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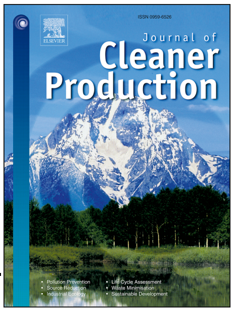

Analysis of Risk Factors in Sustainable Supply Chain Management in an Emerging Economy of Leather Industry

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Analysis of Risk Factors in Sustainable Supply Chain Management in an Emerging Economy of Leather Industry

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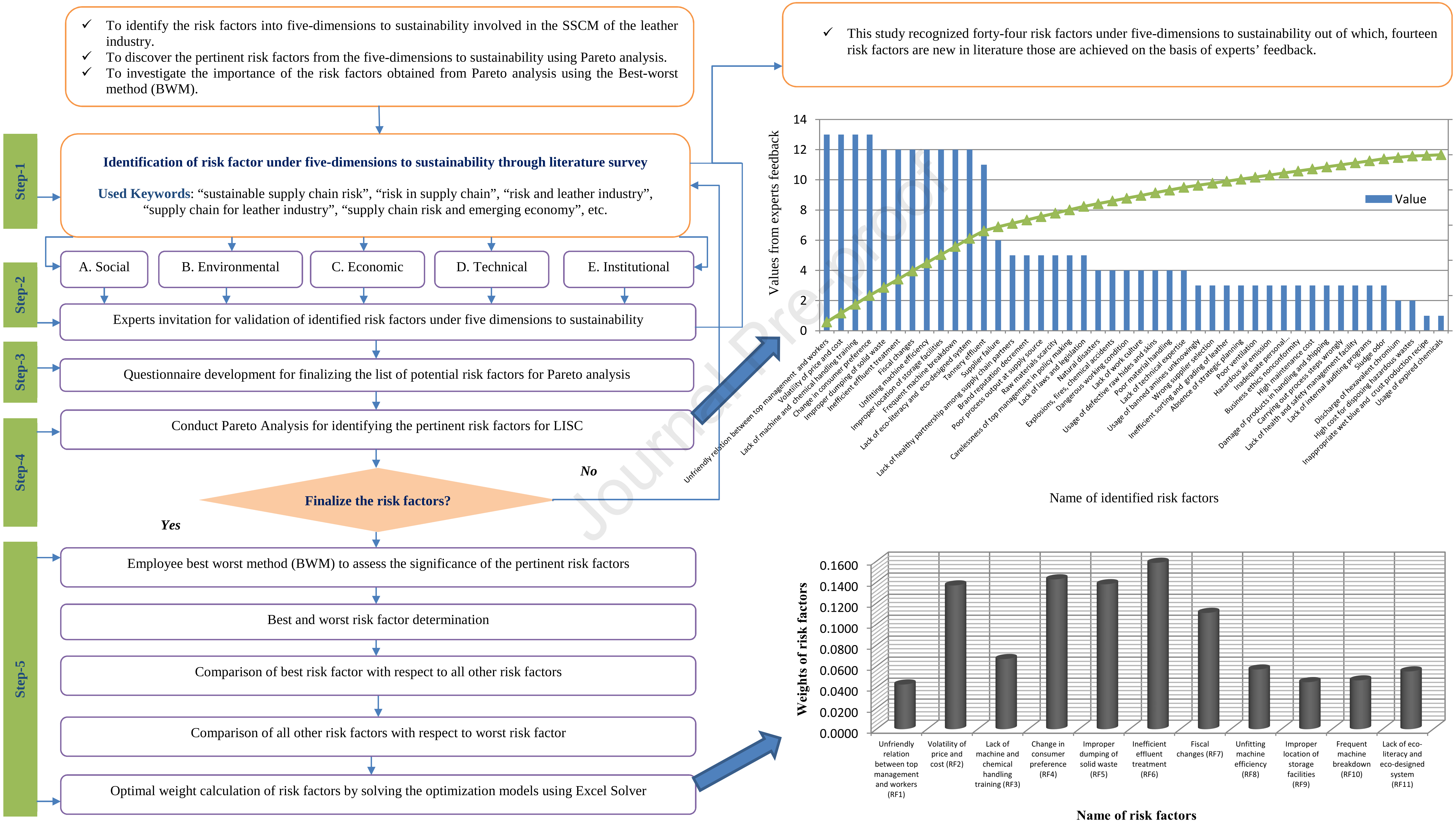
Graphical Abstract



Analysis of Risk Factors in Sustainable Supply Chain Management in an Emerging Economy of Leather Industry

Abstract

In the present competitive business environment and era of globalized marketing, supply chain (SC) of the leather industry is facing a variety of risks. Hence, one of the fundamental concerns in the leather industry supply chain (LISC) is recognizing and prioritizing the various risk factors for attaining sustainability. The present study is an attempt to determine a comprehensive evaluation of SC risk factors considering the case of the leather industry. Based on the literature search and interviews with the domain experts', forty-four risk factors in the context of LISC are identified. The identified risk factors are further segregated into five-dimensions to sustainability (social, environmental, economic, technical, and institutional). A Pareto analysis is performed to discover the most pertinent risk factors. Further, the best-worst method (BWM) is embraced for evaluating the importance of each pertinent risk factor for the decision-making purpose. The findings from the study reflect that 'inefficient effluent treatment', 'change in consumer preference', 'improper dumping of solid waste', 'volatility of price and cost' and 'fiscal changes' are the crucial risk factors that are required to be addressed for the successful execution of sustainable supply chain management (SSCM) practices in an emerging economy context. It is expected that the results and findings will assist the leather industry managers in decision-making for better administration and alleviation of supply chain risks to achieve sustainability.

Keywords: Risk assessment; Best-worst method; Leather industry; Pareto analysis; Sustainable supply chain.

1. Introduction

In the current business situation, many ambiguities affect the business operating environment of an industry. The emergence of globalization, subcontracting, and constantly enhancing the competitive atmosphere has given growth to supply chain management (SCM) problems (Saberi et al., 2019; Dwivedi et al., 2019b). Consequently, industries are enforced to implement advanced methods to improve business performance. To promote the performance of SC, manufacturing firms are continuously focusing on executing different strategies. These strategies can be in the form of SC flexibility, coordination, supplier selection, demand forecasting, and revenue sharing (Shenoi et al., 2018). Supply chain managers place an enormous extent of devotion and determination in successfully instigating SCM practices to endure in the long course and further achieve competitive advantages. Ambiguous working environment and complex interactions between contributing individuals such as manufacturers, suppliers, and retailers have made SC susceptible to numerous risks (Moktadir et al., 2018b).

The risk refers to the possibility of undesirable negative significances from an activity (Giannakis and Papadopoulos, 2016). It can be outlined as a specific expectancy of loss, the superior the possibility that this loss will occur, the larger the risk (Heckmann et al., 2015; Zsidisin, 2003). The risk might be instigated by natural disasters or man-made troubles and can have severe significances for industries in form of financial and operational complications that possibly lead to business interruptions (Rajesh et al., 2015; da Silva et al., 2020). Also, various development in industries such as subcontracting, lowering the supply base, and smaller product life spans have enlarged the industry's acquaintance to SC risks (Trkman et al., 2016). These risks can have a major influence on both the short and long-term performance of the industry. Therefore, effective management of these risks is required in the industry in order to reduce harm.

