Measuring sustainability performance using an integrated model

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Abstract

This study presents a sustainability performance measurement model integrating the Balanced Scorecard (BSC) perspective and the Fuzzy multiple-criteria decision-making (FMCDM) approach. First, this study proposes a list of twenty-one indexes of sustainability, based on four BSC-based dimensions, in line with triple bottom line sustainability dimensions, derived from the literature and experts' inputs. Then, the relative weight of each sustainability index was evaluated using the Fuzzy Analytic Hierarchy Process (FAHP). To demonstrate the proposed approach, we practically measure the sustainability performance using three MCDM methods — Simple Additive Weighting (SAW), fuzzy Technique for Order Preference by Similarity to Ideal Situation (TOPSIS), and fuzzy Multi-Criteria Optimization and Compromise Solution (VIKOR). Finally, strategies for improving sustainability performance for a real-word case are suggested. The proposed measurement model can be an appropriate tool for industrial managers seeking to evaluate the efficacy of their sustainability strategies.

Keywords: Sustainability measurement; Fuzzy multiple-criteria decision-making; Balanced scorecard; Leather industry.

1. Introduction

Today, the depletion of natural resources, massive energy consumption, and environmental pollution associated with industrial development are degrading ecosystems, with 60 percent of this degradation being the absence of sustainability (Szilagyi et al., 2018). Recently, there has been debate in the literature about how to ensure a sustainable planet. In this regard, industries around the world play a vital role to ensure a sustainable planet by integrating their environmental and social performance with their economic performance. Industries such as leather, textiles, cosmetics, plastics, and pharmaceuticals are major contributors to environmental pollution in Bangladesh and these industries often violate societal standards, posing a threat to their sustainability. As such, industrial managers are constantly facing many challenges of balancing their economic performance against social and environmental considerations, intending to achieve sustainability in their firms (Jeswani et al., 2015; Marshall et al., 2015). Besides, improving sustainability performance can boost a company's competitive edge (Cui et al., 2019). Hence, while business entities are paying more attention to adopting sustainable practices in their supply chains, industrial managers need appropriate tools to measure sustainability performance, so that they can identify where they may be falling short in the achievement of sustainable business ecosystems.

Traditional performance assessment systems mostly include financial measures and ignore non-financial measures (Eberl & Schwaiger, 2005). Kaplan and Norton (1992) introduced a performance measuring perspective known as the Balanced Scorecard (BSC) that overcomes the limitations of traditional performance assessment systems. The BSC perspective combines both financial and non-financial factors in providing a basis for performance assessment and thus creates a performance management system for any organization (Modak et al., 2017). Since many social and environmental attributes of sustainability are non-financial, the BSC approach can be an appropriate tool for measuring sustainability in any kind of organization (Schaltegger & Wagner, 2006). Moreover, the BSC model has been successfully applied in many companies to implement sustainable corporate strategies (Hsu et al., 2011). At the same time, performance assessment includes the identification of indexes that can be used to evaluate a given factor's relative weight of performance; these indexes, which are generally incommensurable and fuzzy in nature, are evaluated by experts as part of the assessment process. Typically, the experts have different perceptions about each index and may thus assign contrasting performance ratings to one and the same organization. Moreover, it is very intricate to evaluate the performance of alternatives by decision-makers based on particular numerical values. To solve these problems, fuzzy set theory can be applied successfully (Ribeiro et al., 2013). We found studies in the existing literature that used fuzzy set theory along with single or multiple MCDM tools to assess the sustainability performance of alternatives. Though there were some studies on sustainability measurement (SM) model in the literature from many perspectives (Cui et al., 2019; Dressler & Bucher, 2018), there was no specific article that developed a SM model for the leather industry by integrating the BSC perspective with multiple MCDM tools. We found that the BSC approach is an appropriate perspective for SM (Hsu et al., 2011), and many studies used MCDM tools for the performance assessment of alternatives (Solangi et al., 2021). Hence, we integrate Fuzzy Multiple-Criteria Decision-Making (FMCDM) methods, i.e., FAHP, SAW, TOPSIS, and VIKOR along with the BSC approach to develop a sustainability performance measurement framework. Sustainability performance measurement, in short, comprises uncertainties—e.g., types of fuzziness and interval data—that can be resolved by fuzzy logic-based methods (Aleksić et al., 2014; Xiao, 2020; Xiao et al., 2021; Xiao et al., 2021). FAHP method is very suitable to compute the relative weights of each index in a hierarchical structure during performance assessment where consistency ratios of experts are checked to get reliable results and thereby these weights of criteria are further used by other MCDM tools to evaluate the performance of alternatives (Büyüközkan et al., 2017; Suganthi, 2018). SAW is a very simple method for ranking alternatives, which involves normal arithmetic operations and it has risk neutrality behaviour in experts' judgments (Chen, 2012). During a performance assessment system, cost-benefit analysis of criteria may arise. When it comes to the benefit criteria, the greater the values, the better the performance. Alternatively, if the values of cost criteria are small, the performance will be the higher. This cost-benefit analysis can be solved by the TOPSIS method that is very necessary for ranking alternatives. Meanwhile, the most suitability of the VIKOR method is that it can provide a compromise solution (closest to the ideal solution) for ranking alternatives within many conflicting criteria (Suganthi, 2018). Since the results of alternatives can be changed due to the application of different MCDM tools, we apply three MCDM tools, i.e., SAW, TOPSIS, and VIKOR in our developed SM framework, to validate the results.

Since sustainability issues depend on the nature of an industry, a particular industrial context should be considered to develop a sustainability performance model. Therefore, we test the developed framework by using data from the leather industry of Bangladesh. The leather manufacturing industry is known as one of the most environmentally hazardous industries in the world due to its negative impacts on ecosystems. In Bangladesh, this industry is threatened due to a lack of strict environmental regulations and compliance practices. The leather sector, which is a major export-earning sector in Bangladesh, earned $797.6 million in the fiscal year 2019-2020, with this figure representing a 21.79% drop as compared with the previous year (World Footwear, 2020). Better uptake of sustainable practices can boost the industry's future growth, and ensure wider acceptance in international markets. Therefore, the objectives of this study are set as follows:

1. To identify the indexes for sustainability performance measurement in the leather industry;

2. To develop a hierarchical assessment framework for measuring the leather industry's sustainability performance, by integrating BSC perspective and fuzzy MCDM tools;
3. To test the developed framework by using data from three leather-processing companies in Bangladesh.

The rest of the paper is structured as follows: Section 2 presents the literature review on sustainability, performance assessment and the BSC approach, existing SM frameworks, and proposed MCDM tools in sustainability measurement. Section 3 then presents our case study and methodology. Section 4 details the real-life case application, involving Bangladeshi leather processing factories; this section includes details about data collection, data analysis, and results. We discuss results and their practical implications in Section 5. Finally, Section 6 includes conclusions and directions for future research.

2. Literature review

2.1. Sustainability

Sustainability can be best understood from the concept of sustainable development. The most widely adopted definition of sustainable development is that "Sustainable development is economic growth that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Husgafvel et al. (2013), for their part, defined sustainable development as an attempt to integrate environmental, economic, and social accountability. Along these lines, the Triple Bottom Line (TBL) is the most prominent framework for addressing issues of sustainability; it focuses on the jointly economic, social, and environmental dimensions of sustainability (Elkington, 1998). The present study incorporates the TBL concept into its use of the BSC approach.

2.2. Performance assessment and the Balanced Scorecard approach

Traditional performance evaluation systems measure only financial indexes, such as physical and tangible assets, while avoiding intellectual and other intangible assets of an organization. Since performance assessment factors are multidimensional, using financial measures alone cannot reflect all the relevant domains of a business entity. The Balanced Scorecard (BSC) approach was proposed by Kaplan and Norton in 1992 as a performance assessment system that combines both monetary and non-monetary measures (Kaplan & Norton, 1992). Indeed, the inclusion of the term "Balanced" in the name of the BSC approach suggests that it seeks to create a level between monetary and non-monetary measures.

The BSC approach considers four dimensions—namely, financial performance, customers, internal business processes, and learning and growth—to measure an organization's overall performance. Researchers have adopted the BSC model to assess the sustainability performance of an organization, and also to address decision-making problems. Such as Hsu et al. (2011) applied the BSC model to measure the sustainability performance of the semiconductor industry in Taiwan, Singh et al., (2018) assessed the sustainability performance of small- and medium-sized enterprises (SMEs) by using the BSC approach, and Nicoletti Junior et al. (2018) incorporated the BSC model to develop a sustainability evaluation model. The BSC approach can help organizations design, communicate, and concretize their business strategies. The present study follows the BSC approach, providing the first application of the approach for purposes of performance assessment in the leather industry.

2.3. Existing sustainability measurement (SM) frameworks

Using stakeholders' perceptions and opinions, Karaca et al. (2020) developed an SM model for building performance evaluation based on Rapid Sustainability Assessment Method (RSAM). Digalwar et al. (2020) assessed the social sustainability performance of an Indian Manufacturing industry. Cui et al. (2019) developed an SM model to measure corporate sustainability by integrating grey theory with decision-making trial and evaluation laboratory (DEMATEL) technique for high-tech firms in China. Tseng et al. (2019) proposed a hierarchical framework for evaluating the corporate sustainability performance of the textile industry in Taiwanese by using a hybrid DEMATEL method. Reza & Islam (2019) measured the sustainability of the knitwear industry of Bangladesh by using both qualitative and quantitative methods. Dressler & Bucher (2018) evaluated the sustainability of South African frugal innovation by integrating sustainable development goals (SDGs) into the TBL concept of sustainability. Khodakarami et al. (2015) evaluated sustainability in supply chain management (SCM) in resin producing companies by using the data envelopment analysis (DEA) method. In addition, using dynamic DEA, Yousefi et al. (2016) developed an SM model for evaluating suppliers and tested its efficacy for a case company in Iran.

Most of these studies focused merely on social sustainability, environmental sustainability, and corporate sustainability. Very few studies developed SM frameworks by integrating three dimensions of sustainability but did not identify the gaps of performance of alternatives and explore the diversified sustainability indexes by using the BSC approach. Against this backdrop, this study offers an SM framework for performance measurement of three leather processing companies by using the BSC approach with FMCDM tools.

2.4. Proposed MCDM tools

Previous studies have applied various MCDM methods in assessing the performance of organizations, ranking the alternative performance decision paths. Figueiredo et al. (2021) used the FAHP method to select sustainable materials for building construction. Solangi et al. (2021) applied FAHP to assess the relative importance of renewable energy barriers for sustainability in Pakistan and then the fuzzy TOPSIS method was adopted to find overcoming strategies of these barriers. Awasthi et al. (2018) followed the FAHP method to calculate the relative weights of sustainable global supplier selection criteria and then evaluated suppliers' performances by the fuzzy VIKOR method. Lee et al. (2008) used FAHP coupled with the BSC approach, to analyze the performance of IT departments in the Taiwan manufacturing industry; Modak et al. (2017) adopted FAHP along with the BSC perspective to evaluate the outsourcing performance of an Indian coal mining organization. In addition, Dodangeh et al. (2010) used the TOPSIS technique, combined with the BSC approach, to select the best alternative in decision-making problems. Yalcin et al. (2012) followed FAHP to find out the weights of performance criteria of some manufacturing companies in Turkish, and then TOPSIS and VIKOR methods were used to evaluate their performances. Wu et al. (2009) assessed the performance of three banks by using SAW, TOPSIS, and VIKOR combined with the BSC approach.

