a weight of 0.189. The importance of this KPI for sustainable collaboration has been recognized in several studies (Kim et al., 2015; Wong, 2013). It has been considered as the key for building long-term commitment, trust, and transparency between suppliers and manufacturers and for strengthening the relationship between them (Rönnberg-Sjödin, 2013). It helps to measure and understand how much information the supplier is willing to share with the manufacturer. The results further suggest that the second most important KPI is "Environmental Management System (KPI_1^D)" with a weight 0.176. Environmental management system has been identified by numerous studies (Hashemi et al., 2015; Öztürk & Özçelik, 2014) as an influential criterion for developing the manufacturer–supplier relationship; it demonstrates assessing the willingness of the supplier to sustainably collaborate with the manufacturer. Yang et al. (2010) have proved in their study that it affects the relationship of manufacturer and supplier positively as well as helps in achieving competitive advantage in the market. Collaborative resource sharing plays a most important role for creating transparency, increasing visibility in the SC, and building long term relationships (Morgan et al., 2018). "Resource Sharing (KPI_9^D)" ranks third in order of desirability with a weight of 0.148. For building a long-term relationship, partners need to check the level of leveraging capabilities, assets, and willingness to invest in capabilities and assets together (Um & Kim, 2019). Further, "Environmental Competencies (KPI_3^D)" rank in decreasing order of desirability after KPI_5^D, KPI_1^D, and KPI_9^D. The implication of this result is that the case company needs to work on willingness towards synchronization of environmental competencies after ensuring that suppliers have desirability w.r.t. KPI_1^D and KPI_9^D, respectively, in order to achieve a successful manufacturer–supplier collaboration. The rest of the KPIs are ranked in decreasing order of desirability: the order is "Incentive Alignment (KPI_8^D)," "Interests and Rights of Employees (KPI_7^D)," "Training Education and Community Influence (KPI_6^D)," "Pollution Controls (KPI_2^D)," and "Recycling (KPI_4^D)."

The outcomes of this phase are used in the next phase for incumbent supplier evaluation.

Phase II Evaluation of supplier performance based on the KPIs through TODIM

judgment, the aggregated performance matrix of suppliers for their potentiality and desirability is computed. Then, normalization of aggregated performance matrix of suppliers based on their potentiality as well as desirability is carried out. Further, the output of Phase I is used for determining the relative weight of each KPI to the reference KPI for supplier's potentiality and desirability. Finally, the global value of each supplier with respect to supplier's potentiality and supplier's desirability is calculated and shown in Tables 8 and 9, respectively. These results depict the global values for 11 existing suppliers based on their potentiality and desirability.

According to Table 8, supplier S_{10} is ranked the top supplier with global value of 1. The top supplier is followed by suppliers S_5, S_8, S_6, S_{11}, S_2, S_9, S_3, S_1, S_4, and S_7. Thus, S_{10} is the most capable supplier, and S_7 has the least global value w.r.t to potentiality among the 11 existing suppliers.

The global values of suppliers based on their desirability KPIs are shown in Table 9. Supplier S_3 ranked first with the global value of 1. Suppliers S_6, S_1, S_9, S_5, S_{11}, S_8, S_7, S_2, S_{10}, and S_4 follow with global values of 0.839, 0.758, 0.672, 0.557, 0.329, 0.280, 0.278, 0.178, 0.120, and 0 respectively. It depicts S_4 is the least willing for building manufacturer–supplier relationship and S_3 is the most willing among all the suppliers.

For assessing the implication of the results obtained from Phase II, the quantification of global values with respect to potentiality and desirability of suppliers is not enough. A detailed analysis is required to weigh global values of both metrics against each other. Hence, Phase III is performed for providing the clear vision and recommendations for the supplier selection strategy. The global values obtained in this phase become input for Phase III.

Phase III Final decision on selection strategy of supplier based on supplier classification

For providing a clear vision for selection strategy for each existing supplier, suppliers are classified into four types and accordingly further into three zones, namely: red, yellow, and green. This classification is done by plotting the global values of desirability and potentiality of each supplier on the two-dimensional coordinate axis for better visual assessment. As can be seen in Figure 4, the supplier classification grid is divided into four types based on the high and low TODIM global values as explained in Table 10. Certain actions can be suggested to a company for deciding the appropriate selection strategy for each existing supplier and for enhancing the overall performance of the supply chain of the company. The classification of suppliers can be understood from the discussion that follows:

1. Red Zone

for the company to choose the "supplier switching" strategy and replace incumbent suppliers with new ones.