The leather industry is one of the largest industrial domains in Bangladesh and can be seen as an important originator of the growth of the economy (Moktadir et al., 2018c, 2018d, 2019b). In Bangladesh, the leather industry has been publicized as a prospective segment in the country because of the availability of raw materials and lower manufacturing expense. At present, Bangladesh meets the requirement for around ten percent of the total leather market in the world and exports leather, leather goods and leather footwear to different countries like UK, Australia, South Korea, Germany, China, Japan, US, Spain, Singapore, France and UAE (Moktadir et al., 2018a; Kumar et al., 2020). However, the industry surfaces many difficulties in instigating SSCM practices due to evolving many risks. According to the data of the Export Promotion Bureau (EPB), the export performance of the leather sector has been reduced significantly from July to June of the fiscal year FY2019-2020. The data showed that the export performance of the leather sector in the FY2019-2020 was only 797.60 million US dollar which is far below compared to the last fiscal year's value of 1019.78 million US dollar. A major decline of 21.79 percent export earnings was noticed in the FY2019-2020 from leather, leather goods, and leather footwear sub-sector. The overall contribution to Gross Domestic Product (GDP) of this sector was 2.37 percent for FY2019-2020 (EPB Report, 2020). The data reflects that the leather industry of Bangladesh is confronting a reduction in its export revenue. The evolving risks in the SC of the leather industry impact in executing SSCM practices and can be found as one of the causes for this reduction. Risk management in the context of the LISC is a newly researched domain. Examining risk factors will contribute to the enhancement of sustainable practices and performance in SSCM of the leather industry.

Several studies can be realized from literature related to risk assessment and management of various industries (Mital et al., 2018; Bello et al., 2018; Đurić et al., 2019; Sharma and Bhat, 2012). For instance, Junaid et al., (2020) performed a study for risk investigation in the domain of the automobile industry and used a neutrosophic Analytical Hierarchy Process (AHP) and Technique of Order Preference Similarity to the Ideal Solution (TOPSIS). The outcomes from their study suggested that SC resilience is the most important criteria for managing the SC risks. Similarly, a study was executed for the prioritization of SC risks related to the automotive industry (Bello et al., 2018; Đurić et al., 2019; Sharma and Bhat, 2012). In recent times, Ghadge et al., (2020) reviewed the management process of the climate change risks and evaluated the potential disruptions generated by global warming. Ivanov and Dolgui, (2020) evaluated the conditions enclosing the employment of digital twins when handling the risks in SC and clarified the exposure of interactions among the risk data, disturbance modeling, and performance assessment. Panjehfouladgaran and Lim, (2020) conducted a study to identify risk factors related to reverse logistics and suggested risk mitigation strategies to alleviate risk factors by relying on a supply chain risk management (SCRM) approach. Babu et al., (2020) investigated the interactions among risk factors in Indian manufacturing small and medium enterprises (SMEs) using interpretive structural modeling (ISM) approach and analyzed nine risk factors, in which external, information technology and financial risks were the most influencing risk factors whereas delay and market risks were the most dependent risk factors. Similarly, Birkel et al., (2019) suggested a risk framework considering the sustainability aspects in the context of Industry 4.0. Xu et al., (2019) demonstrated the supply chain sustainability risk under the triple bottom line approach and assessed nine risk factors under three dimensions to sustainability of two case companies from the apparel and automotive industries. Supply chain risk analysis was carried out by Ferreira et al., (2018) considering the case of the shipbuilding industry and they investigated SCRM technologies that serve as a risk management tool for supply chain planning.

Moktadir et al., (2018b) performed a study for modeling the risk factors related to pharmaceutical SCs by adopting the Delphi and AHP techniques. Also, a study related to fuzzy Bayesian network risk analysis was conducted considering the case of pipeline damage (Zhang et al., 2016).

The analysis from the recent studies performed above and related works presented in Section 2.2 reveals that no study exists in the literature that contributes to building a risk evaluation framework for the SSCM of the leather industry. To accomplish this gap, the present study discourses below-mentioned research questions.

(a) What are the risk factors in SSCM of the leather industry?

(b) How these risk factors of leather industry can be assessed?

(c) How will these risk factors be useful in achieving sustainable practices in the leather industry?

(d) How will the crucial risk factors help to endow with practical and managerial insights to the industrial managers?

Investigating the risk factors for the SSCM of the leather industry would result in achieving high performance through weakening vulnerabilities in the SC. To address the research questions, this study offers the following objectives.

- ✓ To identify the risk factors into five-dimensions to sustainability involved in the SSCM of the leather industry.
- ✓ To discover the pertinent risk factors from the five-dimensions to sustainability using Pareto analysis.
- ✓ To investigate the importance of the risk factors obtained from Pareto analysis using the Best-worst method (BWM).

The contributions of this study can be summarized as follows:

(a) This study recognized forty-four risk factors under five-dimensions to sustainability out of which, fourteen risk factors are new in literature those are achieved on the basis of experts' feedback.

(b) A Pareto analysis is performed for obtaining the pertinent risk factors from the five-dimensions to sustainability.

(c) The BWM is proposed for ranking the risk factors obtained from the Pareto analysis. First time, the risk factors associated with the SSCM of the leather industry are examined using the proposed methodology.

(d) An exemplary real-case application of the projected risk assessment model is presented in the context of an emerging economy.

In this study, a Pareto based BWM was used due to some unique characteristics that are: i) Pareto tool helps to identify the pertinent risk factors for leather industry domain with the assistance of experts' feedback (Bajaj et al., 2018), ii) Pareto tool can assist to identify significant risk factors by differentiating vital and nonessential risk factors without any complexity (Kumar et al., 2019), iii) BWM is a ranking method that can aid practitioners and industry experts' to discover the significance of the risk factors with better consistency in results compared to AHP or fuzzy-AHP (Rezaei, 2015; Moktadir et al., 2020a), iv) In BWM, it needs less number of pair-wise comparison matrix (Moktadir et al., 2020b), (v) BWM uses pair-wise comparison scale from 1-9 while AHP uses a scale from 1/9 to 9 (Mi et al., 2019).

The rest of the paper is structured as follows. Section 2 reflects the literature review. The solution methodology has been depicted in Section 3. Section 4 includes the analysis of Pareto and BWM to assess the risks in the leather industry's supply network. The findings of the study along with sensitivity analysis have been reflected in Section 5. Section 6 describes the theoretical and practical implications. Lastly, the research is concluded in Section 7**.**

2. Literature review

Risk is described as the level of disclosure to ambiguities that the industry must comprehend and manage efficiently while implementing strategies to attain business goals and generate value (Tang, 2006; Munir et al., 2020). Also, the risk is termed as the possibility that practical results will not meet expectancies. In this study, the emphasis is done on identifying the risks related to SSCM of the leather industry. To identify and assess the risks, a two-step methodology is adopted. In the first step, an extant literature survey is employed to obtain the SC risks related to the leather industry, and further these risks are confirmed by taking inputs from the industry experts'.

2.1 Risk management

In the business scenario, technological advancements and rapid transformations have led to an expansion in the source of risk. This brings in the need for the proficient management of the risk. Risk management is an organized process that assists industries to understand what is a risk, who is at risk, what are the present regulators for those risks and provisions that must be issued about whether these regulators are adequate or not (Tupa et al., 2017). Risk management refers to plan, monitor, and control events that are based on information resulting from the risk analysis even (Soin and Collier, 2013; Chu et al., 2020). It is a complete process through which the risks are evaluated and managed. Implementing appropriate risk management within the industries has become a legitimate prerequisite above any ethical responsibility to safeguard its employees (Giannakis and Papadopoulos, 2016; Hosseini and Ivanov, 2020). The prime purpose of risk management is to alleviate the susceptibility of a SC. Also, risk management confronts an issue in managing an assembly of risks present within a SC (Tummala and Schoenherr, 2011; Wang and Jie, 2020). To tackle these issues, the risk management process comprises of four basic steps:

(a) The first step is to identify risks that assist to advance a common considerate of future ambiguities enveloping the SC. The objectives of risk identification are to determine significant risks and to distinguish future uncertainties to accomplish them efficiently (Kern et al., 2012). Thus, risk identification desires to adopt a comprehensive method to recognize all possible intimidations and susceptibilities in SC. To originate the progression of risk management, a preliminary evaluation of the current risks must be performed (Neiger et al., 2009). If the risks are identified initially, the possibility of risk can be condensed by taking appropriate measures and facilitating risk management. Risks are identified by adopting various methods such as risk mapping, and risk checklist (Klöber-Koch et al., 2018).