The application of a single MCDM tool in measuring the performance of alternatives, however, does not ensure reliable results. Several previous studies have thus used more than one MCDM tool to measure the performance of alternatives. In short, findings from multiple MCDM methods are reliable compared to those based on a single method. Therefore, this study proposes three MCDM methods—namely, SAW, Fuzzy TOPSIS, and Fuzzy VIKOR—to ensure a rigorous sustainability measurement model.

In this study, we have identified twenty-one indexes of sustainability based on an extant literature review and experts' inputs. The indexes are categorized into the four dimensions of BSC, as shown in Table 1. A general description of all the indexes is included in Appendix A (see Table A1).

Table 1: Indexes of sustainability from the Balanced Score Card (BSC) perspective.

BSC dimension	**Code**	**Sustainability index**	**TBL dimension**	**Source**
F: Financial	F1	Sales revenue from green products	Economic	(Epstein & Wisner, 2001; Horbach, 2016)
	F2	Return on investment	Economic	(Figge et al., 2002; Wu et al., 2009)
	F3	Net profit margin	Economic	(Figge et al., 2002; Hsu et al., 2011)
	F4	Debt ratio	Economic	(Singh et al., 2018; Wang & Wang, 2014)
	F5	Investment in energy-conservation and	Economic	(Hristov et al., 2019; Hsu et al., 2011)

		emission-reduction technologies		
	F6	Income from recycling goods	Economic	(Hsu et al., 2011; Sidiropoulos et al., 2004)
C: Customer	C1	Customer satisfaction	Social	(Figge et al., 2002; Huang et al., 2011)
	C2	Customer retention rate	Social	(Huang et al., 2011; Wu et al., 2009)
	C3	Customer increasing rate	Social	(Singh et al., 2018; Wu et al., 2009)
	C4	Increasing the number of green products	Environmental	(Boerrigter, 2015; Hsu et al., 2011b)
	C5	Profit per customer	Economic	(Figge et al., 2002; Wu et al., 2009)
I: Internal business processes	I1	Reduction of chemical consumption	Environmental	(Boerrigter, 2015; Kumar Gupta et al., 2018)
	I2	Reduction of greenhouse gas emissions	Environmental	(Omoloso et al., 2021; Zhang et al., 2019)
	I3	Efficiency of effluent treatment plants	Environmental	Proposed by experts
	I4	Participation of employees in business decisions	Social	(Knoepfel, 2001; Moktadir, Rahman, et al., 2018)
	I5	Innovation processes	Environmental	(Figge et al., 2002; Omoloso et al., 2021)
	I6	Solid waste recycling rate	Environmental	Proposed by experts
L: Learning and growth	L1	Supplier's performance	Social	(Boerrigter, 2015; Epstein & Wisner, 2001)
	L2	Complaints from stakeholders	Social	(Garcia et al., 2016; Wu et al., 2009)

	L3	Workforce diversity	Social	(Boerrigter, 2015; Omoloso et al., 2021)
	L4	Training and skills	Social	(Hoyt & Matuszek, 2001; Moktadir, Rahman, et al., 2018)

3. Case study and methodology

3.1. The case study in the context

The leather industry of Bangladesh is one of the major export-earning sectors in the country. The industry employs 858,000 workers directly and indirectly (Islam et al., 2019), and it has been identified as a "thrust sector" due to its high value and scope (Hong, 2018). This industry exports different products such as crust leather, semi-finished leather, finished leather, leather footwear, ladies bags, backpacks, wallets, belts, travel bags, and purses to more developed countries. Yet the leather industry is also considered as one of the most environmentally hazardous industries in Bangladesh, due to its reliance on toxic chemicals, the release of untreated hazardous effluents, and unhealthy working conditions (Kolomaznik et al., 2008). Hence, this industry can be treated as a test-case for developing, introducing, and improving sustainability practices, in ways that may be able to guide other industries as well.

To date, there have been only a few studies of sustainability in the leather industry. These studies have discussed, for instance, the barriers to sustainable supply chain management in the leather industry (Moktadir et al., 2018), the drivers of the circular economy in the context of the leather industry in Bangladesh (Moktadir et al., 2018), the barriers to implementing green supply chain management techniques among leather producers (Sarker et al., 2018), the traceability of supply chain sustainability concerning the production of leather shoes (Marconi et al., 2017), and social sustainability enablers in the leather-footwear industry (Munny et al., 2019).

The literature review revealed that there were no studies of the development of sustainability performance assessment framework for the leather industry, although we found some previous works that used a variety of approaches for measuring sustainability in other industries. Furthermore, there has been no prior attempt to develop a sustainability performance assessment framework by integrating the BSC approach into FMCDM in the context of TBL dimensions. In this line of thoughts, the present study seeks to fill these research gaps by developing a framework for assessing the leather industry's sustainability performance with an integrated approach. To demonstrate the execution of our developed framework, we measured the sustainability performance of three companies from the leather industry in Bangladesh by using three MCDM methods: SAW, Fuzzy TOPSIS, and Fuzzy VIKOR. The proposed research framework is depicted in Figure 1.

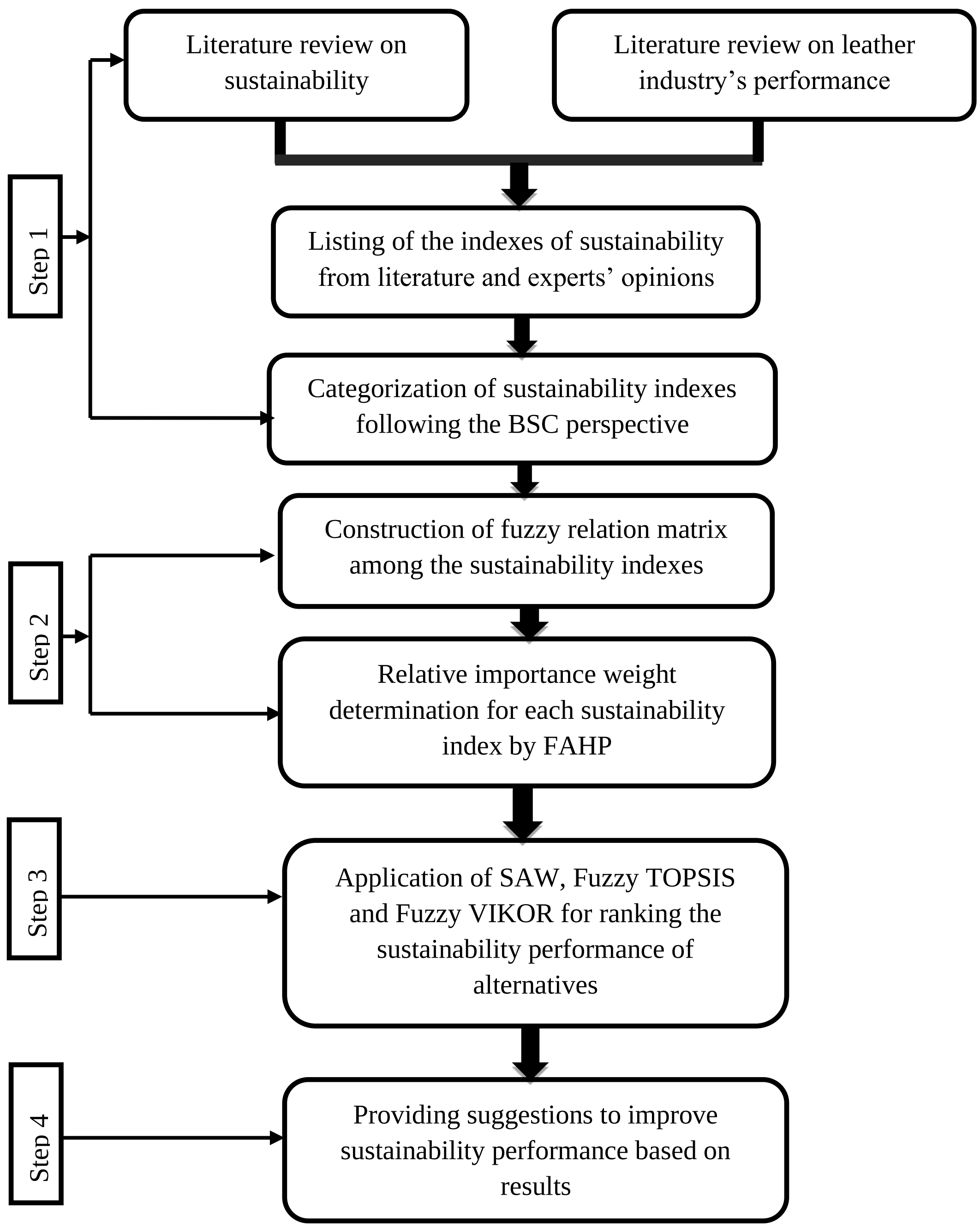


Figure 1: A sustainability measurement framework based on an integrated approach.

3.2. Case and expert selection

The proper selection of cases plays a vital role in addressing theoretical aspects of problems via a case-study approach. In this paper, we used the purposive sampling technique, whereby three case companies from the leather industry of Bangladesh and an expert panel of ten members were selected. The selected three companies were under pressure to implement more sustainable business practices, and to improve their overall sustainability performance. Therefore, these companies offered us an opportunity to test our sustainability indexes, with a view to developing a framework for assessing sustainability by means of which a leather-processing company can measure its sustainability performance. Table A2 in Appendix A presents a brief description of each company. As for the 10 experts in our panel, eight experts were selected from four leading companies (including 3 case companies) in the leather industry; these experts have more than four years of working experience in top management positions. The remaining two experts are academics with more than five years of experience doing research in the field of sustainability. The details about our expert panel are presented in Table A3 in Appendix A. Using Google forms and face-to-face interviews, all necessary data were collected from the experts.

3.3. Solution methodologies

3.3.1 Fuzzy set theory

In our daily life, we regularly use some subjective expressions like “not very clear,” “probably so,” and “very likely”; these expressions reflect how human thought typically involves uncertainty (Wu et al., 2009). The problems of uncertainty, inconsistency, and ambivalence in human decision-making processes can be solved by fuzzy set theory, which was introduced by Zadeh (1965). Our study incorporates fuzzy set theory into sustainability performance assessment—specifically, in connection with assessments of evaluators’ subjective judgments. In this regard, triangular fuzzy numbers (TFN), as described by Mon et al. (1994), were used for computational purposes. Basic definition and arithmetic operations of TFN can be found in (Islam et al., 2019). In TFN, the three points of a symmetric triangle, i.e., the left, middle, and right points of the base of a triangle, indicate each membership function (see Figure 2). In this study, we used five basic linguistic expressions to establish a fuzzy, 5-level scale that allowed for comparisons among sustainability indexes of the alternatives (i.e., the illustrative companies) as rated by the evaluators in the context of the BSC perspective (see Figure 3).