2. Yellow Zone

   Type II and Type III suppliers belong to the yellow zone, which we can term as the indecisive zone where more analysis is needed before deciding on the selection strategy. In Type II category, there is only one supplier, S_1, with high desirability and low potentiality, which indicates that the company needs to work only on potentiality of the supplier. There is a choice of either investing in supplier development or switching to new suppliers. Because in this scenario, it is difficult to choose a strategy for supplier S_1 (unlike the Type I category). Hence, for a Type II supplier, before deciding on a final selection strategy, the company needs to examine the expenses of both strategies. If supplier switching cost is less than the supplier development cost, it is suggested to company to opt for supplier switching and replace supplier S_1 with a new supplier; otherwise, they must choose supplier development option. The reasons for supplier's low potentiality must be identified and then proper assistance must be offered to supplier S_1 to improve potentiality.

   Four suppliers, S_2, S_8, S_{10}, and S_{11}, are categorized as Type III suppliers. They have low desirability and high potentiality. For this category, the selection strategy scenario is the same as Type II category. Type III suppliers have performed low in the desirability metric, so the preferable focus of the company must be on encouraging and educating the supplier towards sustainable aspects. If the supplier does not seem to be willing to do so, then supplier switching is safer option to choose. However, supplier development can be a good option if these suppliers show willingness to cooperate and make efforts towards sustainability; they have already shown their capability. The company may want to opt for S_{11} for supplier development because he is very good at potentiality with global value 0.658 and he is acceptable at desirability with global value 0.329. By comparison, S_{10} is best at potentiality with global value 1.000 but he is very low at desirability with global value 0.120. Hence, there is a distinct need to see suppliers' performance in the desirability metric, to compare it to the desirability of other suppliers, and to choose accordingly.

3. Green Zone

   Type IV category suppliers S_3, S_5, S_6 and S_9 portray high desirability and high potentiality and belong to the green zone. For this category, it is advisable that the company must choose the "supplier retention" strategy and continue to work with them without any change. This category is the best to work with. They have excellent potentiality as well as desirability. However, for sustaining the relationship, it is suggested that the company continuously monitor these suppliers by using the proposed supplier evaluation model.

could be categorized into managerial implications and research implications as follows:

8.2.1 | Managerial implications

The proposed conceptual framework is developed for a home appliance company to take crucial decisions about their existing suppliers in terms of developing a long-term sustainable relationship. This study can be useful for managers for evaluating suppliers about various key performance indicators and for choosing the selection strategy for sustainable collaboration. Integrated BWM-TODIM technique is utilized as an effective methodology for the evaluation process in presence of conflicting quantifiable and non-quantifiable KPIs. It would also help managers to provide their opinions, form their decision structure, and determine the relative importance of their suppliers. The following managerial implications are drawn from the results discussion.

i. It is challenging to take strategic decisions like supplier selection for sustainable collaboration. Hence, only ranking of suppliers is not enough for selection of suppliers based on identified KPIs. A detailed analysis as carried out in the study is necessary for guiding managers to take appropriate action. Classification of suppliers helps in this regard as shown in result and discussion. For the suppliers who are low in performance w.r.t. potentiality and desirability metric (red zone), it is suggested to the decision makers that 'supplier switching' is the ideal strategy. For suppliers who are performing high in both metrics (green zone), then it is recommended for the company definitely to retain their suppliers. The green zone suppliers can be considered as the benchmark for low performing suppliers.
ii. The result of study shows that for evaluation of suppliers for a sustainable collaboration, the desirability metric of suppliers is important in addition to the potentiality metric. As the classification grid shows, Type III suppliers may be chosen if they have high global values in the potentiality metric. With consideration only on potentiality, suppliers S_2, S_8, S_{10} and S_{11} will be selected for supplier retention; however, these suppliers do not perform well when evaluated under the desirability metric, which also plays a significant role for long-term commitment towards sustainability. Therefore, the study emphasizes a detailed evaluation of suppliers in terms of the desirability metric and suggests for a second stage of evaluation of Type III.
iii. For suppliers in the yellow zone, the values of the potentiality metric and desirability metric are in conflict, creating a need to delve further to understand what compromised strategy will