(b) In the second step, risk assessment is carried out. Risk assessment signifies to the allocation of possibilities to risk-origination activities available in the system. It is independent since each forecaster has their own understanding of what comprises a risk and the behavior of downstream and upstream relationships (Gaudenzi and Borghesi, 2006). The assessment of the risk can be performed qualitatively or quantitatively through professional suggestions (Fan and Stevenson, 2018). The influence of risk assessment can be enhanced by blending the data with the instinctive opinion which further leads to a more vigorous form of risks. All identified risks are usually assessed in terms of their probability of existence and influence on SC performance.

(c) Risk management events are implemented in the third step. This step comprises of the risk mitigation measures to effort on the pre-determined risks to minimize the severity of its importance. The choice for a risk mitigation strategy also varies on the category of risk and the organization's financial plan (Sarker et al., 2016). Risks are mostly interconnected with one another, so it becomes necessary to monitor the risks that have negative dependencies (Aqlan and Lam, 2015; Er Kara et al., 2020).

(d) In the fourth step, risk monitoring is performed. Risk is not a stagnant event so it becomes necessary to monitor the appearance of the risk and further suggest changes in the risk treatment strategy if required (Trkman and McCormack, 2009). This step is imperative for the risk management process.

2.2. Relevant works on risk assessment and gaps in the literature

The literature survey performed in the domain of risk management highlights various multi-criteria decision analysis (MCDA) techniques to assess the SC risks. Mokrini and Aouam (2020) used an integrated fuzzy-based MCDA technique to quantify healthcare logistics outsourcing risks. The study was applied to a real case of logistical outsourcing to private service providers in the context of the Moroccan pharmaceutical supply chain. Also, Abdel-Basset and Mohamed, (2020) used plithogenic based TOPSIS and CRITIC methods to assess the SSCM risks in the context of the telecommunication industry. K.T. et al., (2019) assessed the inbound SC risks using a hybrid Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytical Network Process (ANP) based MCDA approach in the domain of electronic SC.

Similarly, Ozturkoglu et al., (2019) employed a fuzzy-based DEMATEL approach to assessing the risk factors in the ship recycling industry. Rezaei et al., (2019) investigated risks in the automotive aftermarket industry using an artificial neural network (ANN) model. Also, Schaefer et al., (2019) proposed the Monte Carlo based AHP model to measure the suppliers' water risk. Further, Wu et al., (2019) demonstrated potential risk factors for electric vehicle SC using a fuzzy synthetic evaluation model. Mithun et al., (2019) investigated the food SC risk factors and obtained the cause-effect interactions adopting the grey-based DEMATEL approach. Also, a literature review on SCRM including risk assessment, treatment, and monitoring was performed by Fan and Stevenson, (2018). Further, Moktadir et al., (2018b) utilized Delphi based AHP approach to assess the risks in the pharmaceutical industry of Bangladesh. Similarly, the identification of best SC subjected to minimum risk was carried out by adopting MCDA techniques in the context of Indian manufacturing industries (Chand et al., 2017). Similarly, identification of risk factors in the SC with the intent of enhancing the customer value was proposed to generate a model for evaluating the social risks along global supply chains considering the case of the automotive industry (Zimmer et al., 2017). Tupa et al., (2017) studied different characteristics of risk management employment for Industry 4.0. The study suggested a framework for the implementation of risk management towards Industry 4.0 concept.

Further, a fuzzy multi-criteria risk management study was performed considering the case of an aluminum industry (Gul and Guneri, 2016). A system dynamic analysis was carried out for risk assessment in the fashion apparel SC industry to understand the effect of lead time and delivery delays on the SC performance (Mehrjoo and Pasek, 2016). Similarly, Giannakis and Papadopoulos, (2016) performed an empirical analysis to generate insights on how to manage risks related to sustainability in an integrated manner. Shenoi et al., (2016) performed risk management in the context of the manufacturing industries in India by adopting Performance and Importance Analysis (IPA) to suggest strategic recommendations for manufacturing industries to improve their SC performance. Rajesh et al., (2015) performed a study to determine the potential enablers to alleviate supply chain risks considering the case of electronic supply chains. The study adopted a combined gray theory and DEMATEL technique to obtain interactions among the enablers to mitigate the risks. Also, a systems method to model the SC risks and their influence on the SC network was discussed (Ghadge et al., 2013). The study suggested a framework for SCRM considering the case of an industrial study. Similarly, a risk management model for the textile industry was studied (Wang et al., 2012a). Thun and Hoenig, (2011) carried out an empirical investigation of SCRM in the automobile industry.

Several studies related to risk identification, assessment, mitigation, and treatment for different industries are analyzed in the literature. Different MCDA techniques are practiced in the literature for evaluating the risks in SC. The literature review confirmed that work on risk assessment focusing on five-dimensions to sustainability in LISC still is a research gap.

Therefore, this study contributes to SCRA literature by identifying risk factors under five dimensions to sustainability and assessed the pertinent risk factors by offering an integrated Pareto based BWM in the unique domain of LISC.

2.3 Five-dimensional sustainability approaches

The conventional sustainability approach covers the three dimensions (i.e. social, environmental, and economic) (Dwivedi et al., 2019a). This model is like a triangular model but unable to deal with the entire systems of the organizations. Therefore, Iddrisu and Bhattacharyya, (2015) invented a five-dimensional sustainability approaches that can shade the social, environmental, economic, technical, and institutional dimensions (see Figure 1). Besides, the authors Valinejad and Rahmani, (2018) also utilized five-dimensional approaches to assess the risk in the telecommunication industry. The five-dimensional sustainability approaches can be explained as follows:

a. Social sustainability: This dimension indicates the social advantages of SC activities. It can help to assess the social acceptance of the system in a society.

b. Environmental sustainability: The environmental sustainability approach efforts on the negative impacts of the activities in an organization.

c. Economic Sustainability: This dimension ensures the economic viability of the systems to encourage the organization to invest in achieving sustainability.

d. Technical sustainability: This dimension helps to check the technical sustainability of the system by considering technical issues. It focuses on the technical structure of an organization along with input and output.

e. Institutional sustainability: This dimension focuses on the management facility and its impacts on sustainability. It includes management systems, training, plan, and strategy, etc.

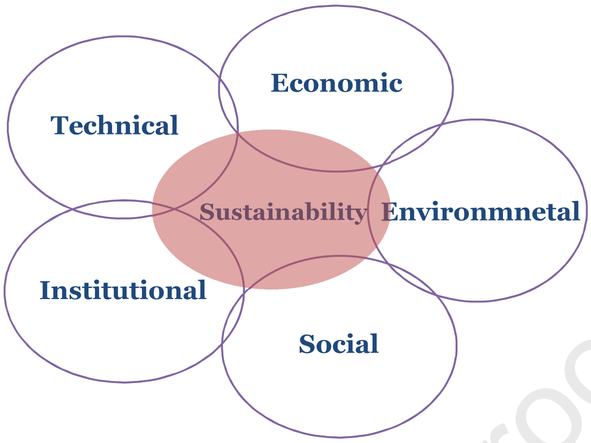


Figure 1: Five-dimensional sustainability approaches

2.4 Supply chain risk in the leather industry

A rigorous and organized literature investigation was conducted in the context of SC risks, management, and assessment of risks and sustainable operations. The literature survey resulted in the identification of thirty potential risk factors related to SSCM of the Bangladeshi leather industry. Table 1 reflects the identified risk factors along with their references. Further, the identified SC risk factors were segregated into five-dimensions to sustainability like social, environmental, economic, technical, and institutional perspectives.

