Sustainability Performance Assessment Framework Based on a Hybrid Approach: A Case of Leather Industry

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CERTIFICATE OF APPROVAL

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BOARD OF EXAMINERS

1. Dr. Syed Mithun Ali — Chairman (Supervisor)
   Associate Professor
   Department of Industrial and Production Engineering
   BUET, Dhaka

2. Dr. Abdullahil Azeem — Member
   Professor
   Department of Industrial and Production Engineering
   BUET, Dhaka

3. Dr. Ferdous Sarwar — Member
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   Department of Industrial and Production Engineering
   BUET, Dhaka

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Md. Rayhan Sarker

This Work is Dedicated to My Parents

Table of content

Table of content

List of Figures

List of Tables

Nomenclature

BNP	: Best Non-Fuzzy Performance
BSC	: Balanced Scorecard
DEMATEL	: Decision Making Trial and Evaluation Laboratory
EPB	: Export Promotion Bureau
FAHP	: Fuzzy Analytic Hierarchy Process
FAN	: Fuzzy Analytical Network
FIS	: Fuzzy Inference System
FMCDM	: Fuzzy Multi-criteria Decision Making
LCA	: Life Cycle Assessment
RASM	: Rapid Sustainability Assessment Method
SAW	: Simple Additive Weighting
SWARA	: Step-wise Weight Assessment Ratio Analysis
TOPSIS	: Technique for Order of Preference by Similarity to Ideal Solution
VIKOR	: VlseKriterijumska Optimizacija I Kompromisno Resenje
$\tilde{a}_{ij}$	: Triangular Fuzzy Number of Criterion i to Criterion j
$\lambda_{\max}$	: Eigen Value of the Comparison Matrix
$\tilde{a}_{in}$	: Fuzzy Comparison Value of Criterion i to Criterion n
$\tilde{r}_i$	: Geometric Mean
$\tilde{w}_i$	: Fuzzy Weight
$\tilde{E}_{ij}^{k}$	: Fuzzy Performance Evaluation by Evaluator k of Alternative i Under Criterion j
$\tilde{E}_{ij}$	: Average Fuzzy Judgment Value
d_i^*	: Positive Ideal Solution
d_i^-	: Negative Ideal Solution
C_i^*	: Relative Closeness to the Ideal Solution
S_i	: Maximum Group Utility Value
R_i	: Minimum Individual Regret Value
Q_i	: Gap from Ideal Solution

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Abstract

In today's world, sustainability is not an option but rather a necessity for any business entity. In the literature, several sustainability assessment models have been proposed based on the economic, social, and environmental dimensions of sustainability. However, it is challenging for practitioners and researchers to assess the sustainability of an organization in a way that reflects all of these dimensions. Accordingly, using the leather industry in Bangladesh as a case study, this study proposes a sustainability performance evaluation model integrating the Balanced Scorecard (BSC) perspective and the Fuzzy Multiple Criteria Decision Making (FMCDM) approach. As a first step, we create a list of 21 indexes of sustainability, based on four BSC-based dimensions derived from the literature and experts' inputs. Then, we estimate the relative weight of each sustainability index using a model based on the Fuzzy Analytic Hierarchy Process (FAHP). Results indicate that the top five important indexes of sustainability are customer satisfaction, customer retention rate, investment in energy-conservation and emission-reduction technologies, sales revenue from green product, and the efficiency of effluent treatment plant. To demonstrate our approach, we evaluate the sustainability performance of three illustrative companies from the leather industry 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). Comparing the performance of the three companies, we highlight strategies for improving their sustainability performance. We thereby show that the proposed model can be an appropriate tool for industrial managers seeking to evaluate the efficacy of their sustainability strategies to gain a competitive advantage.

Chapter 1

Introduction

1.1 Introduction

Today, depletion of natural resources, energy consumption, and environment pollution are deteriorating human ecosystems with the progress of industrial development (Szilagyi et al., 2018). Industries such as leather, textiles, cosmetics, plastics and pharmaceuticals are the major contributors of environmental pollution. As such, industrial managers are constantly facing challenges to balance their economic performance with social and environmental contributions with an aim to achieve sustainability in their firms (Marshall et al., 2015). Therefore, introducing sustainability issues can achieve competitive advantage to firms (Chang et al., 2019; Cui et al., 2019; Glavič & Lukman, 2007; Hansen & Schaltegger, 2016; Kuhlman & Farrington, 2010). While business firms are becoming more interested in adopting sustainability in supply chains, industrial managers need new tools and measures of sustainability performance so that they can identify the achievement and gaps towards sustainable business ecosystems.

Traditional performance assessment system mostly includes financial measures and ignores non-financial measures (Eberl & Schwaiger, 2005; Hafeez et al., 2002). In 1992, Kaplan & Norton, introduced a performance measuring perspective that removes the barriers of traditional system; the perspective is known as Balanced Scorecard (BSC) which combines both financial and non-financial factors for performance management system (Busco & Quattrone, 2015; Chofreh & Goni, 2017; S. Lee & Seo, 2016; Modak et al., 2017; Rafiq et al., 2020; Varmazyar et al., 2016). Since many social and environmental attributes of sustainability are non-financial, the BSC approach can be an appropriate tool for measuring sustainability for any kind of organization (Schaltegger & Wagner, 2006). Moreover, performance assessment includes the identification of relevant weight of performance indexes and to evaluate these indexes by experts that are generally incommensurable and fuzzy in nature. In addition, the experts have different perception about each index and distinct performance rating for an organization. Therefore, sustainability performance assessment comprises uncertainties such as fuzziness and interval data that can be resolved by fuzzy logic based methods. Hence, this research adopts fuzzy multiple criteria decision making tools (FMCDM) along with BSC approach to develop a sustainability performance assessment framework. This framework has been tested with the data from the leather industry of Bangladesh. The leather manufacturing industry is known as one of the most hazardous industries in the world due to its negative impacts towards environment. In Bangladesh, this industry has been facing vulnerable conditions due to a lack of strict environmental regulations and compliance practices. According to the Export Promotion Bureau (EPB) of Bangladesh, the second export-earning leather sector gained $797.6 million in the last fiscal year 2019-2020 that witnessed a 21.79% fall than that of previous year (World Footwear, 2020). Meanwhile, better adaptation of sustainable practices can boost the industry’s future growth and to ensure better acceptability in international markets. Thus, the leather industry has been selected as a real life case to investigate the applicability of the proposed sustainability performance framework.

1.2 Objectives of the thesis

The main aim of the study is to develop a framework to assess sustainability performance in the context of the leather industry. This study also attempts to fulfill the following research objectives.

1. To identify the indexes for sustainability performance measurement of 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.

1.3 Scope of the thesis

The thesis is organized into six chapters including this one. The chapters are structured in the following way.

Chapter 1 represents the introduction and objectives of the study.

Chapter 2 presents the literature review on sustainability, performance assessment and Balanced Scorecard (BSC), sustainability assessment, application of MCDM tools, indexes of sustainability assessment, and research gap and contribution.

Chapter 3 presents the research design and solution methodology. FAHP (Fuzzy Analytical Hierarchy Process), Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution Method), and Fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) solution methodologies are presented in this chapter.

Chapter 4 describes a real case application of Bangladeshi leather processing factory for modeling a sustainability performance assessment framework. Data collection, and analysis are presented in this chapter.

Chapter 5 incorporates results, discussion, and implications on findings of this study.

Finally, conclusions, and future works are presented in Chapter 6. References and appendix are presented at the end of the thesis.

Chapter 2

Literature review

Firstly, this chapter provides a general concept about sustainability, performance assessment, and Balanced Scorecard. Then, it represents an extant literature review on sustainability assessment framework, application of MCDM tools, and indexes of sustainability under BSC dimensions. This chapter helps us to find out research gaps and the areas to be contributed.

2.1 Sustainability

The term sustainability has gained great attention to governments, researchers, environmentalists and economists in this 21st century all over the world. 17 Sustainable Development Goals (SDGs) along with 169 objectives were set up in 2015 Paris Agreement by the General Assembly of the United Nations (UN) (United Nations, 2015), to ensure the world economic prosperity, social equity and environmental quality simultaneously within 2030 (Pradhan et al., 2017). Therefore, industrial managers are opted to think about their strategies on achieving sustainability in order to meet SDGs. The most accepted definition of sustainable development was introduced by the World Commission on Environment and Development (WCED), a UN body: "Sustainable development is economic growth that meets the needs of present without compromising the ability of future generations to meet their own needs" under the Brundtland Commission's Our Common Future report of 1987 (WCED, 1987). Husgafvel et al (2013) defined sustainable development which aims is to integrate environmental, economic and social accounts. Sustainable development can guarantee the protection of the environment and resources today and tomorrow. It is also one that is self-sustaining and meets the needs of present and future generations (Abiona & Bello, 2013). Sustainability is a need that is an aggregation of the needs and requirements of various stakeholders such as customers, local communities, government, environmentalists, public and investors. In this line of thought, the Triple Bottom Line (TBL) (see Fig. 1.1.) is the most prominent framework of sustainability that focuses on economic, social and environmental values of sustainability (Elkington, 1998), adapted in this study under BSC dimensions.

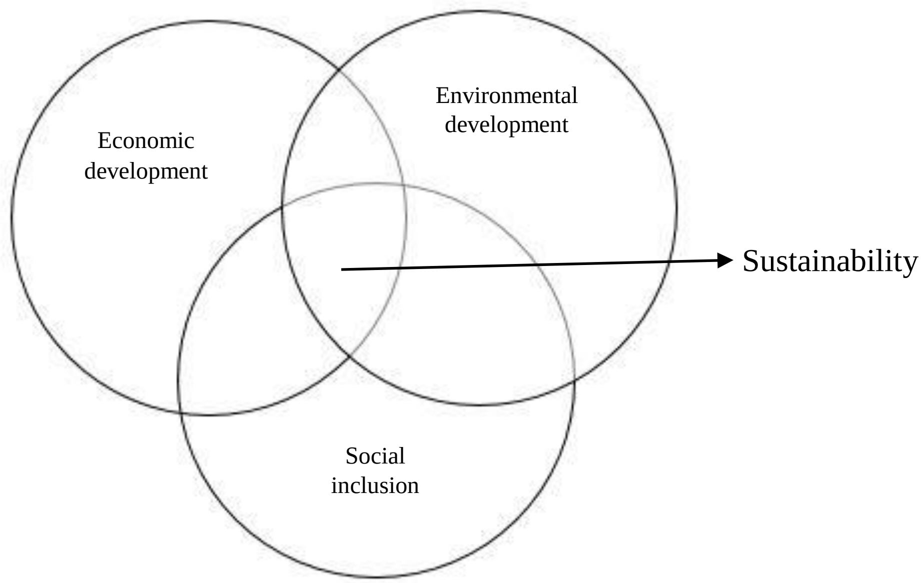

Fig. 1.1: Triple Bottom Line (TBL) framework of sustainability.

2.2 Performance assessment and Balanced Scorecard (BSC)

Performance is defined to as the measurement of the goals of a business entity, while assessment is referred to as the goals that an entity can effectively gain during a planned time (Lebas, 1995). Performance assessment helps industrial managers to investigate whether resources are allocated properly and assists them to establish a decision making and communication process for continual improvement. Traditional performance evaluation systems only measure financial indexes, physical, and tangible assets avoiding other intellectual, and intangible assets of an organization. Since performance assessment factors are multidimensional, only financial measures can't reflect all domains of a business entity. For example, it is difficult to measure product quality, customers' satisfaction, process quality and organizational learning etc. from financial perspective (Möller & Schaltegger, 2005). Therefore, including of both financial and non-financial parameters is important in case of performance assessment for any business. The Balanced Scorecard (BSC) approach has been proposed by Kaplan and Norton in 1992 for performance assessment system that combines both financial and non-financial measures (Kaplan & Norton, 1992).