8.2.2 | Research implications

From a theoretical perspective, this research offers a new perspective for understanding and explaining the performance measures of suppliers needed for the development of successful manufacturer–supplier collaboration. The details of the research implications are as follows:

i. This study supports the idea that willingness of supplier towards building long-term relationships with manufacturer is as important as the capability of the supplier. Most past studies in this area have developed only supplier evaluation models based only on the capabilities of supplier (Yawar & Seuring, 2017). In the current study, suppliers' potentiality as well as desirability for building sustainable relationship are considered as sustainable collaboration cannot survive without the desirability of both manufacturer and supplier.
ii. The present study is an attempt to provide the KPIs for suppliers' evaluation in terms of potentiality and desirability to develop a long-term relationship with the manufacturer. Based on evaluation matrices filled by decision makers, the importance of KPIs is recognized. The proper understanding of these KPIs could help academicians in developing sustainable relationship-focused performance measures and evaluation decisions.
iii. The current study offers a framework for supplier evaluation with a focus on sustainable manufacturer–supplier collaboration to make complicated decisions of supplier and their respective strategy selection with ease. This framework could be used for synthesizing the judgments of decision makers to solve supplier evaluation and selection problems by practitioners.

9 | CONCLUSION

This study considers the supplier's potentiality and desirability for supplier performance evaluation to implement sustainable manufacturer–supplier collaboration. Suppliers has been considered one of the key players for manufacturing companies, which is why this study evaluates the performance of suppliers in terms of the ability of the supplier to contribute to the sustainable collaboration and willingness to be part of the sustainable collaboration with the manufacturer. The choice of performance indicators on which the potentiality and desirability of supplier can be measured is found the critical challenge for manufacturing companies. With the help of PBV theory, the theoretical support to the study has been provided. Further, a framework for supplier performance evaluation is developed for the evaluation and selection of suppliers for a sustainable manufacturer–supplier collaboration to showcase the applicability of theoretical framework. The potentiality and desirability KPIs, a three-phase mathematical model is proposed to evaluate the sustainable performance of incumbent suppliers and accordingly decide on the suitable supplier selection strategy for each of them. In Phase I, the proposed model uses BWM for determining the weights of identified KPIs for the potentiality metric as well as for the desirability metric. BWM is an effective and easy technique as compared to most other methods; it requires substantially fewer numbers of pairwise comparisons for evaluation of alternatives. Final evaluation rankings (in terms of global values) of incumbent suppliers are generated through TODIM in Phase II. This method is adopted for dealing with the decision maker's bounded rationality. Further, suppliers are classified into zones based on their levels of potentiality metric and desirability metric. This classification is shown through a two-dimensional plot formed by using the outputs of Phase II. The horizontal and vertical axes of the grid represent desirability and potentiality of suppliers, respectively. Based on this grid, suppliers are classified in to four types (Type I, Type II, Type III, and Type IV) and accordingly into three zones (red, yellow, and green). Finally, selection strategy is suggested for suppliers based on the analysis of this classification.

The highlight of the study is consideration of sustainable KPIs to evaluate the potentiality as well as the desirability of suppliers for a long-term sustainable relationship. Moreover, the novelty of the study also lies in the development of an effective multi-criteria model for assessment of suppliers and for the selection of an appropriate strategy based on a detailed result analysis. Although the proposed model has many strengths in achieving a sustainable manufacturer–supplier relationship, improvements and modifications for future studies are recognized. Some of these are mentioned below:

- The classification of suppliers was done only on the basis of two grades: High and Low. Further analysis is needed to understand how low is the performance value of the supplier marked as low grade and the cost, effort, and time needed to develop such a supplier. Hence, the conflicting decision of supplier switching or supplier development requires another stage of evaluation for comprehending the associated financial risk and operational risk. A mathematical optimization model or an analytical model may provide better result implications for suppliers ranked in the yellow zone.
- The revalidation of this framework is not carried out due to paucity of time. This point should be addressed in future studies and the revalidation of framework should be carried out under a new data collection process.
- In this framework, subjectivity of the judgments of decision makers is considered but uncertainty of their judgments is neglected. For handling the uncertainty of judgments, fuzzy theory, grey theory, or rough set theory could be used in future research (Sharma et al.,

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