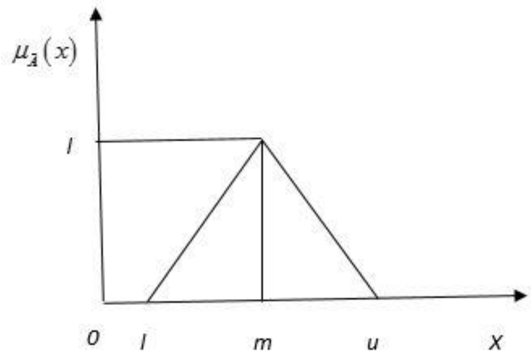
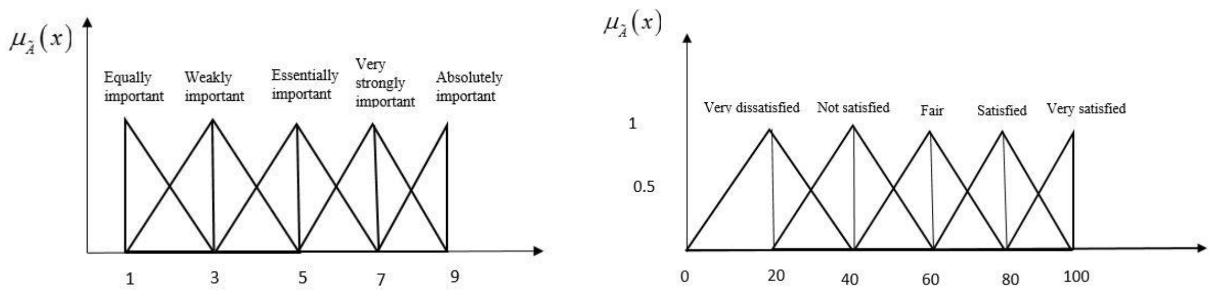


Figure 2: Membership function of the TFN.



(a) Linguistic variables for criteria comparisons.

(b) Five levels of linguistic scale for sustainability measurement.

Figure 3: Membership functions of the linguistic variables.

3.3.2 The fuzzy analytical hierarchy process (FAHP)

The analytical hierarchy process (AHP) was presented by Saaty (1990) as a useful technique for complex decision-making situations involving multiple options. In order to offer a preference list among several options, the AHP presents multiple elements in a hierarchical framework. With pairwise comparisons, this method employs a 9-point scale in which decision-makers evaluate the relative importance of certain criteria. The AHP, on the other hand, has several limitations. The 9-point judgment scale, for example, is unbalanced and thus uncertainty and imprecision can influence the pairwise-comparisons matrix. Buckley (1985) suggested FAHP, which incorporates fuzzy sets into AHP, to solve these problems. Decision-makers in FAHP express their opinions as interval values rather than fixed values. The proposed sustainability indicators are compared using FAHP to determine their relative importance. The steps of FAHP in determining sustainability criteria weights are outlined below.

Step 1: Formulation of fuzzy pairwise comparison matrices among the sustainability indexes under each BSC dimension and also for four BSC dimensions. For building these pairwise comparison matrices, every expert provides linguistic concepts using TFN. Eq. (1) shows the resulting comparison matrices.

$$\tilde{B} = \begin{bmatrix} 1 & \tilde{b}_{12} & \cdots & \tilde{b}_{1n} \\ \tilde{b}_{21} & 1 & \cdots & \tilde{b}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{b}_{n1} & \tilde{b}_{n2} & \ldots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{b}_{12} & \cdots & \tilde{b}_{1n} \\ 1/\tilde{b}_{12} & 1 & \cdots & \tilde{b}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{b}_{1n} & 1/\tilde{b}_{2n} & \ldots & 1 \end{bmatrix} \tag{1}$$

Step 2: Checking the consistency of the fuzzy pairwise comparison matrices. According to theory, the maximal eigenvalue of a comparison matrix with *k* dimensions must be equal to *k*. However, it is difficult to design consistent comparison matrices in practice. Different comparison matrices that satisfy the consistency ratio can be defined as consistent matrices. The consistency ratio is a mathematical method for determining whether or not a comparison matrix is consistent, as illustrated in Eq. (2).

$$CR = \frac{CI}{RI} \tag{2}$$

Where *CR* stands for consistency ratio, *CI* stands for consistency index, and *RI* represents average random index with the exact dimension of matrix *B*. Table 2 provides the value of the average random index.

Table 2: The value of the average random consistency index (*RI*).

k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The consistency index is calculated by Eq. (3).

$$CI = \frac{\lambda_{\max} - k}{k - 1} \tag{3}$$

Where $\lambda_{\max}$ symbolizes the maximal eigenvalue of the comparison matrix *B* and *k* is the dimension of this matrix. If $CR < 0.1$, then the matrix will be consistent. Alternatively, if $CR \geq 0.1$, then the matrix must be adjusted.

Step 3: Computation of the fuzzy geometric mean for each sustainability index by (Eq. 4).

$$\tilde{r}_l = \left[\tilde{b}_{l1} \otimes \cdots \otimes \tilde{b}_{lk}\right]^{1/k} \quad (4)$$

Where $\tilde{b}_{lk}$, is the fuzzy comparison value of criterion *l* to criterion *k* and $\tilde{r}_l$ is the geometric mean.

Step 4: Computation of the fuzzy weights by normalization. The fuzzy weights of the l^{th} criterion $(\tilde{w}_l)$ can be expressed as Eq. 5, where $\tilde{w}_l$ is denoted as $\tilde{w}_l = (P_{wl}, Q_{wl}, R_{wl})$ by a TFN, and P_{wl}, Q_{wl}, and R_{wl} represent the lower, middle, and upper values of the fuzzy weights of the l^{th} criterion.

$$\tilde{w}_l = \tilde{r}_l \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_k)^{-1} \quad (5)$$

3.3.3 The synthetic value of fuzzy judgments

As decision-makers' subjective judgements may differ, fuzzy judgments are used to synthesis the viewpoints of many decision-makers so that a rational and fair evaluation can be achieved. The processes are mentioned below to achieve this synthesis.

Step 1: Sustainability performance evaluation of the alternatives. The performances of the alternatives are measured against five linguistic variables as illustrated in Figure 3(b). $\tilde{E}_{lm}^{n}$ is denoted as fuzzy evaluation of sustainability performance provided by the decision-makers *n* towards alternative *l* under criterion *m* as shown in Eq. (6).

$$\tilde{E}_{lm}^{n} = \left(PE_{lm}^{n}, QE_{lm}^{n}, RE_{lm}^{n}\right) \quad (6)$$

Where $\tilde{E}_{lm}$ denotes the average fuzzy judgment values given by *t* decision-makers as represented in Eq. (7).

$$\tilde{E}_{lm}^{n} = (1/t) \otimes \left(\tilde{E}_{lm}^{1} \oplus \tilde{E}_{lm}^{2} \oplus \cdots \oplus \tilde{E}_{lm}^{t}\right) \quad (7)$$

The lower, middle, and upper values of the three endpoints of $\tilde{E}_{lm}$ can be calculated by Eq. (8).

$$PE_{lm} = \left(\sum_{n=1}^{t} PE_{lm}^{n}\right) \Big/ t, \quad QE_{lm} = \left(\sum_{n=1}^{t} QE_{lm}^{n}\right) \Big/ t, \quad RE_{lm} = \left(\sum_{n=1}^{t} UE_{lm}^{n}\right) \Big/ t. \quad (8)$$

Step 2: Fuzzy synthetic decision. The critical vector $(\tilde{w})$ is derived as Eq. (9) based on the fuzzy weight, $(\tilde{w}_m)$ of each index, computed by FAHP whereas the fuzzy performance matrix $(\tilde{E})$ of all the alternatives as Eq. (10) can be calculated from the fuzzy performance value of each alternative under *k* criteria.

$$\tilde{w} = (\tilde{w}_1, \ldots, \tilde{w}_m, \ldots, \tilde{w}_k)^s \tag{9}$$

$$\tilde{E} = [\tilde{e}_{lm}] \tag{10}$$

The final result $\tilde{T}$ can be computed as given in Eq. (11).

$$\tilde{T} = \tilde{E} \Leftrightarrow \tilde{w} \tag{11}$$

Where the sign, $\Leftrightarrow$, defines the computation of fuzzy addition and fuzzy multiplication. The approximate multiplied outcome of the fuzzy multiplication is considered here because the computation of fuzzy multiplication is fairly difficult. $\tilde{T}_l$ is the appropriate fuzzy number as Eq. (12), where PT_l, QT_l and RT_l are the lower, middle and upper synthetic values of alternative *l*, respectively. The calculations are mentioned below as Eq. (13).

$$\tilde{T}_l = (PT_l, QT_l, RT_l) \tag{12}$$

Where $PT_l = \sum_{m=1}^{k} Pw_m \times PE_{lm},\ QT_l = \sum_{m=1}^{k} Qw_m \times QE_{lm},\ RT_l = \sum_{m=1}^{k} Rw_m \times RE_{lm}.$ (13)

Step 3: Ordering the fuzzy number. The results of fuzzy synthetic decision should be defuzzified to make a ranking among alternatives. The best non-fuzzy performance (BNP) value can be obtained by Eq. (14), which is used for ranking the alternatives.

$$BNP_l = \left[(RT_l - PT_l) + (QT_l - PT_l) \right] / 3 + PT_l \quad \forall l. \tag{14}$$

3.3.4 Fuzzy TOPSIS method

Hwang & Yoon (1981) proposed the fuzzy TOPSIS method. According to this method, the best option would be the one that should have the smallest Euclidian distance from the positive ideal solution (PIS) and the largest distance from the negative ideal solution (NIS). The steps involved in the Fuzzy TOPSIS method are presented below.

Step 1: Structuring the core sustainability performance matrix. The structure of the performance matrix (*Y*) is shown in Eq. (15). If an MCDM problem has *O* alternatives $\{C_1, C_2, \ldots, C_O\}$ that are assessed by *k* attributes $\{D_1, D_2, \ldots, D_k\}$; then the performance matrix will be obtained with *O* rows and *K* columns as follows where y_{lm} denotes the performance value of *l* alternative in *m* criterion.

$$D_1 \quad \cdots \quad D_m \quad \cdots \quad D_p$$

$$Y = \begin{matrix} C_1 \\ \vdots \\ C_l \\ \vdots \\ C_o \end{matrix} \begin{bmatrix} y_{11} & \cdots & y_{1m} & \cdots & y_{1k} \\ \vdots & & \vdots & & \vdots \\ y_{l1} & \cdots & y_{lm} & \cdots & y_{lk} \\ \vdots & & \vdots & & \vdots \\ y_{o1} & \cdots & y_{om} & \cdots & y_{ok} \end{bmatrix} \tag{15}$$

$y_1^* \quad \cdots \quad y_m^* \quad \cdots \quad y_k^*$ Aspired level

$y_1^- \quad \cdots \quad y_m^- \quad \cdots \quad y_k^-$ Tolerable/worst level

Step 2: Computation of the normalized decision matrix. The normalized value of r_{lm} is defined in Eq. (16).

$$r_{lm} = \frac{\left|y_{lm} - y_m^-\right|}{\left|y_{lm}^* - y_m^-\right|}, \qquad l = 1, 2, \ldots, o; \;\; m = 1, 2, \ldots, k. \tag{16}$$

Step 3: Computation of the weighted normalized decision matrix. The normalized performance matrix has to be weighted as given in Eq. (17).

$$v_{lm} = w_m \times r_{lm}, \;\; l = 1, 2, \ldots, o; \;\; m = 1, 2, \ldots, k. \tag{17}$$

where w_m is the weight of the criteria m, and v_{lm} is the weighted normalized performance matrix.

Step 4: Determination of the PIS and NIS. The d_l^* and d_l^- are defined as PIS and NIS respectively, as shown in Eqs. (18) and (19).