2.4.1 Social dimension related risk factors

Social risk is outlined as an indication of the effect of hazardous industrial events on societies, permitting comparison with the tolerance criteria ultimately suggested by the authorities and organizations (Köksal et al., 2017). It also refers to the possibility that a group of a certain number of people is exposed each year to a victim of a specific accident. In the present study, the risk factors such as dangerous working conditions, inadequate personal protective equipment, unfriendly relation between top management and workers, lack of work culture, lack of healthy partnership among SC partners, and business ethics nonconformity are identified from the literature review and considered under the social dimension.

2.4.2 Environmental dimension related risk factors

Improper disposal of hazardous waste and accidental release of chemicals from the leather industry are some of the factors that contribute towards the degradation of the environment. Also, increased use of industrial chemicals and toxicants pollutes the environment, because of the insufficient environmental management plan in developing countries (Srinivasa Gowd et al., 2010). In this work, the risk factors identified from the literature review such as natural disasters, tannery effluent, poor ventilation, hazardous air emission, discharge of hexavalent chromium, and explosion, fire, chemical accidents are considered under the environmental dimension.

2.4.3 Economic dimension related risk factors

Economic risk factors indicate the possibility that the economic conditions might affect the investment and expectations of the organizations. In the present study, the risk factors identified from the literature review such as volatility of price and cost, absence of strategic planning, lack of laws and legislations, high cost for disposing of hazardous wastes, high maintenance cost, and fiscal changes are considered under the economic dimension based on literature review.

2.4.4 Technical dimension related risk factors

Technical risks refer to the risk factors that are linked with human and organizational errors which affect the interfaces among the human, organization, and technical systems (Verbano and Venturini, 2011). The prime purpose associated with the technical risk factors is to measure the losses that occur due to various processes and system failures. Also, leading accident risks that are caused because of some operational vulnerabilities are included under the domain of technical risks (Yang et al., 2018). In the present study, the eight risk factors such as lack of technical expertise, frequent machine breakdown, damage of products in handling and shipping, poor process output at supply source, change in consumer preference, supplier failure, raw material scarcity, and wrong supplier selection are identified from the existing literature and considered under the technical dimension.

2.4.5 Institutional dimension related risk factors

Institutional risk refers to handling the threats to organizations accountable for the management of societal risk or threats to the legality of procedures in the form of loss of reputation, responsibilities, and bureaucratic failure (Zeng et al., 2017). In this study, risk factors such as carelessness of top management in policymaking, absence of strategic planning, lack of laws and legislations, lack of health and safety management facility, lack of eco-literacy and eco-designed system and lack of internal auditing programs are identified from the literature review and considered under the institutional dimension.

3. Research methodology

In order to attain the research objectives, and to analyze the pertinent risk factors associated in SSCM of the leather industry in an emerging economy, we have followed a systematic research methodology, which is illustrated in Figure 2.

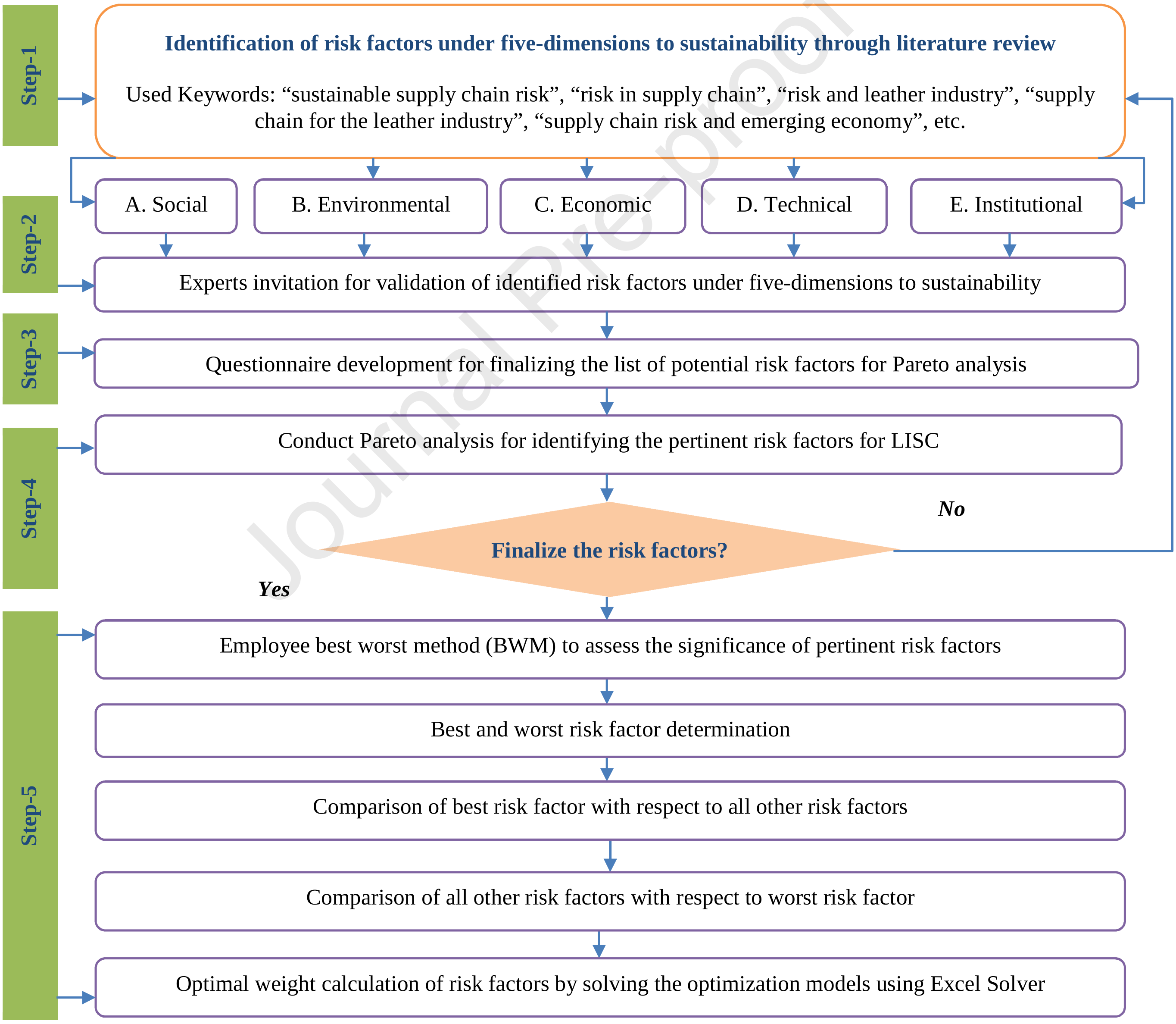


Figure 2: Proposed research methodology

Step 1: Identification of potential risk factors through a literature survey

In this step, a rigorous literature survey is conducted to identify SSCM risk factors that are essential for the leather industry. To identify the potential risk factors, several keywords such as "sustainable supply chain risk", "risk in supply chain", "risk and leather industry", "supply chain for the leather industry", and "supply chain risk and emerging economy", are used to search databases such as the web of science, science direct, and Google scholar. Table 1 shows the identified potential SC risk factors under five-dimensions to sustainability for the leather industry supply chain.