The BSC is an important tool that can be applied to evaluate performance for any kind of business organization. The name balanced defines that Balanced Scorecard approach (BSC) balances between financial and non-financial measures. It will help industrial managers not only to focus on improving the performance but also provides insights to them on an organization's health (Wu et al. 2009). The BSC approach comprises four dimensions namely finance, customer, internal business process, and learning and growth to measure an organization's performance. Firstly, financial perspective measures the performance of a firm based on financial aspect such as profitability, revenue growth, cost reduction and return on investment etc. Secondly, customer perspective focuses on various aspects (i.e., customer satisfaction, customer increasing rate and profit per customer etc.) of target customer group that facilitates an organization to achieve financial goals. Thirdly, internal business process discovers the core processes (i.e., innovation, services and efficiency etc.) of a business entity that helps a firm to achieve its objectives efficiently and satisfy its customers, and all stakeholders. Fourthly, learning and growth focuses on sustaining the ability of a firm to achieve its vision for improvement that comprises internal skills, capabilities and technical infrastructure. Many researchers have adopted the BSC model to assess the performance of an organization, and for decision making problems. H. Y. Wu et al. (2009) used the BSC model for measuring the performance of three banks. Bentes et al. (2012) assessed the performance of a Brazilian telecom company using the BSC approach. In addition, Modak et al. (2017) investigated the outsourcing performance assessment of Indian coal mining organization following the BSC model. Moreover, Lee & Seo (2016), Huang et al. (2011), Kucukaltan et al. (2016), Xu & Yeh (2012), Khan et al. (2011), Ilmari Rautiainen (2009), and Cho & Lee (2011) applied the BSC perspective in different decision making problems.

Malmi (2001) has identified five reasons to adopt the BSC approach: (1) to convert strategy into action; (2) to manage quality programs; (3) to support change agendas; (4) to follow managerial fads and fashion and (5) to avoid traditional budgeting. The BSC approach facilitates an organization to design, communicate and materialize its strategy. The BSC is a systematic approach which integrates intangible and physical assets into a comprehensive model that purposes is to formulate a hierarchic system of strategic objectives in the context of four perspectives, aligned towards the financial perspective.

After reviewing existing literature, it can be ascertained that BSC is an appropriate tool to evaluate performance of an organization. There has been no application of BSC approach in the leather industry for performance assessment. So, this study investigates the appropriateness of BSC perspective to assess sustainability performance of the leather industry.

2.3 Sustainability assessment (SA) framework

Manufacturing firms are continuously facing pressure from environmental legislation bodies, stakeholders and buyers to ensure sustainability. Therefore, it has become necessary to measure a firm's sustainability performance. In recent years, SA framework has been identified as an important tool for any kind of business organization. Many researchers have found this scope of work very interesting. We have found several literatures about the development of SA framework. There are several methods to assess sustainability performance including conceptual research, empirical research, peer review, survey, case study, or hybrid method. Many researchers have focused on environmental sustainability and a few researchers have focused on social sustainability (Andersen et al., 2020; Digalwar et al., 2020). On the contrary, many researchers developed SA framework including economic, environmental, and social aspects of sustainability (Nicoletti Junior et al., 2018; Sangwan et al., 2018; S. Singh et al., 2018). Besides, sustainability balanced scorecard (SBSC) has been introduced by many researchers to measure the performance of sustainability, integrating economic, environmental, and social dimensions of sustainability with four perspectives of BSC (Boerrigter, 2015; Figge et al., 2002; Nikolaou & Tsalis, 2013). Various types of tools such as RASM, LCA, FAN, SWARA, FIS, DEMATEL, Grey theory, and machine learning were used by many researchers to develop SA framework (Abdella et al., 2020; Akhanova et al., 2019; Andersen et al., 2020; Cui et al., 2019; Karaca et al., 2020; S. Singh et al., 2018). We highlight recent development in SA literature in Table 2.1.

Table 2.1: Research on sustainability assessment.

Authors	Nature of the contributions	Findings	Methods	Context
Karaca et al. (2020)	Development of sustainability model using stakeholders' perceptions and opinions for building performance evaluation	The priority order of sustainability dimensions is Environmental, economic, and social and functional respectively. Indoor air quality, Natural ventilation, and Heat loss/Insulation are the top 3 indicators respectively among 32 sub-indicators of building sustainability.	RASM	Construction industry for Kazakhstan
Abdella et al. (2020)	Development and assessment of a sustainability food consumption model	80% of total carbon foot prints come from the food supply chain. The most important environmental impact indicators are animal slaughtering, rendering, and processing.	Machine learning techniques: k-means clustering and logistics regression	Food industry for U.S.
Andersen et al. (2020)	Assessment of environmental sustainability	Reduction of energy consumption, recycling and reusing of materials are the dominant factors to achieve environmental sustainability.	LCA	Construction industry for Denmark
Digalwar et al. (2020)	Assessment of social sustainability	Four categories of social sustainability indicators: Work condition, work environment, work safety, and skill development respectively based on their importance.	Survey	Manufacturing industry, India

Table 2.1: Research on sustainability assessment (Continued).

Authors	Nature of the contributions	Findings	Methods	Context
Cui et al. (2019)	Assessment of corporate sustainability using hybrid approach	Socio-environment is the most important aspect among 3 aspects of corporate sustainability. The first three important indexes of corporate sustainability are pollution emission control capability, Investment in energy conservation and emission reduction technologies, and Green product sales revenue among 14 indicators.	Hybrid method that integrates Frequency analysis, Cluster analysis, Grey theory and DEMATEL techniques	High-tech firms for China
Akhanova et al. (2019)	Assessment of building sustainability	The first 3 perspectives are Indoor environmental quality and Building architectural planning solutions quality, Construction site selection and Infrastructure, and energy efficiency criteria among 9 categories. Total 46 sustainability indicators were identified.	SWARA	Construction industry for Kazakhstan
Tseng et al. (2019)	Introduction of a hybrid method to assess corporate sustainability performance	The top 3 aspects are as follows: firm's economic activities, stakeholder management, and operational control among total six aspects. Total 21 sustainability criteria were identified of which manager attitude and behavior, eco-operational process, and legal	FSM, DEMATEL	Textile industry for Taiwanese

Table 2.1: Research on sustainability assessment (Continued).

Authors	**Nature of the contributions**	**Findings**	**Methods**	**Context**
		compliance were first 3 important indexes respectively.		
Nicoletti Junior et al. (2018)	Development of a sustainability model to provide enterprises and managers with an evaluation system for making decisions, and to identify improvement opportunities	12 sustainability indicators from TBL × BSC matrix correlations	Conceptual model	Food and beverage companies for Brazil
Singh et al. (2018)	Assessment of sustainability performance	9 performance indicators under 4 perspectives of BSC. The first three performance indicators were found as customers' satisfaction, annual training hours/employee, and debt ratio.	FAHP, FIS, and BSC	Manufacturing SMEs company for India
Sangwan et al. (2018)	Development of a sustainability readiness assessment model	121 KPIs considering life cycle stages throughout the supply chain, resources, critical factors, and sustainability dimensions. The 3 critical factors of sustainability are sustainable policies, product sustainability, and process sustainability.	Conceptual model	Automotive manufacturing organization for India

2.4 Application of MCDM tools

Many researchers have adopted different types of MCDM tools for assessing performance of an organization, and ranking among alternatives. Dwi Putra et al. (2018) applied FAHP in order to rank the quality of gem stones; Lee et al. (2008) used FAHP from the context of BSC to analyze the performance of IT department in the manufacturing industry in Taiwan; Modak et al. (2017) adopted FAHP along with BSC perspective to evaluate the outsourcing performance of Indian coal mining organization; S. Lee & Seo (2016) ranked the alternatives in the selection of the best cloud service using BSC, fuzzy Delphi method, and FAHP. Dodangeh et al. (2010) and Varmazyar et al. (2016) used TOPSIS technique following BSC approach to rank among alternatives in decision making problems. Saeid Saeida Ardekani, Ali Morovati Sharifabadi (2013) applied FAHP to evaluate each aspect of BSC, and then used VIKOR to rank among ceramic and tile companies. Many studies have followed more than one MCDM tools at a time for measuring the performance of alternatives. Yalcin et al. (2012) used FAHP to compute the weights of the criteria, and then TOPSIS, and VIKOR were used to rank the manufacturing companies in a Turkish industry. H. Y. Wu et al. (2009) assessed the performance of three banks using SAW, TOPSIS, and VIKOR under BSC dimensions. In an another study conducted by Stanujkić et al. (2013) found the performance ranking among Serbian banks using SAW, TOPSIS, and VIKOR. Akcan & Güldeş (2019) solved a supplier selection problem of hospital using SAW and TOPSIS, and disclosed a preference ranking among suppliers. Furthermore, Ameri et al. (2018) identified the prone areas of soil erosion using SAW, TOPSIS, and VIKOR.

There are various MCDM tools in which selection of a suitable method plays an important role in performance assessment. The application of a single MCDM tools in measuring performance of alternatives doesn’t ensure robust result (Akhavan et al., 2015). Hence, many researches have applied several MCDM tools jointly in order to get more accurate final decision; a robust aggregation method is necessary when the number of alternatives increases, to ascertain reliable decisions (Jahan et al., 2011; Pomerol & Barba-Romero, 2000). Therefore, this study proposes the combination of MCDM tools (i.e. SAW, Fuzzy TOPSIS, and Fuzzy VIKOR) to ensure appropriate result in case of sustainability performance assessment of three companies of Bangladeshi leather industry.

2.5 Indexes of sustainability assessment

There are three dimensions of sustainability such as economic, environmental and social. Many researchers have used four perspectives of BSC to incorporate the three dimensions of sustainability (Falle et al., 2016; Hubbard, 2009; Rabbani et al., 2014). The dimensions of sustainability under four perspectives of BSC approach namely financial, customer, internal business process and learning and growth can be described as follows.

2.5.1 Financial perspective

Financial perspective defines how much economic success has been achieved through the transformation of an organization's strategy (Kalender & Vayvay, 2016). It plays a double role: firstly, it represents the economic performance, a strategy is expected to gain. Secondly, it is the end point of cause and effect relationships related with other dimensions of BSC (Figge et al., 2002). It generally covers economic success of an organization that includes revenue growth, return on investment, profit margin and cost reduction etc.; this concept emphasizes on the importance of value drivers for future profitability. From this perspective, sustainability can be defined as staying in business and generating a favorable return for investors.

2.5.2 Customer perspective

Customer perspective identifies the relevant customers and market segments that are related to achieve financial goals of an organization. This perspective identifies customer satisfaction, customer segments, loyalty, acquisition and market share etc. (Soderberg et al., 2011). This field makes it possible to get the products, services and internal processes into line with the requirements of present and future markets. From this view point, sustainability means providing value and satisfy the customers who are conscious about sustainability.

2.5.3 Internal business process perspective

Internal business process focuses on the performance of the key internal processes that drive the business. This domain identifies the internal processes on value creation that enable the firms to meet the requirements of customers in the target markets and those of shareholders through innovation, production, and after sales etc. (Möller & Schaltegger, 2005). From this view point, sustainability includes waste management, materials and energy flow in eco-efficient way.