Positive Ideal solution (PIS):

$$d_l^* = \{v_1^*, \ldots\ldots, v_k^*\}, where\ v_m^* = \max\,(v_{lm})\ if\ m \in M; \min\,(v_{lm})\ if\ m \in M' \} \tag{18}$$

Negative ideal solution (NIS):

$$d_l^- = \{v_1^-, \ldots\ldots, v_k^-\}, where\ v_m^- = \min(v_{lm})\ if\ m \in M; \max(v_{lm})\ if\ m \in M' \} \tag{19}$$

Where M is a set of benefit criteria and M' is a set of cost criteria.

Step 5: Computation of the differences of each alternative from the positive ideal alternative (d_l^*) and from the negative ideal alternative (d_l^-) as given in Eqs. (20) – (21).

$$d_l^* = \sqrt{\sum (v_{lm} - v_m^*)^2} \text{ for } l = 1, 2, 3, \ldots\ldots, o \tag{20}$$

$$d_l^- = \sqrt{\sum (v_{lm} - v_m^-)^2} \text{ for } l = 1, 2, 3, \ldots\ldots, o \quad (21)$$

Step 6: Computation of the relative closeness (RC_l^*) to the ideal solution or similarities. The relative closeness of alternative A_l with respect to the ideal solution d_l^* is defined in Eq. (22).

$$RC_l^* = \frac{d_l^-}{d_l^* + d_l^-}\ ; 0 \leq RC_l^* \leq 1, \text{ for } l = 1, 2, 3, \ldots\ldots, o \quad (22)$$

Step 7: Ranking of the alternatives according to RC_l^* values in decreasing order.

3.3.5 Fuzzy VIKOR

Fuzzy VIKOR is known as a MCDM optimization and compromise solution, which is an appropriate tool for measuring the closeness of a given solution to the ideal alternative (Opricovic & Tzeng, 2007; Rostamzadeh et al., 2015). The steps used in this compromise ranking algorithm are presented below (Liu et al., 2013).

Step 1: Determination of the best and worst values of all sustainability criteria. Let, m^{th} criterion denotes a benefit, then the best values for all criteria functions are $\{y_m^* \,|m = 1, 2, \ldots, k\}$ and the worst values are $\{y_m^- \,|m = 1, 2, \ldots, k\}$.

Step 2: Computation of the differences from the ideal alternative by Eqs. (23) – (25).

$$d_l^p = \left\{ \sum_{m=1}^{k} \left(w_m \frac{|y_m^* - y_{lm}|}{|y_m^* - y_m^-|} \right)^p \right\}^{1/p}, \ l = 1, 2, \ldots, o, \quad (23)$$

$$G_l = d_l^{p=1} = \sum_{m=1}^{k} \left(W_m \frac{|y_m^* - y_{lm}|}{|y_m^* - y_m^-|} \right), l = 1, 2, \ldots, o, \quad (24)$$

$$H_l = d_l^{p=\infty} = \max_m \left\{ w_m \frac{|y_m^* - y_{lm}|}{|y_m^* - y_m^-|} \,|m = 1, 2, \ldots, k \right\}, l = 1, 2, \ldots, o, \quad (25)$$

Where $G_l, H_l \in [0,1]$ and 0 denotes the best level and 1 represents the worst level.

Step 3: Computation of the gaps $\{Q_l \,|l = 1, 2, \ldots, o\}$ for ranking by Eq. (26).

$$Q_l = v\left[\frac{\left(G_l - G^*\right)}{\left(G^- - G^*\right)}\right] + (1-v)\left[\frac{\left(H_l - H^*\right)}{\left(H^- - H^*\right)}\right], l = 1, 2, \ldots, o, \tag{26}$$

Step 4: Ranking of the alternatives according to the values of *G*, *H*, and *Q*, in decreasing order.

4. Application of the proposed integrated method

4.1. Data Collection

In this study, we took the following three steps to collect data.

Step 1: A total of twenty-eight indexes of sustainability were extrapolated from the literature review. Then the list was provided to the expert panel to establish a final list by adding or removing indexes based on their evaluations. The endorsed list is presented in Table 1.

Step 2: The fuzzy comparison matrices for the sustainability indexes and the BSC dimensions were constructed with respect to the linguistic variables and the linguistic scale, vis-à-vis the evaluations by the panel of experts. Then the consistency ratio (*CR*) was checked with the help of Eqs. (2) - (3), to validate the fuzzy matrix of the experts' ratings.

Step 3: Three case companies in the Bangladeshi leather industry were selected, for the purposes of applying the proposed framework for sustainability measurement.

In this step, four industrial experts were first asked to provide their feedback on the performance of the three selected companies (*A*, *B*, and *C*), using the fuzzy linguistic variable scale. Then their linguistic ratings were converted into fuzzy triangular numbers. Finally, the performances of the three alternatives (i.e., illustrative companies) were evaluated by means of MCDM tools: SAW, Fuzzy TOPSIS, and Fuzzy VIKOR.

4.2. Analysis using FAHP

The constructed fuzzy comparison matrices involving the sustainability indexes and the BSC dimensions by the panel of experts were employed to evaluate the fuzzy weights of each index by using Eqs. (4) and (5). In this regard, $\tilde{r}_l$ is the geometric mean, which was calculated by using Eq. (4). Best non-fuzzy performance (BNP) and standardized BNP of each index were determined in order to identify their relative importance, as presented in Table 3.

Table 3 represents the standardized BNP value for four dimensions of the BSC system as Financial: 0.2426, Customers: 0.4885, Internal business process: 0.2225, and Learning and growth: 0.0464. The greater the value of standardized BNP of an index, the more important the index is. Therefore, the preference ranking of the four dimensions of the BSC approach is Customer, Financial, Internal business processes, and Learning and growth, respectively. Meanwhile, the top five priority indexes of sustainability are customer satisfaction (*C1*), Customer retention rate (*C2*), Investment in energy-conservation and emission-reduction technologies (*F5*), sales revenue from green products (*F1*), and Efficiency of effluent treatment plants (*I3*), based on their standardized BNP values of 0.2071, 0.1046, 0.0909, 0.0707, and 0.0657, respectively. The lowest standardized BNP value is recorded for Workforce diversity (*L3*): 0.0015, meaning that it is the least important index of sustainability.

Table 3: Fuzzy weights of the sustainability evaluation indexes by FAHP.

Indexes	Local weights	Overall weights	BNP	STD_BNP	Rank
F	(0.1138, 0.2245, 0.5378)		0.2920	0.2426	2
F1	(0.0557, 0.2415, 0.8394)	(0.0063, 0.0542, 0.4514)	0.1707	0.0707	4
F2	(0.0471, 0.1932, 0.6868)	(0.0054, 0.0434, 0.3694)	0.1394	0.0578	7
F3	(0.0300, 0.0604, 0.3052)	(0.0034, 0.0136, 0.1642)	0.0604	0.0250	14
F4	(0.0380, 0.1063, 0.4324)	(0.0043, 0.0239, 0.2326)	0.0869	0.0360	10
F5	(0.0857, 0.3261, 1.0683)	(0.0098, 0.0732, 0.5746)	0.2192	0.0909	3
F6	(0.0243, 0.0725, 0.2289)	(0.0028, 0.0163, 0.1231)	0.0474	0.0196	15
C	(0.2212, 0.4988, 1.0440)		0.5880	0.4885	1
C1	(0.2137, 0.4956, 1.1536)	(0.0473, 0.2472, 1.2043)	0.4996	0.2071	1
C2	(0.0590, 0.2198, 0.6078)	(0.0131, 0.1096, 0.6345)	0.2524	0.1046	2
C3	(0.0472, 0.1180, 0.3796)	(0.0104, 0.0589, 0.3963)	0.1552	0.0643	6
C4	(0.0381, 0.1192, 0.3101)	(0.0084, 0.0595, 0.3237)	0.1305	0.0541	9
C5	(0.0248, 0.0474, 0.1613)	(0.0055, 0.0236, 0.1683)	0.0658	0.0273	13
I	(0.1003, 0.2286, 0.4745)		0.2678	0.2225	3
I1	(0.0946, 0.2581, 0.7048)	(0.0095, 0.0590, 0.3345)	0.1343	0.0557	8
I2	(0.0408, 0.1502, 0.4330)	(0.0041, 0.0343, 0.2055)	0.0813	0.0337	11
I3	(0.1450, 0.3441, 0.8055)	(0.0145, 0.0787, 0.3822)	0.1585	0.0657	5
I4	(0.0170, 0.0317, 0.0973)	(0.0017, 0.0072, 0.0462)	0.0184	0.0076	19
I5	(0.0530, 0.1434, 0.4027)	(0.0053, 0.0328, 0.1911)	0.0764	0.0317	12
I6	(0.0254, 0.0726, 0.2182)	(0.0025, 0.0166, 0.1035)	0.0409	0.0170	16
L	(0.0309, 0.0481, 0.0886)		0.0559	0.0464	4
L1	(0.2864, 0.4746, 0.8145)	(0.0089, 0.0228, 0.0722)	0.0346	0.0143	17
L2	(0.0461, 0.1145, 0.2419)	(0.0014, 0.0055, 0.0214)	0.0095	0.0039	20

L3	(0.0291, 0.0418, 0.0867)	(0.0009, 0.0020, 0.0077)	0.0035	0.0015	21
L4	(0.1910, 0.3691, 0.6664)	(0.0059, 0.0178, 0.0590)	0.0276	0.0114	18

STD_BNP: Standardized BNP

4.3. Analysis using SAW

Three alternatives (e.g., *A*, *B*, and *C* company) were taken as illustrative examples and examined by the panel of experts via the sustainability evaluation indexes falling under the four dimensions of the BSC perspective. In this regard, five linguistic variables—i.e., "very satisfied," "satisfied," "fair," "not satisfied," and "very dissatisfied"—were used to measure the performance of these three alternatives based on the evaluation indexes. The average fuzzy judgment values for each sustainability index, for the three alternatives were integrated from the experts' ratings, via Eqs. (6) - (8). The final fuzzy synthetic judgments of the three alternatives were computed based on the fuzzy criteria weights and the average fuzzy judgment values by using Eqs. (9) - (13), which are listed in Table 4. The BNP value was calculated by using Eq. (14). In the SAW method, the ranking is established based on the descending order of BNP values. In this study, we find that the BNP values of the three alternatives are *A*: 132.05, *B*: 117.93, and *C*: 112.72, respectively. As a result, it can be inferred that the sustainability performance ranking of the three alternatives is *A* > *B* > *C*.

Table 4: Fuzzy synthetic performance values for the three alternatives, as determined by SAW.