Table 1: Initial identification of risk factors under five-dimensions to sustainability

Dimension to sustainability	**Risk factor**	**Supported references**
A. Social dimension	Dangerous working condition	(Halldórsson et al., 2009), (Song et al., 2017)
	Inadequate personal protective equipment	(Ortolano et al., 2014), (Tafere et al., 2020)
	Unfriendly relation between top management and workers	(Amponsah-Tawiah and Mensah, 2016), (Torabi et al., 2016), (Mithun et al., 2019)
	Lack of work culture	(Torabi et al., 2016), (Song et al., 2017)
	Lack of healthy partnership among supply chain partners	(Awan et al., 2018), (Mithun et al., 2019)
	Business ethics nonconformity	(Roberts, 2003), (Song et al., 2017)
B. Environmental dimension	Natural disasters	(Torabi et al., 2016), (Song et al., 2017)
	Tannery effluent	(Mwinyihija and Mwinyihija, 2010), (Sampaio et al., 2019)
	Poor ventilation	(Dewanti et al., 2018), (Dalju et al., 2019)
	Hazardous air emission	(Brown et al., 2014), (Song et al., 2017)
	Discharge of hexavalent chromium	(Megharaj et al., 2003), (Tseng et al., 2019)
	Explosions, fires, chemical accidents	(Tixier et al., 2002), (Unnikrishnan et al., 2015)
C. Economic dimension	Volatility of price and cost	(Lee and Jang, 2007), (Tang and Nurmaya Musa, 2011), (Song et al., 2017),
	High cost for disposing of hazardous wastes	(Nogueira et al., 2011), (Dües et al., 2013)
	High maintenance cost	(Torabi et al., 2016), (Mithun et al., 2019)
	Fiscal changes	(Becchetti and Sierra, 2003), (Song et al., 2017), (Mithun et al., 2019)
D. Technical dimension	Lack of technical expertise	(Mithun et al., 2019), (Song et al., 2017),
	Frequent machine breakdown	(Mithun et al., 2019), (Moktadir et al., 2018b)
	Damage of products in handling and shipping	(Natarajarathinam et al., 2009), (Lai and Lau, 2012)
	Poor process output at the supply source	(Moktadir et al., 2018b), (Mithun et al., 2019)
	Change in consumer preference	(Shafaei et al., 2009), (Mithun et al., 2019)
	Supplier failure	(Song et al., 2017), (Moktadir et al., 2018b)
	Raw materials scarcity	(Breen, 2008), (Moktadir et al., 2018b)
	Wrong supplier selection	(Song et al., 2017), (Moktadir et al., 2018b)
	Carelessness of top management in policymaking	(Torabi et al., 2016), (Moktadir et al., 2018b), (Mithun et al., 2019)

E. Institutional dimension	Absence of strategic planning	(González-Torre et al., 2010), (Moktadir et al., 2018b)
	Lack of laws and legislation	(Mithun et al., 2019), (Lieder and Rashid, 2016), (Mangla et al., 2015)
	Lack of health and safety management facility	(Halldórsson et al., 2009), (Song et al., 2017)
	Lack of eco-literacy and eco-designed system	(Torabi et al., 2016), (Majumdar and Sinha, 2019)
	Lack of internal auditing programs	(Castanheira et al., 2010), (Ganguly and Kumar, 2019), (Lotto, 2014)

Step 2: Validation of identified risk factor

In this step, the identified risk factors are validated through an expert survey. First, we select experts' who can validate the identified SC risk factors that are essential for the leather industry. The selection process has been done in a very careful manner. We have invited more than fifty experts working in the leather industry by providing a web link (Google survey link) as well as field surveys to identify the potential risk factors. We have received feedback from thirteen experts. The profiles of selected experts are reflected in Table 2.

Table 2: Experts' profiles involved in the validation of identified risks

Expert ID	Industry name	Your working areas	Role	Years of experiences
E1	Footwear	Supply chain management	Assistant manager	15
E2	Footwear	Merchandising	Assistant manager, merchandising	10+
E3	Tannery	Finishing	Senior Manager	20
E4	Footwear	Merchandising	Assistant manager, merchandising	16+
E5	Leather Ltd	Merchandising	Merchandiser	17
E6	Tannery	Supply chain management	Executive	24+
E7	Tannery	Production	Chief production manager	22
E8	Tannery	Production	Executive	21
E9	Tannery	Production	Executive	20
E10	Leather Goods	Merchandising	Merchandiser	15
E11	Leather Goods	Supply chain management	Executive	16+
E12	Footwear	Product development	Executive	17
E13	Educational Institute	Teaching and research	Faculty	6+

Step 3: Questionnaire development

Once the experts are identified to validate the identified potential SC risk factors, we have developed a questionnaire. The questionnaire is designed by considering the identified potential risk factors from the literature review that are essential for the leather industry. Developed questionnaires are given to the experts, as mentioned in Table 2, and requested their opinions. A sample questionnaire can be found in Appendix A. Based on the experts' feedback, we have identified fourteen additional risk factors. We have obtained three risk factors (improper dumping of solid waste, sludge odor, and inefficient effluent treatment) for the environmental dimension. We have not received any new risk factors for social and institutional dimensions. Moreover, we have identified two new risk factors for the economic dimension and nine risk factors for the technical dimension based on experts' opinions. The additional list of identified risk factors related to the LISC is presented in Table 3.

Table 3: Identified additional risk factors related in the LISC based on experts' feedback

Dimension to sustainability	Risk factor	Supported references
B. Environmental dimension	Improper dumping of solid waste	Experts' feedback
	Sludge odor	Experts' feedback
	Inefficient effluent treatment	Experts' feedback
C. Economic dimension	Usage of defective raw hides & skins	Experts' feedback
	Brand reputation decrement	Experts' feedback
D. Technical dimension	Unfitting machine efficiency	Experts' feedback
	Poor material handling	Experts' feedback
	Improper location of storage facilities	Experts' feedback
	Lack of machine and chemical handling training	Experts' feedback
	Inefficient sorting and grading of leather	Experts' feedback
	Inappropriate wet blue and crust production recipe	Experts' feedback
	Carrying out process steps wrongly	Experts' feedback
	Usage of expired chemicals	Experts' feedback
	Usage of banned amines unknowingly	Experts' feedback

Step 4: Most pertinent risk factors identification using Pareto analysis

In this step, a Pareto analysis has been performed to summarize experts' opinions and recognize the pertinent risk factors from the five-dimensions to sustainability that are essential for the leather industry. Pareto chart is a widely used technique and is mainly used to highlight the major problems and help management and decision-makers in the decision-making process (Khan et al., 2019). A Pareto chart is a type of chart that is consists of a bar graph and a line graph. The bar represents the type of attributes that are under consideration. In our case, identified risk factors that are essential for the leather industry are represented as a bar. The line represents the cumulative percentage of the occurrence of the attributes. In our case, the line represents the experts' opinion frequency. In the Pareto chart, the bar is always shown in descending order. This helps to see the most frequent attribute. In our case, it represents the most essential risk factors of the leather industry.

Step 5: Application of the best-worst method

In this step, the ranking of the identified the pertinent risk factors is determined by applying the BWM. BWM is a relatively new method that was developed in 2015 (Rezaei, 2015). After its development, it has been extensively used in various applications such as in supplier development (Rezaei, 2015); sustainable supply chain (Wan Ahmad et al., 2017); logistics (Rezaei et al., 2018); energy (Moktadir et al., 2019a); manufacturing (Moktadir et al., 2018c); transportation (Groenendijk et al., 2018); mining (Sabilla Ajrina et al., 2018); and technology (van de Kaa et al., 2019).

In other MCDA methods (Chowdhury and Paul, 2020), such as AHP, there are several challenges, and inconsistency issues raised in pair-wise comparison that leads to inconsistency (Mi et al., 2019). To overcome this, (Rezaei, 2015) developed the BWM as a new way of doing a pair-wise comparison. In this method, decision-makers have at least a reference that is best or worst and they have to do the only comparison with that reference in the complex decision-making process (Mi et al., 2019). BWM consists of five steps which are as follows (Rezaei, 2015).