2.5.4 Learning and growth perspective

Human resources are strategic factor for an organization's success. This perspective focuses on internal skills and capabilities in order to correlate them to the strategic goals of an organization (Figge et al., 2002). In another way, it can be said that this field focuses on the infrastructure required for achieving the goals of other three dimensions of BSC. Qualification, motivation, goal orientation of employees, and information systems are most important in this perspective. From this perspective, sustainability means managing a corporate culture in an organization that will value sustainability.

In this study, we identify twenty-one relevant indexes of sustainability from extant literature review and experts' inputs. Total twenty-one indexes were categorized into four dimensions of BSC which is listed in Table 2.2. The general description of all indexes is attached in Appendix A (see Table A1).

Table 2.2: Indexes of sustainability in the context of Balanced Score Card (BSC) from literature review and experts' feedback.

BSC dimension	Code	Index	Reference
F: Financial	F1	Sales revenue from green product	(Horbach, 2016)
	F2	Return on investment	(H. Y. Wu et al., 2009)
	F3	Net profit margin	(Figge et al., 2002)
	F4	Debt ratio	(Wang & Wang, 2014)
	F5	Investment in energy-conservation and emission reduction technologies	(Hristov et al., 2019)
	F6	Income from recycling goods	Proposed by experts
C: Customer	C1	Customer satisfaction	(Figge et al., 2002)
	C2	Customer retention rate	(H. Y. Wu et al., 2009)
	C3	Customer increasing rate	(H. Y. Wu et al., 2009)
	C4	Increasing the number of green products	(Boerrigter, 2015)
	C5	Profit per customer	(Figge et al., 2002)
I: Internal business process	I1	Reduction of chemical consumption	(Boerrigter, 2015)
	I2	Reduction of greenhouse gas emission	(Zhang et al., 2019)
	I3	Efficiency of effluent treatment plant	Proposed by experts
	I4	Participation of employees in business decisions	(Knoepfel, 2001)
	I5	Innovation process	(Figge et al., 2002)
	I6	Solid waste recycling rate	Proposed by experts
L: Learning and growth	L1	Suppliers' performance	(Boerrigter, 2015)
	L2	Complaints from stakeholders	(H. Y. Wu et al., 2009)
	L3	Workforce diversity	(Boerrigter, 2015)
	L4	Training and skill	(Hoyt & Matuszek, 2001)

2.6 Research gap and contribution

There have been some studies about the development of sustainability performance assessment framework in the field of high-tech firms, banks, SMEs (small to medium size enterprises), semi-conductor industry, manufacturing firms and architectures, mentioned in the previous sections. Most of the studies explored the sustainability performance of an organization focusing on process sustainability, environmental sustainability, corporate sustainability rather than focusing on overall organization's performance. In addition, most of the works considered a few number of indicators that didn't reflect all aspects of sustainability and very few studies comprised too much indicators that made the model too much complex and time consuming. On the other hand, very few researches were conducted in the domain of sustainability of the leather industry, i.e., barriers of sustainable supply chain management for leather industry (Moktadir et al., 2018a), drivers to circular economy of leather industry in Bangladesh (Moktadir et al., 2018b), barriers of green supply chain management implementation (Sarker et al., 2018), traceability of leather shoe supply chain sustainability (Marconi et al., 2017). Moreover, many studies were conducted on treating leather industrial effluent and its impact towards environment sustainability (Abdel-Shafy et al., 2016; Espinoza-Quiñones et al., 2009). Literature unveiled that there was no study in the development of sustainability performance assessment framework for the leather industry, albeit we have found some literature in measuring sustainability for some other industries using different approaches. Furthermore, there was no study about the development of sustainability performance assessment framework integrating BSC into FMCDM. Thus, this study attempts to fill this research gap developing a framework for measuring sustainability performance of the leather industry using a hybrid approach. The leather industry of Bangladesh is the second export earning sector of Bangladesh which enrolls 858,000 employees directly and indirectly (Islam et al., 2019). This industry is considered as an area by the researchers to develop, introduce, and improve of sustainability practices which will guide other industries also. The major contribution of this research work is to find out the most important indexes of sustainability reflecting all the three domains of sustainability (i.e., economic, environmental, and social) from the context of BSC dimensions for the leather industry. Then the priority of sustainability indexes is depicted based on fuzzy weight of each criterion by FAHP. To understand this framework, three companies of the leather industry in Bangladesh are selected to measure their sustainability performance using MCDM tools (i.e. SAW, Fuzzy TOPSIS, and Fuzzy VIKOR).

Chapter 3

Research Design and Methodology

Firstly, this chapter describes the step by step procedures of the research framework. Then the sampling technique of this study for experts' and case companies' selection is presented in this chapter. Finally, we describe the solution methodologies, i.e., FAHP, Fuzzy TOPSIS, and Fuzzy VIKOR for this study.

3.1 Research Design

The aim of the research work was to develop a sustainability assessment framework following BSC approach for the leather industry of Bangladesh. The relevant indexes of sustainability for the leather industry were screened from literature review and experts' feedback. In this research, twenty-eight indexes of sustainability were identified from literature review. After discussion with the experts' panel, twenty-one indexes were selected finally to formulate the framework of sustainability. These twenty-one indexes were categorized into four dimensions of BSC. Then fuzzy comparison matrices were formed among criteria and sub-criteria of sustainability by the experts, followed by checking consistency ratio. FAHP was followed to compute relative weight of each criterion which was further used for computing performance rating of three leather processing companies of Bangladesh using SAW, Fuzzy TOPSIS, and Fuzzy VIKOR respectively.

The proposed research framework is depicted in Fig. 3.1 which is used in this study to reveal the most influential indexes of sustainability and to assess the performance of sustainability for three case companies of the leather industry in Bangladesh.

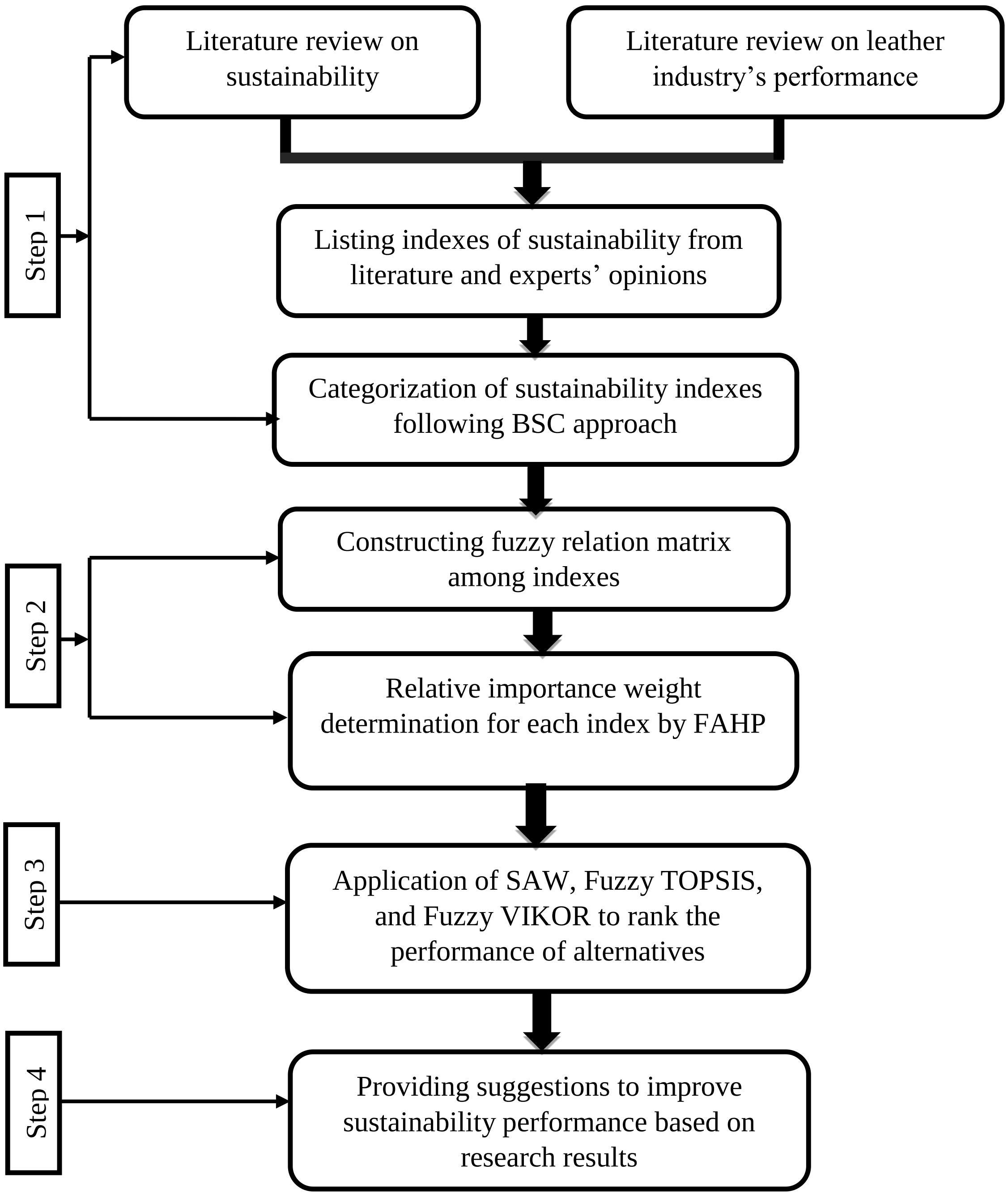

Fig. 3.1: Sustainability assessment framework based on a hybrid approach.

3.2 Case and expert selection

Proper selection of cases plays a vital role in addressing theoretical aspect of problems for a case study. The selection of cases is dependent on a researcher where purposive sampling is adopted rather than statistical sampling (Wagner et al., 1968). The purposive sampling technique is a type of non-probability sampling that is most effective to reach out a targeted sample quickly within the fragment of the population with the most information on the characteristic of interest (Guarte & Barrios, 2006). In purposive sampling, simply, a researcher decides what needs to be investigated and sets out to search expert people who can and are interested to provide the information by their virtue of knowledge and/or experience (Tongco, 2007). The selection of the sampling units in purposive sampling depends on a researcher since the researcher relies on his or her own experience and judgment (Guarte & Barrios, 2006). In this study, we followed purposive sampling where three case companies from the leather industry of Bangladesh, and an expert panel of ten members were selected. The companies were under pressure to practice sustainability, and to improve their sustainability performance. Therefore, the researcher gets an opportunity to explore the sustainability indexes and to develop a framework of sustainability through which a leather processing company can measure its performance. Table A2 in Appendix A presents a brief description of each company.

On the other hand, an expert panel of ten members was formed for data collection purposes. Eight experts were selected from four leading companies of the leather industry. They have working experience of more than 4 years in top management position, and the remaining two experts were from academia who have been doing research in sustainability area for more than five years. The details of the expert panel are attached in Appendix A (see Table A3). However, the name of the experts and the three case companies will not be disclosed in this study to ascertain confidentiality.

3.2 Solution methodology

FAHP, Fuzzy-TOPSIS and Fuzzy-VIKOR methods are described sequentially in this section.