Indexes	***A***	***B***	***C***
F	(0.14, 2.88, 78.72)	(0.1, 2.29, 68.61)	(0.1, 2.28, 67.43)
F1	(0.22, 2.98, 33.86)	(0.13, 2.17, 27.09)	(0.13, 2.17, 27.09)
F2	(0.30, 3.25, 33.24)	(0.21, 2.6, 29.55)	(0.21, 2.6, 27.7)
F3	(0.19, 1.02, 14.77)	(0.15, 0.88, 13.95)	(0.17, 0.95, 14.77)
F4	(0.13, 1.19, 16.28)	(0.17, 1.43, 18.6)	(0.15, 1.31, 17.44)
F5	(0.29, 3.66, 40.22)	(0.15, 2.56, 31.6)	(0.15, 2.56, 31.6)
F6	(0.07, 0.73, 8.00)	(0.04, 0.57, 6.77)	(0.04, 0.57, 6.77)
C	(0.97, 17.87, 249.35)	(0.80, 15.46, 225.89)	(0.69, 14.26, 216.35)
C1	(2.60, 18.54, 108.39)	(2.13, 16.07, 96.35)	(1.65, 13.6, 90.32)
C2	(0.78, 8.77, 60.28)	(0.59, 7.13, 53.94)	(0.65, 7.67, 53.94)
C3	(0.57, 4.41, 35.66)	(0.57, 4.41, 35.66)	(0.47, 3.83, 31.70)
C4	(0.21, 2.68, 21.04)	(0.13, 2.08, 17.81)	(0.13, 2.08, 17.81)
C5	(0.22, 1.42, 13.47)	(0.19, 1.3, 12.63)	(0.22, 1.42, 13.47)
I	(0.12, 2.63, 41.98)	(0.08, 2.18, 36.97)	(0.06, 1.87, 33.86)
I1	(0.24, 2.65, 21.74)	(0.14, 2.06, 18.4)	(0.19, 2.36, 20.07)
I2	(0.10, 1.55, 13.35)	(0.08, 1.37, 12.33)	(0.08, 1.37, 12.33)

I3	(0.51, 4.33, 28.67)	(0.36, 3.54, 24.85)	(0.07, 1.97, 17.2)
I4	(0.09, 0.51, 4.16)	(0.07, 0.43, 3.69)	(0.09, 0.51, 4.16)
I5	(0.19, 1.80, 14.33)	(0.13, 1.47, 12.42)	(0.13, 1.47, 12.42)
I6	(0.05, 0.66, 6.21)	(0.05, 0.66, 6.21)	(0.03, 0.5, 5.18)
L	(0.03, 0.17, 1.24)	(0.02, 0.15, 1.23)	(0.02, 0.14, 1.12)
L1	(0.44, 1.60, 6.13)	(0.4, 1.48, 6.13)	(0.27, 1.14, 5.05)
L2	(0.07, 0.39, 1.93)	(0.04, 0.28, 1.50)	(0.04, 0.25, 1.39)
L3	(0.05, 0.16, 0.69)	(0.04, 0.13, 0.65)	(0.04, 0.14, 0.65)
L4	(0.41, 1.60, 5.90)	(0.32, 1.33, 5.61)	(0.35, 1.42, 5.31)
Synthetic performance	(1.25, 23.56, 371.35)	(1.00, 20.09, 332.70)	(0.87, 18.56, 318.74)
BNP	132.05	117.93	112.72
Ranking	1	2	3

4.4. Analysis using Fuzzy TOPSIS

Next, the fuzzy TOPSIS method was applied to evaluate the performance of the alternatives (i.e., the illustrative three companies'). The BNP values were calculated for the average fuzzy judgment values for the three alternatives by using Eq. (14); the experts' ratings were integrated via Eq. (15). The normalized performance matrix was then computed by Eq. (16). Based on the fuzzy weights of the sustainability performance evaluation indexes, as calculated by FAHP, the weighted normalized performance matrices were computed via Eq. (17) and then Eqs. (18) and (19) were used to compute the PIS and the NIS for the sustainability evaluation index, as depicted in Table 5. As such for *F1* index, the PIS is 0.0707 and the NIS is 0.0000. Table 6 lists the separation between the PIS and the NIS for the three alternatives, based on Eqs. (20) and (21). For example, the separation value of the *A* alternative from the PIS is 0.0360 (least distance) and the separation value of the *A* alternative from the NIS is 0.2992 (largest distance) mean that the *A* alternative is the best performer among the three alternatives. The relative closeness of the ideal solution and performance evaluation, meanwhile, were calculated by Eqs. (22) and (23), as described in Table 7. In the Fuzzy TOPSIS method, the value of relative closeness (RC_l^*) defines the performance of the alternatives being evaluated. The value of RC_l^* denotes how close the performance of an alternative is to the ideal solution. Table 7 represents the RC_l^* values of the three alternatives as *A*: 0.8925, *B*: 0.3656, and *C*: 0.1568. Therefore, it can be said that the *A* alternative has the closest distance to the ideal solution, whereas the *C* alternative has the largest distance from the ideal solution. So, the sustainability performance ranking of the three alternatives can be summarized as $A > B > C$.

Table 5: The weighted normalized performance matrix $[v_{lm}]_{o\times k}$ with the positive ideal solution C^* and the negative ideal solution C^- for the sustainability indexes of the alternatives, as calculated by Fuzzy TOPSIS.

Indexes	***A***	***B***	***C***	C^*	C^-
F1	0.0707	0.0000	0.0000	0.0707	0.0000
F2	0.0578	0.0064	0.0000	0.0578	0.0000
F3	0.0250	0.0000	0.0150	0.0250	0.0000
F4	0.0000	0.0360	0.0180	0.0360	0.0000
F5	0.0909	0.0000	0.0000	0.0909	0.0000
F6	0.0196	0.0000	0.0000	0.0196	0.0000
C1	0.2071	0.0941	0.0000	0.2071	0.0000
C2	0.1046	0.0000	0.0262	0.1046	0.0000
C3	0.0643	0.0643	0.0000	0.0643	0.0000
C4	0.0541	0.0000	0.0000	0.0541	0.0000
C5	0.0273	0.0000	0.0273	0.0273	0.0000
I1	0.0557	0.0000	0.0278	0.0557	0.0000
I2	0.0337	0.0000	0.0000	0.0337	0.0000
I3	0.0657	0.0438	0.0000	0.0657	0.0000
I4	0.0076	0.0000	0.0076	0.0076	0.0000
I5	0.0317	0.0000	0.0000	0.0317	0.0000
I6	0.0170	0.0170	0.0000	0.0170	0.0000
L1	0.0143	0.0117	0.0000	0.0143	0.0000
L2	0.0039	0.0008	0.0000	0.0039	0.0000
L3	0.0015	0.0000	0.0004	0.0015	0.0000
L4	0.0114	0.0000	0.0016	0.0114	0.0000

Table 6: The alternatives' separation from the ideal solution $\left(d_l^*\right)$ and the negative ideal solution $\left(d_l^-\right)$, as calculated by Fuzzy TOPSIS.

Alternatives	d_l^*	d_l^-
A	0.0360	0.2992
B	0.2241	0.1292
C	0.2852	0.0531

Table 7: The alternatives' relative closeness $\left(RC_l^*\right)$ to the ideal solution and sustainability performance order ranking, as calculated by Fuzzy TOPSIS.

Alternatives	RC_l^*	**Rank**

A	0.8925	1
B	0.3656	2
C	0.1568	3

4.5. Analysis using Fuzzy VIKOR

Fuzzy VIKOR was applied to measure the sustainability performance ranking of the three alternatives based on the fuzzy weights of the BSC perspective evaluation indexes, as calculated by FAHP. Table 8 shows the sustainability performance matrix given by Eq. (15) with the best value Y_m^* and worst value Y_m^-. The values of G_l and H_l were calculated by using Eqs. (23) – (25), as shown in Table 9. Then the value of Q_i was computed by using Eq. (26), as depicted in Table 9. In the Fuzzy VIKOR method, the performance ranking of the alternatives is computed following the ascending order of the G_l , H_l , and Q_l values. The ascending order of the G_l values for the three alternatives is 0.0360 (*A*), 0.7258 (*B*), and 0.8760 (*C*); the same order applies to the H_l values, which are 0. 0360 (*A*), 0.1130 (*B*), and 0.2071 (*C*), and also for the Q_l values (when Q_l = 0.5), which are 0.0000 (*A*), 0.6355 (*B*), 1.0000 (*C*). Therefore, it can be inferred from these results that the sustainability performance of the three alternatives can be ranked as *A*, *B*, and *C*, respectively. In addition, the sensitivity of the Fuzzy VIKOR results was checked by Eq. (26) for *V* = 0, 0.5, 1; these results are also listed in Table 10. Since the ranking of the alternatives did not change with different *V* values, it can be said that the result of the Fuzzy VIKOR analysis is reliable. Table 11 represents that the three methods find similar order for sustainability performance of the considered three alternatives as *A* > *B* > *C*. Therefore, it can be said that the findings of the applied model are robust and reliable for sustainability performance evaluation of any company.

Table 8: The performance matrix $[y_{lm}]_{o\times k}$ with the best values y_m^* and the worst values y_m^-, as calculated by Fuzzy VIKOR.

Indexes	***A***	***B***	***C***	y_m^*	y_m^-
F1	55.00	40.00	40.00	55.00	40.00
F2	73.33	60.00	58.33	73.33	58.33
F3	73.33	65.00	70.00	73.33	65.00
F4	50.00	60.00	55.00	60.00	55.00
F5	50.00	35.00	35.00	50.00	35.00
F6	45.00	35.00	35.00	45.00	35.00
C1	73.33	63.33	55.00	73.33	55.00
C2	78.33	65.00	68.33	78.33	65.00
C3	73.33	73.33	63.33	73.33	63.33
C4	45.00	35.00	35.00	45.00	35.00

C5	60.00	55.00	60.00	60.00	55.00
I1	45.00	35.00	40.00	45.00	35.00
I2	45.00	40.00	40.00	45.00	40.00
I3	55.00	45.00	25.00	55.00	25.00
I4	70.00	60.00	70.00	70.00	60.00
I5	55.00	45.00	45.00	55.00	45.00
I6	40.00	40.00	30.00	40.00	30.00
L1	68.33	65.00	50.00	68.33	50.00
L2	70.00	50.00	45.00	70.00	45.00
L3	76.67	65.00	68.33	76.67	65.00
L4	86.67	75.00	76.67	86.67	75.00

Table 9: The values of G_l and H_l, as calculated by Fuzzy VIKOR.

Alternatives	G_l	H_l
A	0.0360 (1)	0.0360 (1)
B	0.7258 (2)	0.1130 (2)
C	0.8760 (3)	0.2071 (3)

Note: ( ) denotes the order in which the alternatives are ranked.

Table 10: A sensitivity analysis of the values of Q_l with $v = 0, 0.5, 1$ as calculated by Fuzzy VIKOR.

Alternatives	$Q_l = 0$	$Q_l = 0.5$	$Q_l = 1$
A	0.0000 (1)	0.0000 (1)	0.0000 (1)
B	0.4497 (2)	0.6355 (2)	0.8212 (2)
C	1.0000 (3)	1.0000 (3)	1.0000 (3)

Note: ( ) denotes the order in which the alternatives are ranked.

Table 11: Sustainability performance ranking by three methods.

Alternatives	SAW	Fuzzy TOPSIS	Fuzzy VIKOR
A	132.05 (1)	0.8925 (1)	0.0000 (1)
B	117.93 (2)	0.3656 (2)	0.6355 (2)
C	112.72 (3)	0.1568 (3)	1.0000 (3)

Note: ( ) denotes the order in which the alternatives are ranked.