- ***i.*** *Set of pertinent risk factors:* In this step, a set of pertinent risk factors from five-dimensions to sustainability that needs to be ranked is identified through Pareto analysis.
- ***ii.*** *Best and worst risk factor determination:* In this step, expert and decision-maker select the best and worst risk factors from the list of identified pertinent risk factors. If there is a tie between two risk factors as the best or worst, it can be chosen arbitrarily. This depends totally on the discretion of the decision-maker.
- ***iii.*** *Comparison of the best risk factor with respect to all other risk factors:* In this step, a pair-wise comparison between the best risk factor B and other risk factors $(j=1,2,\ldots,n)$ is organized and develop a best to others (BO) vector as mentioned in Equation 1.

$$A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn}) \quad (1)$$

Where a_{Bj} denotes the preference degree of the best risk factor B over risk factor j.

iv. *Comparison of all other risk factors with respect to worst risk factor:* In this step, a pair-wise comparison between the other risk factors *(j=1,2,…,n)* and the worst risk factor *W* is prepared and develop others to worst (OW) vector as mentioned in Equation 2.

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW}) \tag{2}$$

Where a_{jW} represents the preference degree of the risk factor j *over* worst risk factor *W*.

v. *Optimal weight calculation of risk factors using the optimization model:* In this step, the weight of each on risk factor is calculated by solving the optimization models presented in Equations (3) and (4). We use Excel solver to solve these optimization models.

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

s.t.

$$\sum_j w_j = 1,$$

$$w_j \geq 0, \text{ for all } j. \tag{3}$$

Model (3) is converted to a linear model and is displayed as:

$$\min \xi^L,$$

s.t.

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

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

$$\sum_j w_j = 1,$$

$$w_j \geq 0, \text{ for all } j. \tag{4}$$

4. Numerical Example

In this section, a numerical explanation of the proposed method has been explained. The model was applied in the LISC of Bangladesh. It is time demanding issues that the leather industry needs to recognize and investigate the sustainable SC risks. Therefore, in this study, the risk factors associated with the leather processing industry have been determined and assessed using the proposed integrated Pareto and BWM. The numerical application of the proposed method has been divided into two phases as follows.

Phase 1: Crucial risk identification using Pareto analysis

In this phase, experts' are asked to ascertain the pertinent risks from five-dimensions to sustainability for the LISC with the help of formulated questionnaires (given in Appendix-A). Based on the experts' feedback, the score for each risk factor, and the cumulative percentage were determined for the Pareto analysis. From the Pareto analysis, it is observed that among the forty-four risk factors, eleven risk factors are responsible for 80% of the risk in the LISC. These risk factors are 'Unfriendly relation between top management and workers', 'Volatility of price and cost', 'Lack of machine and chemical handling training', 'Change in consumer preference', 'Improper dumping of solid waste', 'Inefficient effluent treatment', 'Fiscal changes', 'Unfitting machine efficiency', 'Improper location of storage facilities', 'Frequent machine breakdown', and 'Lack of eco-literacy and eco-designed system'. The result of the Pareto Analysis is shown in Figure 3.

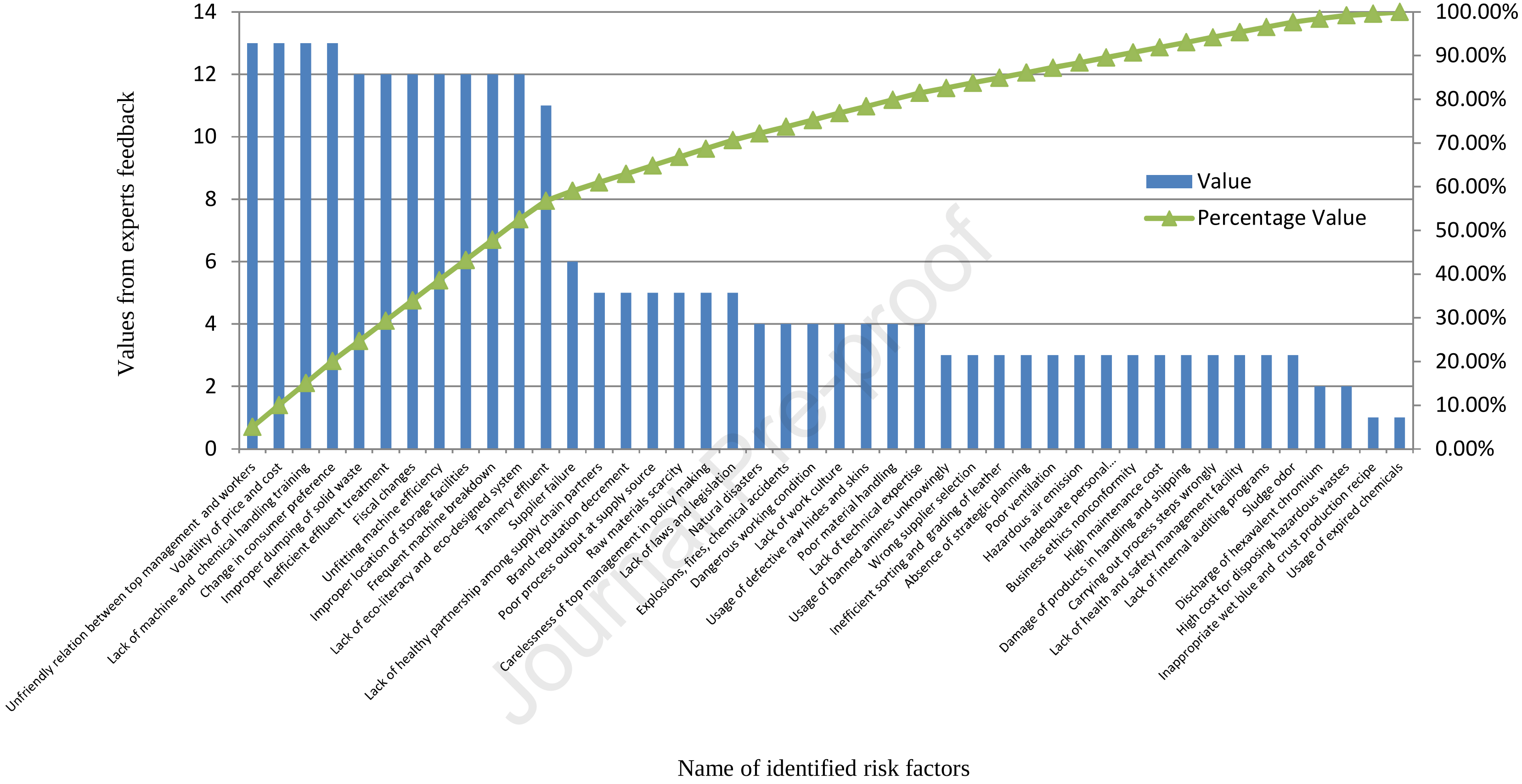


Figure 3: Pareto analysis of identified risks factors

__Phase 2: Application of the Best Worst Method__

In this phase, the BWM was used to assess the risk factors identified from the Pareto analysis. The whole process is described as follows.

Step-1: Set of risk factors for determination

In this step, a list of the eleven pertinent risk factors from five-dimensions to sustainability was identified from the Pareto analysis to examine the impact of each risk factor. The finalized most relevant risk factors are given in Table 4.

Table 4: Selected eleven pertinent risk factors from the Pareto diagram

Name of the selected risk factor with code	Brief description
Unfriendly relation between top management and workers (RF1)	A poor relationship between management and employees can significantly hinder the growth of the company and lead to a huge risk in the production system.
Volatility of price and cost (RF2)	Volatile price and cost could be a risk factor as it cannot confirm timely to ensure the delivery and product quality.
Lack of machine and chemical handling training (RF3)	Lack of proper machine operating and chemical handling safety training can lead to significant damage to product quality.
Change in consumer preference (RF4)	Any change in customers' preferences and choices can make production unstable and can impact on business performance.
Improper dumping of solid waste (RF5)	Disposal of waste in a way that has negative consequences for the environment thus affecting the industry.
Inefficient effluent treatment (RF6)	Inefficient removal of suspended particles including dissolved organic matters and handling of sludge for disposal can have a negative impact on LISC.
Fiscal changes (RF7)	A rapid change in fiscal policy has numerous influences on the economy and it can disturb the flow of investment in the business.
Unfitting machine efficiency (RF8)	The ineffectiveness of machines in transforming energy and power can make a slow work process.
Improper location of storage facilities (RF9)	Lack of proper material handling and storage facilities can impose a negative impact on SC efficiency and sustainability.
Frequent machine breakdown (RF10)	The frequent occurrence of machine breakdown and machine defects can hamper on the timely production and lead to delay in shipment.
Lack of eco-literacy and eco-designed system (RF11)	Lack of focus on eco-friendly production has a negative impact on business to make SC sustainable.