3.2.1 Fuzzy set theory

In our daily life, we use several types of expression such as "not very clear", "probably so", and "very likely" that represent the degree of uncertainty of human thought (H.-Y. Wu et al., 2009). Such type of vagueness and ambiguity in decision making can be solved by fuzzy set theory that was proposed by Zadeh (1965). Fuzzy set theory has been used in various research works as decision making tool in case of uncertainty based information (De et al., 2001; Krohling & de Souza, 2012; McBratney & Odeh, 1997; Rostamzadeh et al., 2015). Therefore, this research included fuzzy set theory into sustainability performance assessment that assessed the evaluators' subjective judgments.

According to classical set theory, the membership function, $\mu_A(x)$ can be denoted as

$$\mu_A(x) = \begin{cases} 1, x \in A \\ 0, x \notin A \end{cases} \quad (3.1)$$

On the other hand, according to Dubois and Prade (1978), fuzzy set A of X is defined by its membership function $\mu_{\tilde{A}}(x)$, $\mu_{\tilde{A}}(x): X \rightarrow [0,1]$ where x symbolizes the criterion and is distinguished by the following attributes: (1) $\mu_{\tilde{A}}(x)$ is a continuous mapping from R (real line) to the closed interval [0, 1]; (2) $\mu_{\tilde{A}}(x)$ is a convex fuzzy subset; (3) $\mu_{\tilde{A}}(x)$ is the normalization of a fuzzy subset which means that there exists a number x_0 such that $\mu_{\tilde{A}}(x_0) = 1$.

Let *Z* be the universal set of discourse, $Z = \{z_1, z_2, z_3, ...z_n\}$. A Fuzzy set "*A* of *Z"* is a set of order in pairs $\{(z_1, f_A(z_1)), (z_2, f_A(z_2)), (z_3, f_A(z_3)), ...(z_n, f_A(z_n))\}$ where $f_A : Z \rightarrow [0,1]$ is the function of *A,* and $f_A(z_i)$ denotes for the membership degree of z_i in *A.*

A tilde '~' over a symbol indicates the symbol of a fuzzy set. TFNs (triangular fuzzy numbers) are easy and realizable for decision making system. A TFN is used when the expert is definitive about a single point representing the total belongingness (Y. Liu et al., 2020). TFNs were used in various fuzzy multi-criteria decision making problems (Erbaş et al., 2018; P. K. Singh & Sarkar, 2019). For this reason, TFNs are used in this study to evaluate the sustainability indexes.

A TFN *M* is given in Fig. 3.2. A TFN is indicated as *(l, m, u)* where *l>m>u*, with *l* as the smallest conceivable value, *m* as the middle value, and *u* as the biggest conceivable value. Each TFN has linear portrayals to its left side and right side with the end goal that its membership function which can be composed as Eq. (3.2).

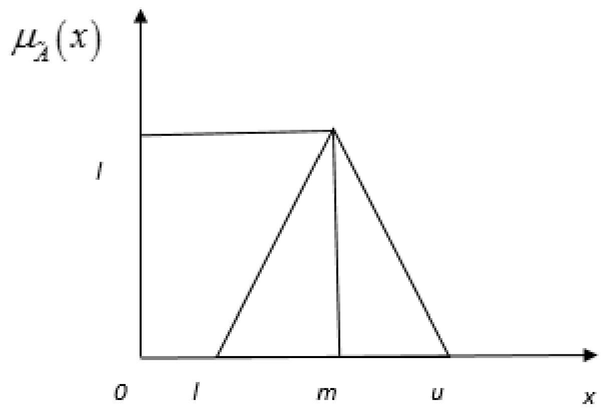

Fig. 3.2: Membership function of the triangular fuzzy number.

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-l)/(m-l) & if\ l \le x \le m. \\ (u-x)/(u-m) & if\ m \le x \le u. \\ 0 & otherwise. \end{cases} \tag{3.2}$$

$Let\ \tilde{G} = (l, m, u)\ and\ \tilde{H} = (o, p, q)$ are two TFNs. Then the basic algebraic operations of TFN are explained as follows.

Addition of a fuzzy number $\oplus$

$$\tilde{G} \oplus \tilde{H} = (l, m, u) \oplus (o, p, q) = (l + o, m + p, u + q) \tag{3.3}$$

Subtraction of a fuzzy number Θ

$$\tilde{G} \Theta \tilde{H} = (l, m, u) \Theta (o, p, q) = (l - o, m - p, u - q) \tag{3.4}$$

Multiplication of a fuzzy number $\otimes$

$$\tilde{G} \otimes \tilde{H} = (l, m, u) \otimes (o, p, q) = (lo, mp, uq) \quad (3.5)$$

Where l > 0, m > 0, u > 0, o > 0, p > 0, q > 0

Division of a fuzzy number $\varnothing$

$$\tilde{G} \varnothing \tilde{H} = \frac{(l, m, u)}{(o, p, q)} = \left(\frac{l}{q}, \frac{m}{p}, \frac{u}{o}\right) \quad (3.6)$$

Where l > 0, m > 0, u > 0, o > 0, p > 0, q > 0

Reciprocal of a fuzzy number:

$$\tilde{G}^{-1} = (l, m, u)^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \quad (3.7)$$

Where l > 0, m > 0, u > 0

3.2.1.1 Linguistic variable

Sometimes, it is very difficult to express those situations that are overtly complex or hard to define; in this regard the concept of linguistic variable is so important. Linguistic variable is an important concept in fuzzy logic and plays a pivotal role in the fuzzy expert system. According to Zadeh (1965), linguistic variables are defined as the variables whose values are words or sentences in a natural or artificial language. In other words, it is a variable made up of a number of words (linguistic terms) with associated degree of membership (Hsieh et al., 2004). In this research, five basic linguistic terms, as “absolutely important,” “very strongly important,” “essentially important,” “weakly important”, and “equally important” with respect to a fuzzy five level scale were used to compare among sustainability indexes in the light of BSC dimensions (see Fig. 3.3). Fuzzy numbers defined by Mon et al. (1994) attached in Table 3.1 were used as computational technique for this study. In Triangular Fuzzy Numbers (TFN), each membership function is represented by the three points of a symmetric triangle such as the left point, middle point and right point. In addition, linguistic variables are used to assess the performance of alternatives by evaluators. In this case, linguistic variables such as “very dissatisfied (0, 20, 40)”, “not satisfied (20, 40, 60)”, “fair (40, 60, 80)”, “satisfied (60, 80, 100)”, and “very satisfied (80, 100, 100)” are used by a triangular fuzzy number within the scale range of 0-100 (see Fig. 3.4).

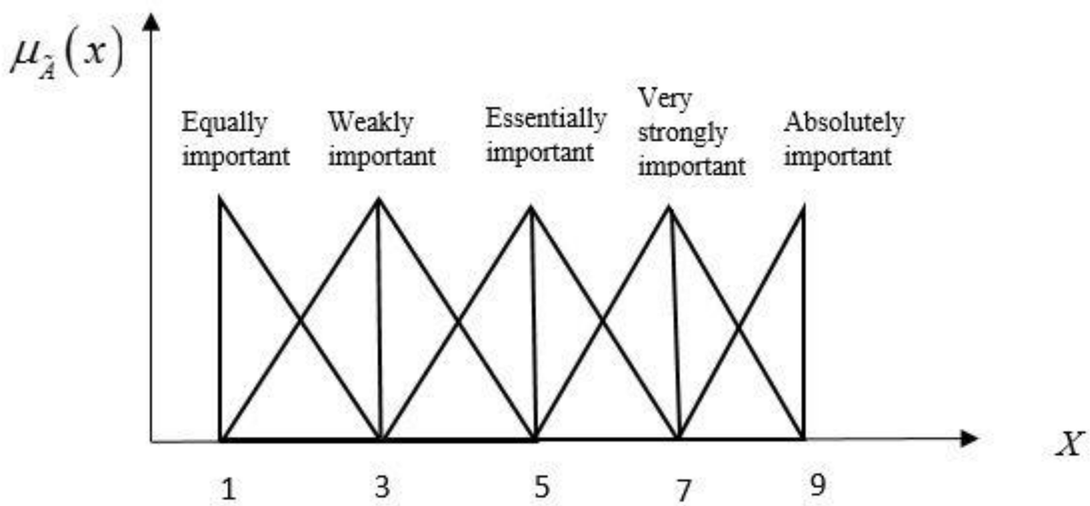

Fig. 3.3: Membership functions of the linguistic variables for criteria comparisons.

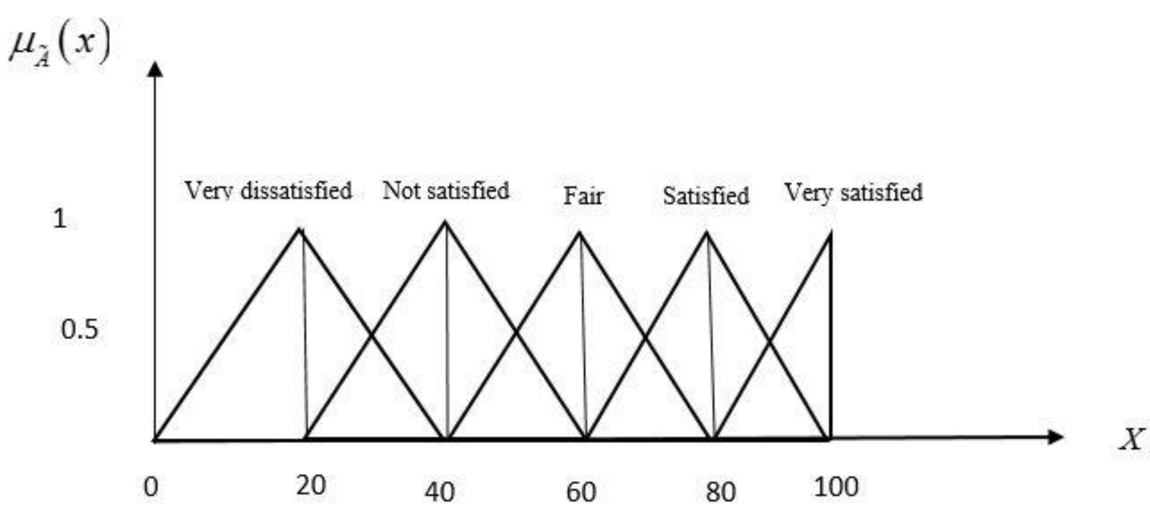

Fig. 3.4: Membership functions of five levels of linguistic scale.

Table 3.1: Membership functions of five levels of the fuzzy linguistic scale for performance assessment.

Notation	Linguistic level	TFN
VS	Very satisfied	(80, 100, 100)
S	Satisfied	(60, 80, 100)
F	Fair	(40, 60, 80)
NS	Not satisfied	(20, 40, 60)
VD	Very dissatisfied	(0, 20, 40)

Table 3.2: Membership functions of the fuzzy linguistic scale.