5. Discussion and practical implications

5.1. Discussion

This study finds that the "Customer (C)" dimension is the most important of the four dimensions of the BSC model when it comes to sustainability measurement, and also that customer satisfaction is the top-priority index among the twenty-one indexes of sustainability. A study conducted by Singh et al. (2018) that developed a sustainability evaluation model for manufacturing small and medium-sized enterprises (SMEs) also found customer satisfaction to be the most important index, but the overall significance of the customer dimension was lower than that of the financial dimension in their study. Hsu et al. (2011) found customer satisfaction as the fourth most important index among twenty-five indexes for sustainability assessment in their study in the context of the semi-conductor industry. Since the leather industry produces goods that primary purpose is to satisfy customers' needs, customer satisfaction should be given more priority in order for the industry to achieve sustainability. Currently, customers are aware of environmental issues, and they demand green products; this demand places pressure on firms to practice sustainability. Moreover, every company in the leather industry should invest to make its customers more loyal and to maintain a healthy relationship with them, given that the second most important index in our study was the customer retention rate.

The financial dimension is the second most important dimension in our study, and investment in energy-conservation and emission-reduction technologies, and sales revenue from green products, were found to be the second and third important sustainability indexes, respectively. Investment in green innovation technology, and green product sales revenues, were identified as important indexes of sustainability in the context of semi-conductor industry as well (Hsu et al., 2011). Therefore, investment in energy-conservation and emission-reduction strategies, and revenue earning from green products, should be highlighted by the leather industry as means for achieving sustainability. Hsu et al. (2011) found firms' profitability index to be the most important index of sustainability for the semi-conductor industry, and Singh et al. (2018) determined that the debt ratio index is the second most important index of sustainability for manufacturing SMEs. By contrast, our study assigns the least importance to these financial indexes, which are ranked fourteenth and tenth respectively, in our analysis.

Internal business processes have received increasing attention from customers, and the expert panel, too, figured them importantly in our framework for SM of the leather industry. In particular, the efficiency of effluent treatment plants (ETP) is a pivotal factor for the leather industry to achieve environmental sustainability. The importance of ETP for the leather industry's sustainability has been highlighted by other studies as well (e.g., Marconi et al., 2017). Furthermore, our study finds the reduction of chemical consumption and greenhouse gas emission to be vital indexes of sustainability, and these changes can be implemented in the processing of leather. In the context of semi-conductor industry, Hsu et al. (2011) also emphasized reduced greenhouse gas emissions, and limited usage of hazardous chemicals. In addition, solid waste is a major problem for the leather industry, because 650 kg solid waste is produced per 1000 kg raw hides/skins during the leather-processing cycle (Sathish et al., 2019). Recycling is a good option for this solid waste, with recycling having been identified as a sustainability index in our study. Solid waste recycling was also highlighted as an important aspect of sustainability for the leather industry by Gupta et al. (2018).

The dimension of learning and growth proved to have the least importance among the four dimensions we used to measure sustainability in the leather industry. In our study, four indexes, i.e., supplier's performance, training and skills, complaints from stakeholders, and workforce diversity were included in this category. In today's competitive business world, any business organization's performance largely depends on its supplier's performance. Pfeffer (2005) described the training and skills of the workforce as a strategic advantage for firms, and Hall and Lansbury (2006) argued that workforce development and skill ecosystems are requirements for any business organization seeking to achieve sustainability. In addition, a study conducted by Singh et al. (2007) showed that stakeholders' interest and participation also play a pivotal role in achieving sustainability. All of these findings support our study results.

The *C* company's performance was far behind that of the *A* factory's in terms of customer satisfaction, customer retention rate, investment in energy-conservation and emission-reduction technologies, sales revenue from green products, and the efficiency of effluent treatment plants—these being the five most important indexes of sustainability in our study. As a result, *C* is the worst performer whereas *A* is the best performer when it comes to sustainability performance. In order to close this gap in sustainability performance, the *C* company should focus more on their customers' needs by launching more green products; they should also improve their internal business processes, such as ETP, innovation processes, and solid waste recycling rates. At the same time, although the *A* company is more sustainable, it can still improve its performance with respect to a number of indexes, such as *F1, F4, F5, F6, C4, C5, I1, I2, I3, I5, I6,* and *L1*, because the company has not gained satisfactory level performance in these indexes.

5.2. Practical implications

The leather industry in Bangladesh is lagging behind other industries in terms of practicing sustainability. Moreover, industrial managers have limited knowledge about how to establish sustainable practices, or about how to measure their sustainability performance. In this regard, our study can guide them, by demonstrating the key factors that need to be practiced to improve sustainability, and that can thus be used to assess organizations' sustainability performance. Several managerial implications can be derived from the results as discussed below.

Investment in energy-conservation and emission-reduction technologies has been identified as a significant index of sustainability. This finding indicates that the sustainability performance of a company largely depends on its investment in technologies that require less energy and reduce the detrimental effects of production activities on the environment. In Bangladesh, industrial managers in the leather industry have not been willing to invest in cleaner technologies; instead, they have adopted traditional technologies, which are degrading our eco-systems. However, industrial managers can gain a competitive advantage in business by using energy-saving and emission-reduction technologies and meeting the market demand for green products (Cui et al., 2019). Senior industrial managers should thus focus on energy conservation, reduced chemical consumption, the optimal usage of resources, and emerging technologies required for sustainable production in the leather industry. They can also expand their financing channels to obtain special funds for investment in energy-conservation and emission-reduction technologies.

Sales revenue from green products is another important factor affecting the sustainability performance of the leather industry. Since different types of environmental pollution are being generated by leather-processing firms, eco-friendly leather manufacturing processes have been initiated, throughout the world, to reduce negative impacts on the ecosystem. Increasing revenue from green products can thus help a company in acquiring a green image in the business market that will increase its sustainability performance. Therefore, industrial managers should engage in rigorous market research to identify customers' needs and they should use effective advertisements to make customers aware of green products. They should emphasize designing green products, and adopt policies that will allow them to enlarge their sales channel for these products. Also, they can introduce green packaging for their products to promote sustainability.

The efficiency of effluent treatment plants also plays a pivotal role in ensuring a company's sustainability performance. The emission-control capability of a firm is likewise a key to competitive advantage (Dimitrova et al., 2007). To upgrade the efficiency of the effluent treatment plants of leather-processing companies, industrial managers should take necessary actions based on the three considerations. First, industrial managers should use less toxic chemicals during leather processing. Second, they should introduce innovation processes that will allow for the reuse of existing chemicals in subsequent leather-processing operations. Third, since a huge amount of solid waste is produced during leather processing, each factory should have a solid waste recycling plant for processing these wastes into useful goods, enabling them to earn revenue by selling these recycled goods. Furthermore, industrial managers should monitor their supplier's performance to ensure good quality products, and to resolve all complaints by stakeholders. In addition, proper training in sustainable practices should be provided to the employees of every leather processing factory by their top management. Moreover, factory managers should compare their organizations' sustainability performance by the proposed model, minimizing any performance gaps between them and other firms, and thereby gaining a competitive advantage in business.

6. Conclusions and directions for future research

This study proposed a novel SM framework and applied it for sustainability performance measurement for the leather industry, which contributes to the existing literature in the following ways. First, an SM framework for the leather industry was developed by using FMCDM tools with the BSC approach and TBL concept, which was not found in any other studies. This study unveiled the most relevant twenty-one indexes of sustainability through an extant literature review and experts' inputs, which can be followed by industrial managers to adopt sustainability practices in the leather industry. This study found two new sustainability indexes for the leather industry, i.e., "Efficiency of effluent treatment plants" and "Solid waste recycling rate", which might be further considered for SM in similar category industries. Moreover, identifying the most important indexes of sustainability based on their relative weights will guide industrial managers to build a priority list of indexes in achieving the desired level of sustainability performance with an efficient resource allocation plan. Second, if a company of the leather industry wants to measure its sustainability performance, it can follow the presented model, which comprises all the perspectives and important indexes of sustainability. Besides, a company can tailor the list of indexes of sustainability, and determine the relative weights of indexes following the present research method by an expert group of that company which is responsible for assessing sustainability performance. Otherwise, the weights of sustainability indexes in this study may be used as a reference. Third, this research model not only provides industrial managers to evaluate their companies' performance of sustainability but also provides an opportunity to compare their performances with other companies. The Fuzzy TOPSIS method provided information to improve the gaps of each sustainability index among the alternatives to achieve the desired level of performance. Finally, the application of the BSC model in this research allowed us to incorporate the diverse perspectives of sustainability, both monetary and non-monetary measures, and the usage of multiple MCDM tools made our research model robust and fit for future research. Our present framework displays to be a practical and useful methodology for assessing the sustainability performance of the leather industry, and it may be applied to other industries also.

The development of an SM framework is a complex project. It is challenging to bring all the aspects of sustainability together into a single framework. In consequence, there are some limitations of this research which should be taken into account in future research. First, the proposed framework in this study included twenty-one indexes of sustainability in the context of the leather industry in Bangladesh. The framework needs to be applied to other industries to test its broader applicability, with more indexes being included within the proposed framework, as necessary. Second, the performance ranking of the alternatives (i.e., the illustrative companies) was determined by three MCDM methods (i.e., SAW, Fuzzy TOPSIS, and Fuzzy VIKOR). Future research should consider algorithms for aggregating results from multiple MCDM methods for the purposes of higher-precision modeling. Finally, although the sustainability performance evaluation indexes may not be mutually independent, the MCDM methods used in this study did not account for interrelationships among the sustainability indexes. Analytical methods such as fuzzy analytic networks (FAN), interpretive structural modelling (ISM), and ELECTRE III can be used to investigate potential relationships among the sustainability indexes. Moreover, the DEMATEL technique can be used to explore causal relationships among the sustainability indexes, and thereby build strategy maps.

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Appendix A

Table A1: Description of the performance indexes of sustainability for the leather industry.

No.	Code	Indexes	Description
1	*F1*	Sales revenue from green product	Yearly revenue from selling environment friendly product.
2	*F2*	Return on investment	The ratio between net income and investment
3	*F3*	Net profit margin	As a percentage of sales, how much net income or profit is created

4	*F4*	Debt ratio	Debt divided by assets
5	*F5*	Investment in energy-conservation and emission reduction technologies	Firm's financial investment in energy saving technologies and cleaner production practices
6	*F6*	Income from recycling goods	Revenue from selling converted useable goods from waste materials
7	*C1*	Customer satisfaction	Customer's happiness about products and services
8	*C2*	Customer retention rate	Capability of holding existing customers
9	*C3*	Customer increasing rate	Growth rate of customers
10	*C4*	Increasing the number of green products	The advancement of introducing environment friendly products in market
11	*C5*	Profit per customer	After tax deduction, earnings divided by total customers
12	*I1*	Reduction of chemical consumption	Reduction of chemical usage through optimization of process parameters
13	*I2*	Reduction of greenhouse gas emission	Firm's reduction of greenhouse gas yearly
14	*I3*	Efficiency of effluent treatment plants	Firm's capability of treating waste water before disposal into environment
15	*I4*	Participation of employees in business decisions	Empowerment of employees that provides them to participate in decision making process
16	*I5*	Innovation processes	Development of new processes in firm's operations
17	*I6*	Solid waste recycling rate	The rate of conversion of solid wastes into useable goods
18	*L1*	Supplier's performance	Suppliers' quality and commitment
19	*L2*	Complaints from stakeholders	Stakeholder criticisms about products, services, and non-compliance issues
20	*L3*	Workforce diversity	Similarities and differences among employees in terms of race, religion, culture, gender and abilities
21	*L4*	Training and skills	Knowledge dissemination program that creates more expert employees

Table A2: Details to three case companies.