Step-2: Best and worst risk factors determination

In this step, the pertinent risk factors are given to five selected experts to mark the best and worst risk factors. Five experts e.g. E3, E6, E7, E8, and E9 from Table 2 from five reputed leather processing companies were nominated based on the highest years of experiences and involvement in the risk assessment process. We communicated with experts via a Google link as well as directly. The selections of best and worst risk factors by the selected five experts are reflected in Table 5.

Table 5: Best and worst risk factors recognized by experts'

Name of the risk factor with code	Best risk factor recognized by expert	Worst risk factor recognized by expert
Unfriendly relation between top management and workers (RF1)		E6
Volatility of price and cost (RF2)	E3	
Lack of machine and chemical handling training (RF3)		E9
Change in consumer preference (RF4)	E8	
Improper dumping of solid waste (RF5)	E7	
Inefficient effluent treatment (RF6)	E6, E9	
Fiscal changes (RF7)		
Unfitting machine efficiency (RF8)		
Improper location of storage facilities (RF9)		E3
Frequent machine breakdown (RF10)		E8
Lack of eco-literacy and eco-designed system (RF11)		E7

Step 3: Comparison of the best risk factor with respect to all other risk factors

In this step, the five experts were requested to put their inclinations of the best risk factor over the other risk factors using a 1-9 points rating scale. The selected best risk factor over the other risk factors from the expert E6 is presented in Table 6. The comparison vector of best risk factor over other risk factors for the experts E3, E7, E8, and E9 is given in Table B1 of Appendix-B.

Table 6: Best risk factor over the other risk factors formulated by expert-6 (E6)

Best to others	RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
Best risk factor (RF6)	9	3	4	2	2	1	4	5	8	6	7

Step 4: Comparison of all other risk factors with respect to the worst risk factor

In this step, five experts were requested to rank their inclinations of the other risk factors over the worst risk factor using a 1-9 points rating scale. The vector formulated by the expert E6 is presented in Table 7. Other vectors from the experts E3, E7, E8, and E9 are given in Table B2 of Appendix-B.

Table 7: Other risk factors to the worst risk factor constructed by expert-6 (E6)

Others to worst	Worst risk factor (RF1)
RF1	1
RF2	4
RF3	2
RF4	8
RF5	2
RF6	9
RF7	6
RF8	7
RF9	5
RF10	3
RF11	5

Step 5: Optimal weight calculation using the optimization model

In this step, the optimal weight of each risk factor is calculated by solving the optimization model and constraints given in Equation 4. The model for expert E6 is given as follows.

Min, ξ^L

Subject to,

$|w_{RF6} - 9w_{RF1}| \leq \xi^L; |w_{RF6} - 3w_{RF2}| \leq \xi^L; |w_{RF6} - 4w_{RF3}| \leq \xi^L; |w_{RF6} - 2w_{RF4}| \leq \xi^L;$

$|w_{RF6} - 2w_{RF5}| \leq \xi^L; |w_{RF6} - 1w_{RF6}| \leq \xi^L; |w_{RF6} - 4w_{RF7}| \leq \xi^L; |w_{RF6} - 5w_{RF8}| \leq \xi^L;$

$|w_{RF6} - 8w_{RF9}| \leq \xi^L; |w_{RF6} - 6w_{RF10}| \leq \xi^L; |w_{RF6} - 7w_{RF11}| \leq \xi^L;$

$|w_{RF1} - 1w_{RF1}| \leq \xi^L; |w_{RF2} - 4w_{RF1}| \leq \xi^L; |w_{RF3} - 2w_{RF1}| \leq \xi^L; |w_{RF4} - 8w_{RF1}| \leq \xi^L;$

$|w_{RF5} - 2w_{RF1}| \leq \xi^L; |w_{RF6} - 9w_{RF1}| \leq \xi^L; |w_{RF7} - 6w_{RF1}| \leq \xi^L; |w_{RF8} - 7w_{RF1}| \leq \xi^L;$

$|w_{RF9} - 5w_{RF1}| \leq \xi^L; |w_{RF10} - 3w_{RF1}| \leq \xi^L; |w_{RF11} - 5w_{RF1}| \leq \xi^L;$

$w_{RF1} + w_{RF2} + w_{RF3} + w_{RF4} + w_{RF5} + w_{RF6} + w_{RF7} + w_{RF8} + w_{RF9} + w_{RF10} + w_{RF11} = 1;$

$w_{RF1}, w_{RF2}, w_{RF3}, w_{RF4}, w_{RF5}, w_{RF6}, w_{RF7}, w_{RF8}, w_{RF9}, w_{RF10}, w_{RF11} \geq 0$

By solving the above-mentioned model in Excel Solver, the optimal weight of each risk factor is obtained and reflected in Table 8. Other models for the experts E3, E7, E8, and E9 are determined and similarly, the optimal weights are computed by using the Excel Solver. The optimal weights of each relevant risk factor by solving other models of experts E3, E7, E8, and E9 are acquired and given in Table B3 of Appendix-B. Further, the consistency ratio of the pairwise comparison checked using the input-based thresholds suggested by Liang et al (2020). It is noticed from the input-based thresholds that all pairwise comparisons are reliable.

Table 8: Optimal weights of identified pertinent risk factors computed with expert-6 (E6) response

Risks factors	Optimal weights
RF1	0.0193
RF2	0.1058
RF3	0.0794
RF4	0.1587
RF5	0.1104
RF6	0.2456
RF7	0.0794
RF8	0.0635
RF9	0.0397
RF10	0.0529
RF11	0.0453
ξ^{L*}	0.0718

To obtain the final results, we calculated the simple averages of the optimal weights obtained from the models of five experts (E3, E6, E7, E8, and E9). The final optimal weights and ranking of each risk factor are presented in Table 9 and Figure 4.

Table 9: Average weights of each risk factor obtained from the five experts'

Name of the risk factor with code	Average weight	Average ξ^{L*}	Final rank
Unfriendly relation between top management and workers (RF1)	0.0427		11
Volatility of price and cost (RF2)	0.1370		4
Lack of machine and chemical handling training (RF3)	0.0669		6
Change in consumer preference (RF4)	0.1427		2
Improper dumping of solid waste (RF5)	0.1381		3
Inefficient effluent treatment (RF6)	0.1585	0.0866	1
Fiscal changes (RF7)	0.1108		5
Unfitting machine efficiency (RF8)	0.0569		7
Improper location of storage facilities (RF9)	0.0449		10
Frequent machine breakdown (RF10)	0.0466		9
Lack of eco-literacy and eco-designed system (RF11)	0.0551		8