Fuzzy number	**Linguistic scales**	**TFN ($\tilde{a}_{ij}$)**	**Reciprocal of a TFN ($\tilde{a}_{ij}$)**
$\tilde{9}$	Absolutely important	(7, 9, 9)	(1/9, 1/9, 1/7)
$\tilde{7}$	Very strongly important	(5, 7, 9)	(1/9, 1/7, 1/5)
$\tilde{5}$	Essentially important	(3, 5, 7)	(1/7, 1/5, 1/3)
$\tilde{3}$	Weakly important	(1, 3, 5)	(1/5, 1/3, 1)
$\tilde{1}$	Equally important	(1, 1, 3)	(1/3, 1, 1)
$\tilde{2},\tilde{4},\tilde{6},\tilde{8}$	Intermediate value between two adjacent judgments		

3.2.2 Fuzzy analytical hierarchy process (FAHP)

Saaty (1990) introduced the Analytical Hierarchy Process (AHP) that is an appropriate tool for complex decision making problems to make a choice among several alternatives. The AHP depicts different factors in a hierarchical structure in order to provide a preference list among different choices. This approach uses a nine point scale through which experts provide their feedback about the relative importance of certain criterions (heading factors and sub-factors) with pairwise comparisons (H.-Y. Wu et al., 2009). There are several applications of analytical hierarchy process such as prioritization of risk factors (Nieto-Morote & Ruz-Vila, 2011), selection of best alternatives (Kilincci & Onal, 2011) and optimal allocation of resources (Ergu et al., 2013). The AHP has some drawbacks such as the nine-point scale of judgment is unbalanced and there is an uncertainty and imprecision at the time of preparing pairwise comparisons matrix. To overcome these limitations, Buckley (1985) proposed FAHP, incorporating fuzzy set into AHP. In FAHP, decision makers provide their judgments in interval value rather than fixed values. This study proposes FAHP to distinguish the relative importance of sustainability indexes. The steps of FAHP are described below to find out the evaluation weights.

Step 1: Construct fuzzy pairwise comparison matrices among all the indexes. Every expert is asked to assign linguistic terms following TFN (see Table 3.2 and Fig. 3.3) for constructing the pairwise comparisons among all the indexes in the dimensions of a hierarchy system. The resultant comparison matrices are like as given below (Eq. 3.8).

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \ldots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \ldots & 1 \end{bmatrix} \tag{3.8}$$

Step 2: Investigate the consistency of the fuzzy pairwise comparison matrices. Buckley (1985) proved that if $A = \left[a_{ij}\right]$ is a positive reciprocal matrix then $\tilde{A} = \left[\tilde{a}_{ij}\right]$ is a fuzzy positive reciprocal matrix. If the result of the comparisons of $A = \left[a_{ij}\right]$ is consistent then the results of the comparisons of $\tilde{A} = \left[\tilde{a}_{ij}\right]$ will be also consistent. If $A_{ik} = A_{ij} A_{jk},\ j, k = 1, 2, \ldots, n,$ then the relationship matrix A can be documented as a consistent matrix. Theory suggests that if a comparison matrix with n dimensions is consistent, its maximal Eigen value must be equal to n. But in practically, it is very tough to construct a comparison matrix that will be consistent with matrix. In real cases, various comparison matrix that satisfy the consistency ratio can be defined as consistent matrix. Determination of consistency ratio is a mathematical way to evaluate whether a comparison matrix is consistent or not, as shown in Eq. (3.9).

$$CR = \frac{CI}{RI} \tag{3.9}$$

Where CR denotes consistency ratio, CI denotes consistency index, and RI indicates average random index with the same dimension of matrix A. The value of average random index is obtained from Table 3.3.

Table 3.3: The value of the average random consistency index (RI).

N	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 following Eq. (3.10).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{3.10}$$

Where, $\lambda_{\max}$ symbolizes the maximal Eigen value of the comparison matrix A, and n denotes the dimension of this matrix. If CR < 0.1, then a matrix will be consistent. On the other hand, if CR $\geq$ 0.1, the matrix must be customized.

Step 3: Calculate the fuzzy geometric mean for each indexes. Fuzzy geometric mean can be calculated by Buckley (1985) as follows (Eq. 3.11).

$$\tilde{r}_i = \left[\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{in}\right]^{1/n} \tag{3.11}$$

Where $\tilde{a}_{in}$, is the fuzzy comparison value of criterion i to criterion n and $\tilde{r}_i$ is the geometric mean.

Step 4: Compute the fuzzy weight by normalization. The fuzzy weight of the ith criterion $(\tilde{w}_i)$ can be expressed as Eq. 3.12., where $\tilde{w}_i$ is denoted as $\tilde{w}_i = (L_{wi}, M_{wi}, U_{wi})$ by a TFN, and L_{wi}, M_{wi}, and U_{wi} represent the lower, middle and upper values of the fuzzy weight of the ith criterion.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_n)^{-1} \tag{3.12}$$

3.2.3 The synthetic value of fuzzy judgment

Since there are differences in subjective judgments among decision makers for each index, the fuzzy judgment is followed to synthesize the various decision makers' opinions so that a reasonable and objective evaluation can be achieved. The stages are enlisted below to get synthetic value.

Step 1: Performance evaluation of the alternatives. The performance of the alternatives is measured against five linguistic variables namely "very dissatisfied", "not satisfied", "fair", "satisfied", and "very satisfied". Each linguistic variable is represented by a TFN with a range of 0-100. $\tilde{E}_{ij}^k$ is denoted as fuzzy evaluation of performance provided by the evaluator k towards alternative i under criterion j as Eq. (3.13)

$$\tilde{E}_{ij}^k = (LE_{ij}^k, ME_{ij}^k, UE_{ij}^k) \tag{3.13}$$

Where $\tilde{E}_{ij}$ denotes the average fuzzy judgment values given by m evaluators as represented in Eq. (3.14).

$$\tilde{E}_{ij}^k = (1/m) \otimes (\tilde{E}_{ij}^1 \oplus \tilde{E}_{ij}^2 \oplus \cdots \oplus \tilde{E}_{ij}^m) \tag{3.14}$$

The lower, middle and upper values of three end points of $\tilde{E}_{ij}$ can be calculated as Eq. (3.15).

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^k\right) \Big/ m,\ ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^k\right) \Big/ m,\ UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^k\right) \Big/ m. \tag{3.15}$$

Step 2: Fuzzy synthetic decision. The critical vector $(\tilde{w})$ is derived as Eq. (3.16) based on the fuzzy weight, $(\tilde{w}_j)$ of each criterion computed by FAHP whereas the fuzzy performance matrix $(\tilde{E})$ of all the alternatives can be calculated from fuzzy performance value of each alternative under n criteria as Eq. (3.17).

$$\tilde{w} = (\tilde{w}_1, \ldots, \tilde{w}_j, \ldots, \tilde{w}_n)^t \tag{3.16}$$

$$\tilde{E} = [\tilde{e}_{ij}] \tag{3.17}$$

The final fuzzy synthetic decision can be calculated from the critical weight vector $(\tilde{w})$ and the fuzzy performance matrix $(\tilde{E})$. The derived result $\tilde{R}$ can be computed as given in Eq. (3.18).

$$\tilde{R} = \tilde{E} \Leftrightarrow \tilde{w} \tag{3.18}$$

Where the sign, $\Leftrightarrow$, defines the computation of fuzzy numbers, comprising fuzzy addition and fuzzy multiplication. Since the computation of fuzzy multiplication is rather complex, the approximate multiplied result of the fuzzy multiplication is considered here. $\tilde{R}_i$ is the appropriate fuzzy number as Eq. (3.19), where LR_i, MR_i and UR_i are the lower, middle and upper synthetic values of alternative i, respectively. The calculations are mentioned below as Eq. (3.20).

$$\tilde{R}_i = (LR_i, MR_i, UR_i) \tag{3.19}$$

Where $LR_i = \sum_{j=1}^{n} Lw_j \times LE_{ij}$, $MR_i = \sum_{j=1}^{n} Mw_j \times ME_{ij}$, $UR_i = \sum_{j=1}^{n} Uw_j \times UE_{ij}$. (3.20)

Step 3: Ranking the fuzzy number. The result of fuzzy synthetic decision for each alternative is as fuzzy number that should be defuzzified to make a ranking among alternatives. The defuzzified fuzzy ranking methods include the center of area (COA), the mean of maximal (MOM), and α-cut. The best non-fuzzy performance (BNP) value can be found easily without any need of further preferences from experts. The BNP value can be obtained by using Eq. (3.21).

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i \quad \forall i. \tag{3.21}$$

Then the ranking of the alternatives is derived based on the BNP value of each alternative.

3.2.4 Fuzzy TOPSIS Method

Hwang & Yoon (1981) proposed the Technique for Order Preference by Similarity to Ideal Situation (TOPSIS). TOPSIS is one of the useful Multi Criteria Decision Making (MCDM) tools. According to this technique, the best alternative would be the one that should have the shortest Euclidian distance from the positive ideal solution (aspired/desired level) and farthest from the negative ideal solution (tolerable level). The steps regarding TOPSIS are as follows.

Step 1: Construct the original performance matrix. The structure of the performance matrix (X) is shown in Eq. (3.20). A MCDM problem with m alternatives $\{A_1, A_2, \ldots, A_m\}$ that are evaluated by n attributes $\{C_1, C_2, \ldots, C_n\}$; a decision matrix will be obtained with m rows and n columns as the following matrix where x_{ij} denotes the performance value of i alternative in criterion j.

$$\begin{array}{c} \\ X = \begin{array}{c} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \\ \\ \\ \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & \cdots & C_j & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1n} \\ \vdots & & \vdots & & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & & \vdots & & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix} \\ \begin{array}{ccccc} x_1^* & \cdots & x_j^* & \cdots & x_n^* \end{array} \text{ Aspired level} \\ \begin{array}{ccccc} x_1^- & \cdots & x_j^- & \cdots & x_n^- \end{array} \text{ Tolerable/worst level} \end{array} \tag{3.22}$$

Step 2: Compute the normalized decision matrix. This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. The normalized value of r_{ij} is defined in Eq. (3.23).

$$r_{ij} = \frac{\left|x_{ij} - x_j^-\right|}{\left|x_{ij}^* - x_j^-\right|}, \;\; i = 1, 2, \ldots, m; \;\; j = 1, 2, \ldots, n. \tag{3.23}$$

Step 3: Compute the weighted normalized decision matrix. Assume a set of weights for each criteria w_j such that $W = \{w_j \mid j = 1, 2, \ldots, n\}$. The normalized performance matrix has to be weighted as given in Eq. (3.24), where w_j is the weight of the criterion j, and v_{ij} is the weighted normalized performance matrix.

$$v_{ij} = w_j \times r_{ij}, \;\; i = 1, 2, \ldots, m; \;\; j = 1, 2, \ldots, n. \tag{3.24}$$

Step 4: Determine the positive ideal and negative ideal solutions. The d_i^* and d_i^- are defined as positive ideal solution (PIS) and negative ideal solution (NIS) respectively, in terms of weighted normalized values, as shown in Eqs. (3.25) and (3.26).

Positive Ideal solution:

$$d_i^* = \{v_1^*, \ldots\ldots, v_n^*\}, where \; v_j^* = \max\left(v_{ij}\right) if \; j \in J; \min\left(v_{ij}\right) if \; j \in J' \} \tag{3.25}$$

Negative ideal solution:

$$d_i^- = \{v_1^-, \ldots\ldots, v_n^-\}, where \; v_j^- = \min\left(v_{ij}\right) if \; j \in J; \max\left(v_{ij}\right) if \; j \in J' \} \tag{3.26}$$

Where J is a set of benefit attributes (larger the better type) and J' is a set of cost attributes (smaller the better type).

Step 5: Calculate the separation measures for each alternative.

The separation of each alternative from the positive ideal alternative is d_i^* as given in Eq. (3.27).

$$d_i^* = \sqrt{\sum (v_{ij} - v_j^*)^2} \text{ for i} = 1, 2, 3, \ldots\ldots, \text{m}. \tag{3.27}$$

Similarly, the separation of each alternative from the negative ideal alternative is d_i^- in Eq. (3.28).

$$d_i^- = \sqrt{\sum (v_{ij} - v_j^-)^2} \text{ for i} = 1, 2, 3, \ldots\ldots, \text{m} \tag{3.28}$$

Step 6: Compute the relative closeness to the ideal solution or similarities. Next, the relative closeness of alternative A_i with respect to the ideal solution d_i^* is defined as follows:

$$C_i^* = \frac{d_i^-}{d_i^* + d_i^-};\ 0 \leq C_i^* \leq 1, \text{ for } i = 1, 2, 3, \ldots\ldots, m \quad (3.29)$$

Evidently, $C_i^* = 1$ if and only if $A_i = d_i^*$ and $C_i^- = 0$ if and only if $A_i = d_i^-$.