Company	**Number of employee**	**Product type**	**Annual turnover**	**Annual export volume**
A	12,456	Finished leather, Footwear, Leather products	$ 184.63 million	$ 97.70 million
B	2,503	Finished leather	$ 25.83 million	$ 19.97 million
C	1,452	Finished leather	$ 22.57 million	$ 17.46 million

Table A3: Experts' profile.

Name of expert	Position	Years of experience	Area
E1	Chief Executive officer (CEO)	27 years	Leather industry
E2	Managing director (MD)	18 years	Leather industry
E3	Assistant manager	10 years	Leather industry
E4	Assistant manager	6 years	Leather industry
E5	Supply chain manager	5 years	Footwear industry
E6	Senior merchandiser	5 years	Footwear industry
E7	Executive officer	4 years	Footwear industry
E8	Executive officer	4 years	Footwear industry
E9	Academician	5 years	Leather engineering
E10	Academician	5 years	Leather products

References

Akhtar, P., Ahmed, Y., Islam, F., Alam, K., Mary, M., Islam, M. Z., Bhuiyan, M. M. H., & Yaakob, Z. (2016). Efficiency of Effluent Treatment Plants and Threat to Human Health and Aquatic Environment in Bangladesh. *Asian Journal of Chemistry*, *28*(1), 60–68. https://doi.org/10.14233/ajchem.2016.19230

Aleksić, A., Stefanović, M., Tadić, D., & Arsovski, S. (2014). A fuzzy model for assessment of organization vulnerability. *Measurement*, *51*(1), 214–223. https://doi.org/10.1016/j.measurement.2014.02.003

Awasthi, A., Govindan, K., & Gold, S. (2018). Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach. *International Journal of Production Economics*, *195*, 106–117. https://doi.org/10.1016/j.ijpe.2017.10.013

Boerrigter, S. (2015). The use of the sustainability balanced scorecard framework for Dutch SMEs as a tool for measuring the performance of their sustainability strategy. *5th IBA Bachelor Thesis Conference*.

Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems*, *17*(3), 233–247. https://doi.org/10.1016/0165-0114(85)90090-9

Busco, C., & Quattrone, P. (2015). Exploring How the Balanced Scorecard Engages and Unfolds: Articulating the Visual Power of Accounting Inscriptions. *Contemporary Accounting Research*, *32*(3), 1236–1262. https://doi.org/10.1111/1911-3846.12105

Büyüközkan, G., Karabulut, Y., & Arsenyan, J. (2017). RFID service provider selection: An integrated fuzzy MCDM approach. *Measurement*, *112*, 88–98. https://doi.org/10.1016/j.measurement.2017.08.018

Chang, C., DiGiovanni, K., & Mei, Y. (2019). Sustainability. *Water Environment Research*, *91*(10), 1129–1149. https://doi.org/10.1002/wer.1210

Chen, T.-Y. (2012). Comparative analysis of SAW and TOPSIS based on interval-valued fuzzy sets: Discussions on score functions and weight constraints. *Expert Systems with Applications*, *39*(2), 1848–1861. https://doi.org/10.1016/j.eswa.2011.08.065

Chofreh, A. G., & Goni, F. A. (2017). Review of Frameworks for Sustainability Implementation. *Sustainable Development*, *25*(3), 180–188. https://doi.org/10.1002/sd.1658

Cui, L., Zhai, M., Dai, J., Liu, Y., & Zhang, P. (2019). Assessing sustainability performance of high-tech firms through a hybrid approach. *Industrial Management & Data Systems*, *119*(8), 1581–1607. https://doi.org/10.1108/IMDS-02-2019-0066

Digalwar, A. K., Dambhare, S., & Saraswat, S. (2020). Social sustainability assessment framework for indian manufacturing industry. *Materials Today: Proceedings*, *28*, 591–598.

https://doi.org/10.1016/j.matpr.2019.12.226

Dimitrova, V., Lagioia, G., & Gallucci, T. (2007). Managerial factors for evaluating eco-clustering approach. *Industrial Management & Data Systems*, *107*(9), 1335–1348. https://doi.org/10.1108/02635570710833992

Dodangeh, J., Yusuff, R. B. M., & Jassbi, J. (2010). Using TOPSİS method with goal programming for best selection of strategic plans in BSC model. *Journal of American Science*, *6*(3), 136–142.

Dressler, A., & Bucher, J. (2018). Introducing a Sustainability Evaluation Framework based on the Sustainable Development Goals applied to Four Cases of South African Frugal Innovation. *Business Strategy & Development*, *1*(4), 276–285. https://doi.org/10.1002/bsd2.37

Dubois, D., & Prade, H. (1978). Operations on fuzzy numbers. *International Journal of Systems Science*, *9*(6), 613–626. https://doi.org/10.1080/00207727808941724

Eberl, M., & Schwaiger, M. (2005). Corporate reputation: disentangling the effects on financial performance. *European Journal of Marketing*, *39*(7/8), 838–854. https://doi.org/10.1108/03090560510601798

Elkington, J. (1998). Partnerships fromcannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, *8*(1), 37–51. https://doi.org/10.1002/tqem.3310080106

Epstein, M. J., & Wisner, P. S. (2001). Using a Balanced Scorecard to Implement Sustainability. *Environmental Quality Management*, *11*(2), 1–10. https://doi.org/10.1002/tqem.1300

Figge, F., Hahn, T., Schaltegger, S., & Wagner, M. (2002). The Sustainability Balanced Scorecard - linking sustainability management to business strategy. *Business Strategy and the Environment*, *11*(5), 269–284. https://doi.org/10.1002/bse.339

Figueiredo, K., Pierott, R., Hammad, A. W. A., & Haddad, A. (2021). Sustainable material choice for construction projects: A Life Cycle Sustainability Assessment framework based on BIM and Fuzzy-AHP. *Building and Environment*, *196*, 107805. https://doi.org/10.1016/j.buildenv.2021.107805

Garcia, S., Cintra, Y., Torres, R. de C. S. R., & Lima, F. G. (2016). Corporate sustainability management: a proposed multi-criteria model to support balanced decision-making. *Journal of Cleaner Production*, *136*, 181–196. https://doi.org/10.1016/j.jclepro.2016.01.110

Glavič, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production*, *15*(18), 1875–1885. https://doi.org/10.1016/j.jclepro.2006.12.006

Gupta, S., Gupta, S., Dhamija, P., & Bag, S. (2018). Sustainability strategies in the Indian leather industry: an empirical analysis. *Benchmarking*. https://doi.org/10.1108/BIJ-06-2017-0140

Hafeez, K., Zhang, Y., & Malak, N. (2002). Determining key capabilities of a firm using analytic hierarchy process. *International Journal of Production Economics*, *76*(1), 39–51. https://doi.org/10.1016/S0925-5273(01)00141-4

Hall, R., & Lansbury, R. D. (2006). Skills in Australia: Towards Workforce Development and Sustainable Skill Ecosystems. *Journal of Industrial Relations*, *48*(5), 575–592. https://doi.org/10.1177/0022185606070106

Hansen, E. G., & Schaltegger, S. (2016). The Sustainability Balanced Scorecard: A Systematic Review of Architectures. *Journal of Business Ethics*, *133*(2), 193–221. https://doi.org/10.1007/s10551-014-2340-3

Hong, S. C. (2018). *ADB BRIEFS: Developing the Leather Industry in Bangladesh*. *102*, 1–8.

Horbach, J. (2016). Empirical determinants of eco-innovation in European countries using the community innovation survey. *Environmental Innovation and Societal Transitions*, *19*, 1–14. https://doi.org/10.1016/j.eist.2015.09.005

Hoyt, J., & Matuszek, T. (2001). Testing the contribution of multi-skilled employees to the financial performance of high-tech organizations. *The Journal of High Technology Management Research*, *12*(2), 167–181. https://doi.org/10.1016/S1047-8310(01)00043-8

Hristov, I., Chirico, A., & Appolloni, A. (2019). Sustainability Value Creation, Survival, and Growth of the Company: A Critical Perspective in the Sustainability Balanced Scorecard (SBSC). *Sustainability*, *11*(7), 2119. https://doi.org/10.3390/su11072119

Hsu, C.-W., Hu, A. H., Chiou, C.-Y., & Chen, T.-C. (2011). Using the FDM and ANP to construct a sustainability balanced scorecard for the semiconductor industry. *Expert Systems with Applications*, *38*(10), 12891–12899. https://doi.org/10.1016/j.eswa.2011.04.082

Huang, H.-C., Lai, M.-C., & Lin, L.-H. (2011). Developing strategic measurement and improvement for the biopharmaceutical firm: Using the BSC hierarchy. *Expert Systems with Applications*, *38*(5), 4875–4881. https://doi.org/10.1016/j.eswa.2010.09.069

Husgafvel, R., Watkins, G., Linkosalmi, L., & Dahl, O. (2013). Review of sustainability management initiatives within Finnish forest products industry companies—Translating Eu level steering into proactive initiatives. *Resources, Conservation and Recycling*, *76*, 1–11. https://doi.org/10.1016/j.resconrec.2013.04.006

Hwang, C.-L., & Yoon, K. (1981). *Methods for Multiple Attribute Decision* (pp. 58–191). https://doi.org/10.1007/978-3-642-48318-9_3

Islam, M. H., Sarker, M. R., Hossain, M. I., Ali, K., & Noor, K. M. A. (2019). Towards Sustainable Supply Chain Management (SSCM): A Case of Leather Industry. *Journal of Operations and*

Strategic Planning, *2*(2), 1–18. https://doi.org/10.1177/2516600X20924313

Jeswani, H. K., Burkinshaw, R., & Azapagic, A. (2015). Environmental sustainability issues in the food–energy–water nexus: Breakfast cereals and snacks. *Sustainable Production and Consumption*, *2*, 17–28. https://doi.org/10.1016/j.spc.2015.08.001

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard--measures that drive performance. *Harvard Business Review*, *70*(1), 71–79. http://www.ncbi.nlm.nih.gov/pubmed/10119714

Karaca, F., Guney, M., Kumisbek, A., Kaskina, D., & Tokbolat, S. (2020). A new stakeholder opinion-based rapid sustainability assessment method (RSAM) for existing residential buildings. *Sustainable Cities and Society*, *60*, 102155. https://doi.org/10.1016/j.scs.2020.102155

Khodakarami, M., Shabani, A., Farzipoor Saen, R., & Azadi, M. (2015). Developing distinctive two-stage data envelopment analysis models: An application in evaluating the sustainability of supply chain management. *Measurement*, *70*, 62–74. https://doi.org/10.1016/j.measurement.2015.03.024

Kilincci, O., & Onal, S. A. (2011). Fuzzy AHP approach for supplier selection in a washing machine company. *Expert Systems with Applications*, *38*(8), 9656–9664. https://doi.org/10.1016/j.eswa.2011.01.159

Knoepfel, I. (2001). Dow Jones Sustainability Group Index: A Global Benchmark for Corporate Sustainability. *Corporate Environmental Strategy*, *8*(1), 6–15. https://doi.org/10.1016/S1066-7938(00)00089-0

Kolomaznik, K., Adamek, M., Andel, I., & Uhlirova, M. (2008). Leather waste—Potential threat to human health, and a new technology of its treatment. *Journal of Hazardous Materials*, *160*(2–3), 514–520. https://doi.org/10.1016/j.jhazmat.2008.03.070

Kotane, I., & Kuzmina-Merlino, I. (2012). Assessment of financial indicators for evaluation of business performance. *European Integration Studies*, *6*. https://doi.org/10.5755/j01.eis.0.6.1554