Step 7: Ranking the preference order.

The best satisfied alternative can now be decided according to preference rank order of C_i^*. Choose an alternative with maximum C_i^* or rank the alternatives according to C_i^* in decreasing order.

3.2.5 Fuzzy VIKOR Method

VIKOR is known as multi-criteria optimization and compromise solution which is an appropriate tool to compare each alternative for every criterion function (Opricovic & Tzeng, 2007; Rostamzadeh et al., 2015). It is a MCDM tool that is based on compromise programming; it measures the closeness to the ideal alternative. The compromising ranking of multi-criteria measure is developed from the L_P-metric that is used as an aggregated function in a compromising programming method (H.-C. Liu et al., 2013; Vinodh et al., 2014). The steps of compromising ranking algorithm are mentioned below.

Step 1: Determine the best (aspired/desired levels) and worst values (tolerable levels). Let, jth criterion denotes a benefit, then the best values for all criteria functions are $\{x_j^* \mid j = 1, 2, \ldots, n\}$ and the worst values are $\{x_j^- \mid j = 1, 2, \ldots, n\}$, respectively.

Step 2: Calculate the differences from ideal alternative $\{S_i \mid i = 1, 2, \ldots, m\}$ and $\{R_i \mid i = 1, 2, \ldots, m\}$ using L_P-metric as Eq. (3.30) through normalization. The relationships are represented in Eqs. (3.31) and (3.32).

$$d_i^p = \left\{ \sum_{j=1}^{n} \left(w_j \frac{\left| x_j^* - x_{ij} \right|}{\left| x_j^* - x_j^- \right|} \right)^p \right\}^{1/p}, \; i = 1, 2, \ldots, m, \tag{3.30}$$

$$S_i = d_i^{p=1} = \sum_{j=1}^{n} \left(W_j \frac{\left| x_j^* - x_{ij} \right|}{\left| x_j^* - x_j^- \right|} \right), i = 1, 2, \ldots, m, \tag{3.31}$$

$$R_i = d_i^{p=\infty} = \max_j \left\{ w_j \frac{\left| x_j^* - x_{ij} \right|}{\left| x_j^* - x_j^- \right|} \middle| j = 1, 2, \ldots, n \right\}, i = 1, 2, \ldots, m, \tag{3.32}$$

Where $S_i, R_i \in [0,1]$ and 0 denotes the aspired/desired level and 1 denotes the worst situations.

Step 3: Calculate the gaps $\{Q_i \mid i = 1, 2, \ldots, m\}$ for ranking. The required equation is given below as Eq. (3.33).

$$Q_i = v \left[\frac{(S_i - S^*)}{(S^- - S^*)} \right] + (1 - v) \left[\frac{(R_i - R^*)}{(R^- - R^*)} \right], i = 1, 2, \ldots, m, \tag{3.33}$$

where $S^* = \min_i S_i$ (the best S^* can be set equal zero), $S^- = \max_i S_i$ (the worst S^- can be set equal one); $R^* = \min_i R_i$ (the best R^* can be set equal zero), $R^- = \max_i R_i$ (the worst R^- can be set equal one), and $v \in [0,1]$ is the weight of strategy of the majority of criteria or the maximum group utility, usually $v = 0.5$. In this study, the values of v were set to equal 0, 0.5, 1 for sensitive analysis.

Step 4: Rank and improve the alternatives according to the values of S, R, and Q, in decreasing order and minimize the gaps among criteria. The three ranking lists are made with the best alternatives having lowest values of S, R, and Q.

Step 5: Suggest a compromise solution. The alternatives $A^{(1)}$, are best ranked for a given criteria weight with minimum Q value if the following two conditions are satisfied.

C1: The alternative $Q(A^{(1)})$ has a satisfactory preferred standpoint if $Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(n-1)$, where $A^{(2)}$ is the option with the second position in the ranking and n is the number of alternatives.

C2. The alternative $Q(A^{(1)})$ must also be the best ranked by S and/or R. The compromise solution is stable within a decision making process when $v > 0.5$ (voting by majority rule), or $v \approx 0.5$ (by consensus), or $v < 0.5$ (with veto).

Step 6: Select the best alternative by picking $Q(A^{(m)})$ as a best trade-off arrangement with the base estimation of Q_i in regards to above conditions.

Chapter 4

Data Collection and Analysis

At the starting of this chapter, we briefly introduce the case leather industry. Then we highlight data collection, and data analysis sections. In data collection section, we describe the step by step procedures for identification of the sustainability indexes, construction of fuzzy comparison matrices, and assessment of sustainability performance of three leather processing companies. In data analysis section, we analyze the data following the described methods in the previous section.

4.1 Industry Background

The required data were collected from the leather industry of Bangladesh. The leather industry in Bangladesh has already been identified as a thrust sector. This is the second export earning sector of Bangladesh which exports various types of product such as finished leather, leather footwear, backpack, wallet, belts, travel bag and ladies bag etc. to the developed countries like China, France, Italy, Germany, USA, UK, Japan, Spain and UAE (Hong, 2018). Moreover, the leather industry is considered as one of the most hazardous industries in Bangladesh due to the uses of different toxic chemicals, disposing of untreated hazardous effluent in the environment, and unhealthy working conditions (Kolomaznik et al., 2008).

Even though, the industry is a major contributing sector to the economy of Bangladesh, it only meets about 0.5% of the total world's leather demand (Sarker et al., 2018). This industry is said to have ample opportunities in contributing towards world market. However, it is not capable of doing so, due to lack of sustainable practices. Therefore, it has become necessary to adopt sustainability practices in the leather industry of Bangladesh for this industry's growth. Since this is a developing country, there are lack of inadequate infrastructure, proper government rules and regulations, and proper investment in adopting sustainability. However, the government of Bangladesh has recently taken an initiative to make a leather industrial park where all leather processing companies will be facilitated under a Common Effluent Treatment Plant (CETP) that will ensure to a large extent of environmental, and social aspects of sustainability. In addition, at present, industrial owners of the leather industry are showing their interests to implement sustainable practices. Therefore, it has become an imperative issue to identify the relevant indexes of sustainability, and to develop a framework so that industrial managers of the leather industry can measure sustainability of their companies.

4.2 Data Collection

In this study, the following three steps were performed for data collection.

Step 1: Total twenty-eight indexes of sustainability were sorted out from literature review. Then the list was provided to the experts' panel in order to establish a final list by adding or removing indexes from literature review based on their opinions. The endorsed list is mentioned in Table 2.2.

Step 2: The fuzzy comparison matrices were constructed among criteria and sub-criteria following linguistic variables (Fig. 3.4) and linguistic scale (see Table 3.1) by the experts' panel. Then consistency ratio (CR) was checked with the help of Eqs. (3.9) and (3.10) to validate the experts' fuzzy matrices which is listed in Table 4.1 - 4.5.

Table 4.1: Fuzzy comparison matrix among four dimensions of BSC.

	F	**C**	**I**	**L**
F	(1, 1, 1)	(0.1, 0.2, 0.3)	(1, 1, 3)	(3, 5, 7)
C	(3, 5, 7)	(1, 1, 1)	(1, 3, 5)	(5, 7, 9)
I	(0.3, 1, 1)	(0.2, 0.3, 1)	(1, 1, 1)	(3, 5, 7)
L	(0.1, 0.2, 0.3)	(0.1, 0.1, 0.2)	(0.1, 0.2, 0.3)	(1, 1, 1)

λ_{max} = 4.159, CI = 0.053, CR = 0.059 < 0.1

Table 4.2: Fuzzy comparison matrix among indexes of financial dimension.

F	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
F1	(1, 1, 1)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(0.2, 0.3, 1)	(1, 3, 5)
F2	(0.2, 0.3, 1)	(1, 1, 1)	(1, 3, 5)	(1, 3, 5)	(0.2, 0.3, 1)	(1, 3, 5)
F3	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(1, 1, 1)	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(1, 1, 3)
F4	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(1, 3, 5)	(1, 1, 1)	(0.1, 0.2, 0.3)	(1, 1, 3)
F5	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(3, 5, 7)	(1, 1, 1)	(1, 3, 5)
F6	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(0.3, 1, 1)	(0.3, 1, 1)	(0.2, 0.3, 1)	(1, 1, 1)

λ_{max} = 6.492, CI = 0.098, CR = 0.079 < 0.1

Table 4.3: Fuzzy comparison matrix among indexes of customer dimension.

C	**C1**	**C2**	**C3**	**C4**	**C5**
C1	(1, 1, 1)	(3, 5, 7)	(5, 7, 9)	(3, 5, 7)	(3, 5, 7)
C2	(0.1, 0.2, 0.3)	(1, 1, 1)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)
C3	(0.1, 0.1, 0.2)	(0.2, 0.3, 1)	(1, 1, 1)	(1, 1, 3)	(1, 3, 5)
C4	(0.1, 0.2, 0.3)	(0.2, 0.3, 1)	(0.3, 1, 1)	(1, 1, 1)	(1, 3, 5)
C5	(0.1, 0.2, 0.3)	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(1, 1, 1)

λ_{max} = 5.368, CI = 0.092, CR = 0.082 < 0.1

Table 4.4: Fuzzy comparison matrix among indexes of internal business process dimension.

I	**I1**	**I2**	**I3**	**I4**	**I5**	**I6**
I1	(1, 1, 1)	(1, 3, 5)	(1, 1, 3)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)
I2	(0.2, 0.3, 1)	(1, 1, 1)	(0.1, 0.1, 0.2)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)
I3	(0.3, 1, 1)	(5, 7, 9)	(1, 1, 1)	(5, 7, 9)	(1, 3, 5)	(3, 5, 7)
I4	(0.1, 0.2, 0.3)	(0.2, 0.3, 1)	(0.1, 0.1, 0.2)	(1, 1, 1)	(0.1, 0.2, 0.3)	(0.2, 0.3, 1)
I5	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(0.2, 0.3, 1)	(3, 5, 7)	(1, 1, 1)	(1, 3, 5)
I6	(0.1, 0.2, 0.3)	(0.2, 0.3, 1)	(0.1, 0.2, 0.3)	(1, 3, 5)	(0.2, 0.3, 1)	(1, 1, 1)

λ_{max} = 6.588, CI = 0.118, CR = 0.095 < 0.1

Table 4.5: Fuzzy comparison matrix among indexes of learning and growth dimension.

L	**L1**	**L2**	**L3**	**L4**
L1	(1, 1, 1)	(5, 7, 9)	(7, 9, 9)	(1, 1, 3)
L2	(0.1, 0.1, 0.2)	(1, 1, 1)	(1, 3, 5)	(0.1, 0.2, 0.3)
L3	(0.1, 0.1, 0.1)	(0.2, 0.3, 1)	(1, 1, 1)	(0.1, 0.1, 0.2)
L4	(0.3, 1, 1)	(3, 5, 7)	(5, 7, 9)	(1, 1, 1)

λ_{max} = 4.096, CI = 0.032, CR = 0.035 < 0.1

Step 3: Three case companies of leather industry were selected to apply the proposed framework of sustainability assessment.

In this step, firstly, four industrial experts (E1, E2, E3, and E4) were asked to provide their feedback on the performance of the three selected companies (A, B, and C) following fuzzy linguistic variable scale (see Table 3.1) which is listed in Appendix A (see Table A4). Then their linguistic ratings were converted into fuzzy triangular number. After that, the performance of three alternatives were evaluated by MCDM tools: SAW, Fuzzy TOPSIS, and Fuzzy VIKOR respectively.

4.2 Data analysis

In this section, we analyzed data obtained from the expert panel using the FAHP, SAW, Fuzzy TOPSIS and Fuzzy VIKOR methods respectively.

4.2.1 Analysis using FAHP

The constructed fuzzy comparison matrices (see Table 4.1 - 4.5) among criteria and sub-criteria of BSC dimensions by the experts' panel were used to find out the fuzzy weight of each criterion using the Eqs. (3.11) and (3.12). In this regard, $\tilde{r}_i$ is the geometric mean was calculated using Eq. (3.11). Fuzzy weight is expressed by a TFN $\tilde{w}_i = (L_{wi}, M_{wi}, U_{wi})$, where L_{wi}, M_{wi}, and U_{wi} represent the lower, middle and upper values of the fuzzy weight of the ith criterion. Best non-fuzzy performance (BNP) and standardized BNP of each criterion were determined in order to identify the relative importance of each criterion which is listed in Table 4.6. The greater the value of standardized BNP of an index, the more important the index is. Therefore, the top five priority indexes of sustainability are found customer satisfaction (C1), Customer retention rate (C2), Investment in energy-conservation and emission reduction (F5), Sales revenue from green product (F1), and Efficiency of effluent treatment plant (I3) based on their standardized BNP values 0.2071, 0.1046, 0.0909, 0.0707, and 0.0657 respectively. The least standardized BNP value is recorded for Workforce diversity (0.0015) which means it is the last important index of sustainability.

Table 4.6: Fuzzy weights of BCS sustainability performance evaluation index by FAHP.

Dimension	Local weight	Index	Local weight	Overall weight	BNP	STD BNP	Rank
F (Financial)	(0.114, 0.225, 0.538)	F1	(0.056, 0.242, 0.839)	(0.006, 0.054, 0.451)	0.171	0.071	4
		F2	(0.047, 0.193, 0.687)	(0.005, 0.043, 0.369)	0.139	0.058	7
		F3	(0.030, 0.060, 0.305)	(0.003, 0.014, 0.164)	0.060	0.025	14
		F4	(0.038, 0.106, 0.432)	(0.004, 0.024, 0.233)	0.087	0.036	10
		F5	(0.086, 0.326, 1.068)	(0.010, 0.073, 0.575)	0.219	0.091	3
		F6	(0.024, 0.073, 0.229)	(0.003, 0.016, 0.123)	0.047	0.020	15
C (Customer)	(0.221, 0.499, 1.044)	C1	(0.214, 0.496, 1.154)	(0.047, 0.247, 1.204)	0.500	0.207	1
		C2	(0.059, 0.220, 0.608)	(0.013, 0.110, 0.635)	0.252	0.105	2
		C3	(0.047, 0.118, 0.380)	(0.010, 0.059, 0.396)	0.155	0.064	6
		C4	(0.038, 0.119, 0.310)	(0.008, 0.059, 0.324)	0.131	0.054	9
		C5	(0.025, 0.047, 0.161)	(0.006, 0.024, 0.168)	0.066	0.027	13
I (Internal business process)	(0.100, 0.229, 0.475)	I1	(0.095, 0.258, 0.705)	(0.010, 0.059, 0.335)	0.1343	0.056	8
		I2	(0.041, 0.150, 0.433)	(0.004, 0.034, 0.206)	0.0813	0.034	11
		I3	(0.145, 0.344, 0.806)	(0.015, 0.079, 0.382)	0.1585	0.066	5
		I4	(0.017, 0.032, 0.097)	(0.002, 0.007, 0.046)	0.0184	0.008	19
		I5	(0.053, 0.143, 0.403)	(0.005, 0.033, 0.191)	0.0764	0.032	12
		I6	(0.025, 0.073, 0.218)	(0.003, 0.017, 0.104)	0.0409	0.017	16
L (Learning and growth)	(0.031, 0.048, 0.089)	L1	(0.286, 0.475, 0.815)	(0.009, 0.023, 0.072)	0.0346	0.014	17
		L2	(0.046, 0.115, 0.242)	(0.001, 0.006, 0.021)	0.0095	0.004	20
		L3	(0.029, 0.042, 0.087)	(0.001, 0.002, 0.008)	0.0035	0.002	21
		L4	(0.191, 0.369, 0.666)	(0.006, 0.018, 0.059)	0.0276	0.011	18

BNP (Best non-fuzzy performance) $= \left[(U-L)+(M-L) \right] / 3 + L.$ $STD\_BNP:$ Standardized BNP

4.2.2 Analysis using SAW

Three alternatives (e.g. A, B, and C company) were taken as for illustrative example and were examined by the experts' panel based on the sustainability evaluation indexes under four dimensions of BSC. In this study, the five linguistic variables, "very satisfied", "satisfied", "fair", "not satisfied", and "very dissatisfied" were used to measure the performance of three alternatives with respect to evaluation indexes. The average fuzzy judgement values of each sustainability index for the three alternatives are listed in Table 4.7, integrated by various experts following the Eqs. (3.13) - (3.15). Then the final fuzzy synthetic judgement of the three alternatives were evaluated from the fuzzy criteria weights (see Table 4.6) and the average fuzzy judgement values (see Table 4.7) by Eqs. (3.16) - (3.20) which is listed in Table 4.8. The BNP value was calculated using the Eq. (3.21). In 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 132.05, 117.93, and 112.72 respectively. As a result, it can be inferred that the sustainability performance order of the three alternatives is A > B > C.

Table 4.7: Average fuzzy judgement values of each evaluation criteria for three alternatives.

Index	**A**	**B**	**C**
F1	(35, 55, 75)	(20, 40, 60)	(20, 40, 60)
F2	(55, 75, 90)	(40, 60, 80)	(40, 60, 75)
F3	(55, 75, 90)	(45, 65, 85)	(50, 70, 90)
F4	(30, 50, 70)	(40, 60, 80)	(35, 55, 75)
F5	(30, 50, 70)	(15, 35, 55)	(15, 35, 55)
F6	(25, 45, 65)	(15, 35, 55)	(15, 35, 55)
C1	(55, 75, 90)	(45, 65, 80)	(35, 55, 75)
C2	(60, 80, 95)	(45, 65, 85)	(50, 70, 85)
C3	(55, 75, 90)	(55, 75, 90)	(45, 65, 80)
C4	(25, 45, 65)	(15, 35, 55)	(15, 35, 55)
C5	(40, 60, 80)	(35, 55, 75)	(40, 60, 80)
I1	(25, 45, 65)	(15, 35, 55)	(20, 40, 60)
I2	(25, 45, 65)	(20, 40, 60)	(20, 40, 60)
I3	(35, 55, 75)	(25, 45, 65)	(5, 25, 45)
I4	(50, 70, 90)	(40, 60, 80)	(50, 70, 90)
I5	(35, 55, 75)	(25, 45, 65)	(25, 45, 65)
I6	(20, 40, 60)	(20, 40, 60)	(10, 30, 50)
L1	(50, 70, 85)	(45, 65, 85)	(30, 50, 70)
L2	(50, 70, 90)	(30, 50, 70)	(25, 45, 65)
L3	(60, 80, 90)	(45, 65, 85)	(50, 70, 85)
L4	(70, 90, 100)	(55, 75, 95)	(60, 80, 90)

Table 4.8: Fuzzy synthetic performance values for three alternatives by SAW.

Index	**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

4.2.3 Analysis using Fuzzy TOPSIS

Then the fuzzy TOPSIS method was applied to evaluate the alternatives' performance. The performance matrix of the three alternatives integrated by experts was computed by Eq. (3.22) as listed in Table 4.9. The normalized performance matrix was computed by Eq. (3.23) as summarized in Table 4.10. According to the fuzzy weights of the BSC performance evaluation indexes by FAHP as depicted in Table 4.6, the weighted normalized performance matrices were computed by Eq. (3.24) and both positive ideal and negative ideal solutions for the BSC evaluation criteria were summarized in Table 4.11 by Eqs. (3.25) and (3.26). Table 4.12 lists the separation of the positive ideal solution and the negative ideal solution for the three alternatives following Eqs. (3.27) and (3.28). The relative closeness to the ideal solution and performance evaluation were calculated by Eqs. (3.29) and (3.30) which is described in Table 4.13. In Fuzzy TOPSIS method, the value of relative closeness (C_i^*) defines the performance of alternatives. The value of C_i^* denotes how close the performance of an alternative to the ideal solution. Table 4.13 represents the values of the three alternatives such as A (0.8925), B (0.3656), and C (0.1568). Therefore, it can be said that the C_i^* value of A alternative is the most closer to the ideal solution and the C alternative has the largest gap to the ideal solution. So, the sustainability performance ranking of the three alternatives is A, B, and C respectively.

Table 4.9: The performance matrix $\left[x_{ij}\right]_{m\times n}$ of three alternatives.

Index	**A**	**B**	**C**
F1	55.00	40.00	40.00
F2	73.33	60.00	58.33
F3	73.33	65.00	70.00
F4	50.00	60.00	55.00
F5	50.00	35.00	35.00
F6	45.00	35.00	35.00
C1	73.33	63.33	55.00
C2	78.33	65.00	68.33
C3	73.33	73.33	63.33
C4	45.00	35.00	35.00
C5	60.00	55.00	60.00
I1	45.00	35.00	40.00
I2	45.00	40.00	40.00
I3	55.00	45.00	25.00
I4	70.00	60.00	70.00
I5	55.00	45.00	45.00
I6	40.00	40.00	30.00
L1	68.33	65.00	50.00
L2	70.00	50.00	45.00
L3	76.67	65.00	68.33
L4	86.67	75.00	76.67

Table 4.10: The normalized performance matrix $\left[r_{ij}\right]_{m\times n}$ of three alternatives.

Index	**A**	**B**	**C**
F1	1.00	0.00	0.00
F2	1.00	0.11	0.00
F3	1.00	0.00	0.60
F4	0.00	1.00	0.50
F5	1.00	0.00	0.00
F6	1.00	0.00	0.00
C1	1.00	0.45	0.00
C2	1.00	0.00	0.25
C3	1.00	1.00	0.00
C4	1.00	0.00	0.00
C5	1.00	0.00	1.00
I1	1.00	0.00	0.50
I2	1.00	0.00	0.00
I3	1.00	0.67	0.00
I4	1.00	0.00	1.00
I5	1.00	0.00	0.00
I6	1.00	1.00	0.00
L1	1.00	0.82	0.00
L2	1.00	0.20	0.00
L3	1.00	0.00	0.29
L4	1.00	0.00	0.14

Table 4.11: The weighted normalized performance matrix $\left[v_{ij}\right]_{m\times n}$ with the positive ideal solution A^* and the negative ideal solutions A^- by Fuzzy TOPSIS.

Index	**A**	**B**	**C**	A^*	A^-
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 4.12: The separations of the ideal solution d_i^* and the negative ideal solution d_i^- by Fuzzy TOPSIS.