Kuhlman, T., & Farrington, J. (2010). What is Sustainability? *Sustainability*, *2*(11), 3436–3448. https://doi.org/10.3390/su2113436

Kumar Gupta, S., Gupta, S., & Gayathiri, S. (2018). “Pollution prevention” is the key to drive sustainability. *Management of Environmental Quality: An International Journal*, *29*(3), 416–426. https://doi.org/10.1108/MEQ-10-2017-0124

Lee, A. H. I., Chen, W.-C., & Chang, C.-J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. *Expert Systems with Applications*, *34*(1), 96–107. https://doi.org/10.1016/j.eswa.2006.08.022

Lee, S., & Seo, K. K. (2016). A Hybrid Multi-Criteria Decision-Making Model for a Cloud Service Selection Problem Using BSC, Fuzzy Delphi Method and Fuzzy AHP. *Wireless Personal Communications*. https://doi.org/10.1007/s11277-015-2976-z

Liu, H.-C., Mao, L.-X., Zhang, Z.-Y., & Li, P. (2013). Induced aggregation operators in the VIKOR method and its application in material selection. *Applied Mathematical Modelling*, *37*(9), 6325–6338. https://doi.org/10.1016/j.apm.2013.01.026

Marconi, M., Marilungo, E., Papetti, A., & Germani, M. (2017). Traceability as a means to investigate supply chain sustainability: the real case of a leather shoe supply chain. *International Journal of Production Research*, *55*(22), 6638–6652. https://doi.org/10.1080/00207543.2017.1332437

Marshall, D., McCarthy, L., McGrath, P., & Claudy, M. (2015). Going above and beyond: how sustainability culture and entrepreneurial orientation drive social sustainability supply chain practice adoption. *Supply Chain Management: An International Journal*, *20*(4), 434–454. https://doi.org/10.1108/SCM-08-2014-0267

Modak, M., Pathak, K., & Ghosh, K. K. (2017). Performance evaluation of outsourcing decision using a BSC and Fuzzy AHP approach: A case of the Indian coal mining organization. *Resources Policy*. https://doi.org/10.1016/j.resourpol.2017.03.002

Moktadir, M. A., Ali, S. M., Rajesh, R., & Paul, S. K. (2018). Modeling the interrelationships among barriers to sustainable supply chain management in leather industry. *Journal of Cleaner Production*, *181*, 631–651. https://doi.org/10.1016/j.jclepro.2018.01.245

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of Cleaner Production*, *174*, 1366–1380. https://doi.org/10.1016/j.jclepro.2017.11.063

Mon, D.-L., Cheng, C.-H., & Lin, J.-C. (1994). Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight. *Fuzzy Sets and Systems*, *62*(2), 127–134. https://doi.org/10.1016/0165-0114(94)90052-3

Munny, A. A., Ali, S. M., Kabir, G., Moktadir, M. A., Rahman, T., & Mahtab, Z. (2019). Enablers of social sustainability in the supply chain: An example of footwear industry from an emerging economy. *Sustainable Production and Consumption*, *20*, 230–242. https://doi.org/10.1016/j.spc.2019.07.003

Nicoletti Junior, A., de Oliveira, M. C., & Helleno, A. L. (2018). Sustainability evaluation model for manufacturing systems based on the correlation between triple bottom line dimensions and balanced scorecard perspectives. *Journal of Cleaner Production*, *190*, 84–93. https://doi.org/10.1016/j.jclepro.2018.04.136

Omoloso, O., Mortimer, K., Wise, W. R., & Jraisat, L. (2021). Sustainability research in the leather industry: A critical review of progress and opportunities for future research. *Journal of Cleaner Production*, *285*, 125441. https://doi.org/10.1016/j.jclepro.2020.125441

Opricovic, S., & Tzeng, G.-H. (2007). Extended VIKOR method in comparison with outranking methods. *European Journal of Operational Research*, *178*(2), 514–529. https://doi.org/10.1016/j.ejor.2006.01.020

Pfeffer, J. (2005). Producing sustainable competitive advantage through the effective management of people. *Academy of Management Perspectives*, *19*(4), 95–106. https://doi.org/10.5465/ame.2005.19417910

Rafiq, M., Zhang, X., Yuan, J., Naz, S., & Maqbool, S. (2020). Impact of a Balanced Scorecard as a Strategic Management System Tool to Improve Sustainable Development: Measuring the Mediation of Organizational Performance through PLS-Smart. *Sustainability*, *12*(4), 1365. https://doi.org/10.3390/su12041365

Reza, A. K., & Islam, M. S. (2019). Measuring the sustainability of the knitwear sector of Bangladesh: Sustainability Vulnerability Index. *Business Strategy and Development*. https://doi.org/10.1002/bsd2.38

Ribeiro, F., Ferreira, P., & Araújo, M. (2013). Evaluating future scenarios for the power generation sector using a Multi-Criteria Decision Analysis (MCDA) tool: The Portuguese case. *Energy*, *52*, 126–136. https://doi.org/10.1016/j.energy.2012.12.036

Rostamzadeh, R., Govindan, K., Esmaeili, A., & Sabaghi, M. (2015). Application of fuzzy VIKOR for evaluation of green supply chain management practices. *Ecological Indicators*, *49*, 188–203. https://doi.org/10.1016/j.ecolind.2014.09.045

Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, *48*(1), 9–26. https://doi.org/10.1016/0377-2217(90)90057-I

Sarker, M. R., Ahmed, F., Deb, A. K., & Chowdhury, M. (2018). Identifying barriers for implementing green supply chain management (GSCM) in footwear industry of Bangladesh: a Delphi study approach. *Leather and Footwear Journal*, *18*(3), 175–186. https://doi.org/10.24264/lfj.18.3.1

Sathish, M., Madhan, B., & Raghava Rao, J. (2019). Leather solid waste: An eco-benign raw material for leather chemical preparation – A circular economy example. *Waste Management*, *87*, 357–367. https://doi.org/10.1016/j.wasman.2019.02.026

Schaltegger, S., & Wagner, M. (2006). Integrative management of sustainability performance, measurement and reporting. *International Journal of Accounting, Auditing and Performance Evaluation*, *3*(1), 1. https://doi.org/10.1504/IJAAPE.2006.010098

Sidiropoulos, M., Mouzakitis, Y., & Adamides, E. (2004). *Applying sustainable indicators to corporate strategy : The eco-balanced Applying Sustainable Indicators to Corporate Strategy : The Eco-balanced Scorecard*. *January*.

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2007). Development of composite sustainability performance index for steel industry. *Ecological Indicators*, *7*(3), 565–588. https://doi.org/10.1016/j.ecolind.2006.06.004

Singh, S., Olugu, E. U., Musa, S. N., & Mahat, A. B. (2018). Fuzzy-based sustainability evaluation method for manufacturing SMEs using balanced scorecard framework. *Journal of Intelligent Manufacturing*, *29*(1), 1–18. https://doi.org/10.1007/s10845-015-1081-1

Solangi, Y. A., Longsheng, C., & Shah, S. A. A. (2021). Assessing and overcoming the renewable energy barriers for sustainable development in Pakistan: An integrated AHP and fuzzy TOPSIS approach. *Renewable Energy*, *173*, 209–222. https://doi.org/10.1016/j.renene.2021.03.141

Suganthi, L. (2018). Multi expert and multi criteria evaluation of sectoral investments for sustainable development: An integrated fuzzy AHP, VIKOR / DEA methodology. *Sustainable Cities and Society*, *43*, 144–156. https://doi.org/10.1016/j.scs.2018.08.022

Szilagyi, A., Mocan, M., Verniquet, A., Churican, A., & Rochat, D. (2018). Eco-innovation, a Business Approach towards Sustainable Processes, Products and Services. *Procedia - Social and Behavioral Sciences*, *238*, 475–484. https://doi.org/10.1016/j.sbspro.2018.04.026

Tseng, M.-L., Wu, K.-J., Ma, L., Kuo, T. C., & Sai, F. (2019). A hierarchical framework for assessing corporate sustainability performance using a hybrid fuzzy synthetic method-DEMATEL. *Technological Forecasting and Social Change*, *144*, 524–533. https://doi.org/10.1016/j.techfore.2017.10.014

Varmazyar, M., Dehghanbaghi, M., & Afkhami, M. (2016). A novel hybrid MCDM model for performance evaluation of research and technology organizations based on BSC approach. *Evaluation and Program Planning*, *58*, 125–140. https://doi.org/10.1016/j.evalprogplan.2016.06.005

Vinodh, S., Nagaraj, S., & Girubha, J. (2014). Application of Fuzzy VIKOR for selection of rapid prototyping technologies in an agile environment. *Rapid Prototyping Journal*, *20*(6), 523–532. https://doi.org/10.1108/RPJ-07-2012-0060

Wang, Z.-X., & Wang, Y.-Y. (2014). Evaluation of the provincial competitiveness of the Chinese high-tech industry using an improved TOPSIS method. *Expert Systems with Applications*, *41*(6), 2824–2831. https://doi.org/10.1016/j.eswa.2013.10.015

WCED. (1987). Our Common Future. Oxford: Oxford University Press. In *World Commission on Environment and Development*.

Wei, J., & Lin, X. (2008). The Multiple Attribute Decision-Making VIKOR Method and its Application. *2008 4th International Conference on Wireless Communications, Networking and Mobile Computing*, 1–4. https://doi.org/10.1109/WiCom.2008.2777

World footwear. (2020). *Bangladesh's leather exports down by 22%*. Retrieved August 12, 2020, from https://www.worldfootwear.com/news/bangladeshs-leather-exports-down-by-22/5242.html

Wu, H.-Y., Tzeng, G.-H., & Chen, Y.-H. (2009). A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Systems with Applications*, *36*(6), 10135–10147. https://doi.org/10.1016/j.eswa.2009.01.005

Xiao, F. (2020). GIQ: A generalized intelligent quality-based approach for fusing multi-source information. *IEEE Transactions on Fuzzy Systems*, *6706*(c), 1–1. https://doi.org/10.1109/TFUZZ.2020.2991296

Xiao, F., Cao, Z., & Jolfaei, A. (2021). A Novel Conflict Measurement in Decision-Making and Its Application in Fault Diagnosis. *IEEE Transactions on Fuzzy Systems, 29*(1), 186–197. https://doi.org/10.1109/TFUZZ.2020.3002431

Xiao, F. (2021) "CEQD: A Complex Mass Function to Predict Interference Effects," in IEEE Transactions on Cybernetics, doi: 10.1109/TCYB.2020.3040770.

Yalcin, N., Bayrakdaroglu, A., & Kahraman, C. (2012). Application of fuzzy multi-criteria decision making methods for financial performance evaluation of Turkish manufacturing industries. *Expert Systems with Applications*, *39*(1), 350–364. https://doi.org/10.1016/j.eswa.2011.07.024

Yousefi, S., Shabanpour, H., Fisher, R., & Saen, R. F. (2016). Evaluating and ranking sustainable suppliers by robust dynamic data envelopment analysis. *Measurement*, *83*, 72–85. https://doi.org/10.1016/j.measurement.2016.01.032

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X

Zhang, L., Xin, H., & Kan, Z. (2019). Sustainability Performance Evaluation of Hybrid Energy System Using an Improved Fuzzy Synthetic Evaluation Approach. *Sustainability*, *11*(5), 1265. https://doi.org/10.3390/su11051265