Alternative	d_i^*	d_i^-
A	0.0360	0.2992
B	0.2241	0.1292
C	0.2852	0.0531

Table 4.13: The relative closeness C_i^* to the ideal solution and preference order ranking by Fuzzy TOPSIS.

Alternative	C_i^*	**Rank**
A	0.8925	1
B	0.3656	2
C	0.1568	3

4.2.4 Analysis using Fuzzy VIKOR

Fuzzy VIKOR was used to make an order of performance ranking of the three alternatives based on the fuzzy weights of the BSC dimensions by FAHP which is listed in Table 4.6. Table 4.14 shows the performance matrix given by the Eq. (3.22) with the best value X_j^* (aspired/desired levels) and worst value X_j^- (tolerable/worst levels). The values of S_i and R_i were computed following Eqs. (3.30) – (3.32) which is listed in Table 4.15. Then the value of Q_i is calculated using Eq. (3.33) which is described in Table 4.16. According to Fuzzy VIKOR method, the performance ranking of alternatives is computed following the ascending order of S_i, R_i, and Q_i values. The ascending order of S_i values for the three alternatives is 0.0360 (A), 0.7258 (B), and 0.8760 (C) as well as for R_i values is 0. 0360 (A), 0.1130 (B), and 0.2071 (C). The ascending order was also found similar for Q_i values such as 0.0000 (A), 0.6355 (B), 1.0000 (C). Therefore, it can be inferred from these results that the ranking of sustainability performance of the three alternatives is A, B, and C respectively. In addition, the sensitivity of Fuzzy VIKOR result was checked by Eq. (3.33) for V = 0, 0.5, 1 which is also listed in Table 4.16. Since the ranking of the alternatives was not changed for different V values, it can be said that the result of Fuzzy VIKOR is robust.

Table 4.14: The performance matrix $\left[x_{ij}\right]_{m\times n}$ with the best values x_j^* and the worst values x_j^- by Fuzzy VIKOR.

Index	**A**	**B**	**C**	x_j^*	x_j^-
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 4.15: The values of S_i and R_i by Fuzzy VIKOR.

Alternative	S_i	R_i
A	0.0360 (1)	0.0360 (1)
B	0.7258 (2)	0.1130 (2)
C	0.8760 (3)	0.2071 (3)

Note: ( ) indicates ranking order.

Table 4.16: The values of Q_i with $v = 0, 0.5, 1$ and preference order ranking by Fuzzy VIKOR for sensitive analysis.

Alternative	$Q_i = 0$	$Q_i = 0.5$	$Q_i = 1$
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: ( ) indicates ranking order.

Chapter 5

Results, Discussion and Implications

This chapter is divided into three sections i.e., results, discussions, and implications. In results section, we summarize the study findings. Then results are elaborated and justified by comparing with the previous literature in discussions section. Finally, suggestions and guidelines to industrial managers are highlighted based on the findings of this study in implications section.

5.1 Results

Experts selected finally twenty-one indexes related to measure the sustainability performance of the leather industry from primarily screened twenty-eight indexes by the literature review. According to BSC approach, twenty-one indexes were grouped into four dimensions such as “F: Financial (F1-F6)”, “C: Customer (C1-C5)”, “I: Internal business process (I1-I6)”, and “L: Learning and growth (L1-L4) (see Table 4.6).” According to calculated fuzzy weights, the top five indexes were “C1: Customer satisfaction (0.2071)” > “C2: Customer retention rate (0.1046)” > “F5: Investment in energy-conservation and emission reduction (0.0909)” > “F1: Sales revenue from green product (0.0707)” > “I3: Efficiency of effluent treatment plant (0.0657).” The preference order for the remaining indexes was C3> F2> I1> C4> F4> I2> I5> C5> F3> F6> I6> L1> L4> I4> L2> L3 which is summarized in Table 4.6. This study found three new indexes namely “Income from recycling goods (F6)” under financial perspective, “Efficiency of effluent treatment plant (I3)” under internal business process perspective and “Solid waste recycling rate (I6)” under internal business process perspective by the experts those were not probably found in any other study to assess the sustainability performance for any kind of industry.

Three companies from the leather industry (e.g., A, B, and C company) in Bangladesh were selected to assess their performance of sustainability by the developed framework. Based on the fuzzy weights of the indexes calculated by FAHP, three MCDM analytical tools namely SAW, Fuzzy TOPSIS, and Fuzzy VIKOR were applied to find out the performance ranking of the three companies. At first, the performance ranking order of the three companies using SAW was found as A (132.05) > B (117.93) > C (112.72) that is presented in Table 4.8. Then the relative closeness (C_i*) to ideal solution of each alternative was derived by Fuzzy TOPSIS method that is A: C* = 0.8925, B: C* = 0.3656, and C: C* = 0.1568 (see Table 4.13). The value of C_i^* shows how close the performance of an alternative to the ideal solution. So, the performance order ranking was found A > B > C by Fuzzy TOPSIS method. Similarly, Fuzzy VIKOR was applied to rank the performance of the three companies. According to Fuzzy VIKOR, the performance ranking was found as A (Q_i = 0.0000) > B (Q_i = 0.6355) > C (Q_i = 1.0000) for v = 0.5 that is listed in Table 4.16. The sensitivity of the Fuzzy VIKOR results were checked for v = 0, 0.5, 1 where the ranking was also found similar that is presented in Table 4.16. In this study, we have found that the performance ranking of the three companies was same (A > B > C) by three MCDM tools: SAW, Fuzzy TOPSIS, and Fuzzy VIKOR.

5.2 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 assessment, 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 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 4th most important index among twenty-five criteria for sustainability assessment in their study of the semi-conductor industry. Since the leather industry produces goods whose 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 technology, 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 14^{th} and 10^{th}, respectively, in our analysis.

Internal business processes have received increasing attention from customers, and they, too, figured importantly in our framework for sustainability assessment in the context of the leather industry. In particular, the efficiency of effluent treatment plants is a pivotal factor for the leather industry to achieve environmental sustainability. The importance of ETP plants 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 their study of the 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 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 performance. Pfeffer (2005) described the training and skills of the workforce as a strategic advantage for firms, and Hall & 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 significant role in sustainability. All of these findings support our study results.

The C factory'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 technology, 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 factory 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, I1, I2, I3, I5, and I6, because it has not yet reached the aspired to/desired levels of performance in connection with these indexes (see Table 4.7).

5.3 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 be used to assess organizations' sustainability performance. Several managerial implications can be derived from the results.

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 using energy-saving and emission-reduction technologies, 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 a manufacturing firm. 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 acquire a green image in the business market that will increase its sustainability performance. Therefore, industrial managers should engage in adequate market research to identify customers' needs and use advertisements to make customers aware of green products. They should emphasize designing green products, and adopt policies that will allow them to enlarge the sales channel for those products. In addition, 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 market competitiveness (Dimitrova et al., 2007). To improve the efficiency of the effluent treatment plants of leather-processing companies, industrial managers should take necessary measures based on the following 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 recycled goods. Furthermore, industrial managers should monitor their supplier performance to ensure good quality products, and to resolve all complaints from stakeholders. In addition, proper training in sustainable practices should be provided to the employees of every factory by top management. Moreover, factory managers should compare their organizations' sustainability performance using the proposed assessment framework, minimizing any performance gaps between them and other firms, and thereby gaining a competitive advantage in business.

Chapter 6

Conclusion and Future Works

6.1 Conclusion

The first and foremost contribution of this research was to develop a sustainability performance assessment framework for the leather industry using FMCDM tools with BSC approach which was not found in other studies. This study unveiled the most relevant twenty-one indexes of sustainability through extant literature review and experts' inputs, which can be followed by industrial managers to adopt sustainability practices in the leather industry. 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 desired level of sustainability performance with effective and efficient resource allocation.

Secondly, 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, the 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 indexes of sustainability in this study may be used as reference.

Thirdly, this research model not only provides industrial managers to evaluate their companies' performance of sustainability but also provides an opportunity to compare their performance with other companies. The Fuzzy TOPSIS method provided information to improve the gaps of each criterion of sustainability among alternatives with a view to achieving aspired/desired level of performance.

Finally, the application of BSC model in this research allowed to incorporate diverse perspectives of sustainability indexes, both financial and non-financial measures, which made our research model robust and fit for future research. Our present framework displays to be feasible and effective model for assessing sustainability performance of the leather industry, and it may be applied for other industries also.

6.2 Future works

The development of a sustainability framework is a very complex issue. It is quite difficult to comprise all aspects of sustainability in a single framework. Therefore, there are some limitations of this research which are discussed below with certain scopes of future works.

Firstly, the developed framework in this research included only twenty-one indexes of sustainability from the context of the leather industry of Bangladesh. We have tested our proposed model for the leather industry only. In such conditions, the model will need to be applied to other industries to investigate its broader applicability, and more indexes can be included in the research framework.

Secondly, the performance ranking of the alternatives in this study was found same by three MCDM (i.e. SAW, Fuzzy TOPSIS, and Fuzzy VIKOR) tools, but ranking might be changed by other MCDM tools. Therefore, other MCDM tools can be applied to evaluate the sustainability performance of the alternatives and results can be compared with this study.

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 indexes. Moreover, the decision making trial and evaluation laboratory (DEMATEL) technique can be used to explore causal relationships among sustainability indexes, and thereby build strategy maps.

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Appendix A

Table A1: Description of the performance indexes of sustainability for 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	After-tax profit/loss divided by total cost
3	F3	Net profit margin	After-tax profit/loss divided by total operating revenues
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 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-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 plant	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 process	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	Suppliers' performance	Suppliers' quality and commitment
19	L2	Complaints from stakeholders	Stakeholder criticisms about products and services
20	L3	Workforce diversity	Similarities and differences among employees in terms of race, religion, culture, gender and abilities
21	L4	Training and skill	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 the 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

Table A4: Experts' feedback on the sustainability performance of three alternatives (A, B, and C) in linguistic variable for each index.

Index	E1			E2			E3			E4		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
F1	S	F	F	NS	VD	VD	F	NS	NS	NS	NS	NS
F2	S	F	NS	F	NS	F	VS	S	S	F	F	NS
F3	VS	S	S	F	NS	F	F	F	F	S	S	S
F4	F	F	F	NS	S	F	F	F	F	NS	NS	NS
F5	F	NS	NS	NS	VD	VD	F	NS	NS	NS	NS	NS
F6	F	NS	NS	NS	VD	NS	NS	NS	NS	NS	NS	VD
C1	S	F	F	S	F	NS	VS	VS	S	NS	NS	NS
C2	S	F	S	VS	F	NS	S	S	VS	F	F	F
C3	VS	F	S	F	F	NS	S	S	VS	F	VS	NS
C4	F	VD	NS	NS	NS	NS	NS	NS	NS	NS	NS	VD
C5	F	F	F	F	F	S	F	F	F	F	NS	NS
I1	NS	VD	VD	NS	VD	NS	F	F	F	NS	NS	NS
I2	F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I3	NS	VD	VD	F	F	VD	S	F	NS	NS	NS	VD
I4	S	S	F	F	S	S	S	NS	S	F	NS	F
I5	F	NS	NS	F	NS	NS	F	F	F	NS	NS	NS
I6	NS	NS	NS	NS	NS	VD	NS	NS	NS	NS	NS	VD
L1	NS	NS	NS	S	S	NS	F	F	NS	VS	S	S
L2	NS	F	NS	F	NS	NS	S	F	F	S	NS	NS
L3	F	NS	NS	F	S	VS	VS	F	F	VS	S	S
L4	S	F	F	VS	S	VS	S	S	F	VS	S	VS