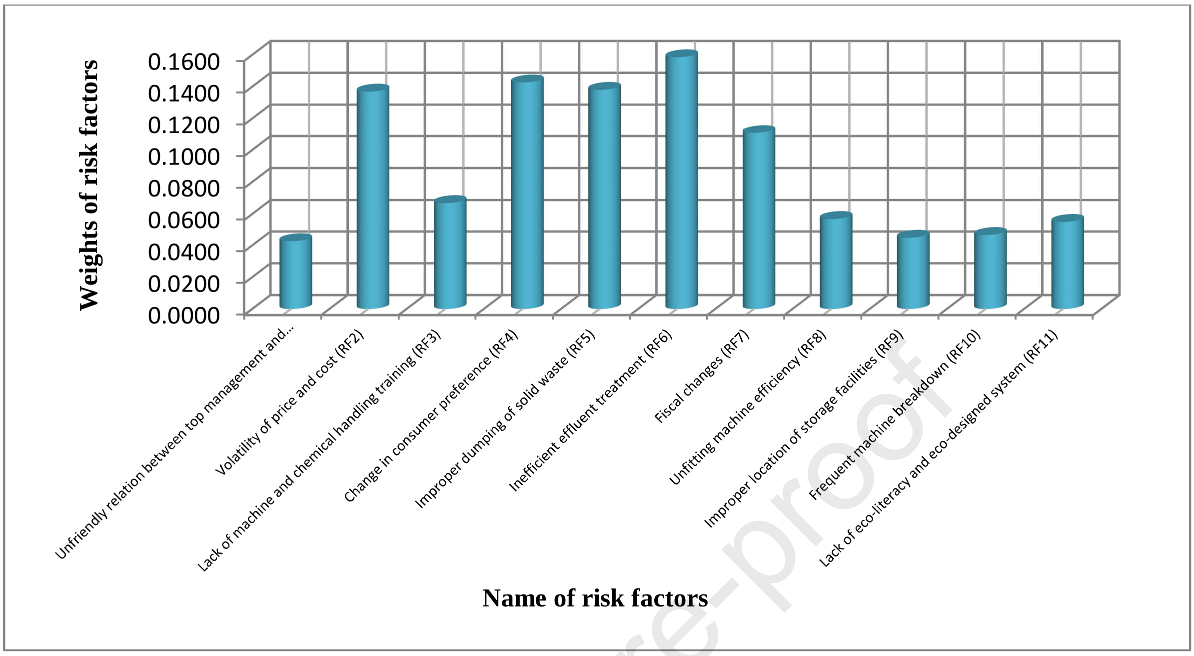


Figure 4: Graphical presentation of the average weight of each pertinent risk factor

5. Results and Discussions

In this study, a literature review was performed to identify the potential risk factors under five-dimensions to sustainability of the LISC, and professional experts' were requested to verify the relevance of the identified risk factors. The risk factors were segregated into environmental, social, economic, technical, and institutional dimensions to sustainability based on the experts' suggestions. Further, a Pareto analysis was conducted to determine the pertinent risk factors from the list of identified potential LISC risk factors. Finally, a BWM was applied for ranking the pertinent risk factors. The computed final results are reflected in Table 9.

5.1 Findings and comparison with existing study

The results from the study reflect that "inefficient effluent treatment (RF6)" is the most crucial risk factor for the LISC with the highest weight of 0.1585. The risk 'inefficient effluent treatment' indicates the effluent treatment system may not work properly in the leather industry. It can impact business performance as well as create a risk of losing foreign buyers. In the leather industry, a huge amount of effluents is produced during chemical operations. Therefore, improper management of such effluents can impose a substantial risk on the quality production of welt blue or crust or finished leather as well as on the profit margin. Efficient treatment facilities can reduce treatment costs or comply with occupational safety and health standards for the leather industry. Cleaner technologies can help to tackle this type of risk factor and to ensure a good working environment in the leather industry. The literature search confirmed that it is a unique risk factor for the LISC as many scholarly articles did not consider this risk factor in their studies. As an example, Mital et al., (2018) quantified the risks involved in the SC of different types of products and did not consider inefficient effluent treatment as a risk factor. Mangla et al., (2015) assessed the risk factors in the Indian poly product-manufacturing companies and identified various types of risk factors such as machine, equipment or facility failure, key supplier failures, and bullwhip effect risks, but did not use 'inefficient effluent treatment' as a risk factor for poly product-manufacturing companies. Dong and Cooper, (2016) proposed a risk assessment model for China's telecommunications equipment and services company but did not take inefficient effluent treatment as a risk factor. Similarly, many of scholars worked on risk assessment in various industrial domains like German premium car manufacturing industry (Zimmer et al., 2017), water-risk assessment (Schaefer et al., 2019), pharmaceutical industry (Moktadir et al., 2018b) but none took the 'inefficient effluent treatment' as a risk factor. Therefore, it can be said that 'inefficient effluent treatment' is a unique risk factor in LISC which should be managed by implementing cleaner technologies to ensure sustainable leather SC.

Next the risk factor "change in consumer preference (RF4)" received the second position in the final analysis with carrying the weight of 0.1427. This second position indicates that this risk factor should be seriously treated to improve SSCM practices in the leather industry. Consumer preferences are imperative issues for business organizations as rapid changes of preferences may affect business activities (Hallikas et al., 2020). In LISC, the demand of eco-friendly leather is increasing recently. To meet the increased demand of eco-friendly leather, the leather industry should address this risk factor by adopting flexibility in the manufacturing system otherwise industry will suffer a massive loss in the profit margin. Very few articles considered this risk factor which is aligned with our findings. For example, Moktadir et al., (2018b) analyzed pharmaceutical risk factors and mentioned that 'uncertainty in the market' can be a risk factor as demand in the market can be changed anytime. Song et al., (2017) researched risk factors for SSCM and used 'demand and supply uncertainty' as a risk factor that can be influenced by many other risk factors. Mithun et al., (2019) identified 'change in customer taste and preferences' as an important risk factor for food SC and mentioned that the food industry may fail to respond to consumer tastes and preferences. Therefore, changes in consumer preferences can be a risk factor for many industries. Contrary to our findings, several scholars did not take this risk factor in their analyses. As an example, Ozturkoglu et al., (2019) proposed a risk assessment model in the domain of the ship recycling industry and did not consider 'change in consumer preference' as a risk factor. Govindan and Chaudhuri, (2016) analyzed risk factors involved in third party service provider selection and considered twenty-two risk factors but did not take the consumer's preferences as a risk factor.

Accordingly, our findings suggest that "improper dumping of solid waste (RF5)" can act as the third most important risk factor for the leather industry with a weight of 0.1381. It is a critical risk factor for LISC as an enormous amount of solid waste is generated in the manufacturing process. The risk factor 'improper dumping of solid waste' needs lots of care to save the environment and society. Uncontrolled dumping may cause a variety of problems in the manufacturing industry such as contaminating air, water, and soil, and blocked draining channels. Additionally, this risk factor can increase greenhouse gas emissions which is a major threat to a sustainable environment. Therefore, this risk should be properly treated by adopting risk mitigation strategies. It is confirmed from the previous literature review that the risk factor 'improper dumping of solid waste (RF5)' is unique in LISC. For example, Mangla and Kumar, (2016) examined a cause-effect relationship among risk factors for initiating the green SC in the plastic industry but did not adopt this risk factor in their analysis. Dong and Cooper, (2016) assessed risks in Chinas' telecommunications equipment and services company and took 31 risk factors, however, they did not consider 'improper dumping of solid waste' as a risk factor. Zimmer et al., (2017) investigated only social risk factors in the German premium car manufacturing Industry and considered six risk factors without considering 'improper dumping of solid waste'. It is clear that the risk factor 'improper dumping of solid waste' is new and appropriate for LISC and decision-makers should concentrate on this risk factor for properly addressing it to improve sustainable LISC practices.

In this study, "volatility of price and cost (RF2)" identified as the fourth vital risk factor with a weight of 0.1370. This risk factor can act as an imperative risk factor for LISC due to several distinctive prices and costs such as design cost, purchase cost, eco-friendly raw material price, sourcing cost, and making cost are involved. The volatility in these prices and costs can create complexity in the pricing and quality of the products. Therefore, it can be a serious economic risk factor and causing problems to achieve sustainable SCs in the leather industry. Many scholarly articles indicated this risk factor is crucial for the SC and suggested to treat this risk factor seriously. As an example, Tang and Nurmaya Musa, (2011) wrote a review article on risk assessment and mentioned the risk factor 'volatility of price and cost' considered by many authors in their risk assessment models. Song et al., (2017) analyzed the interaction and strength of the risk factors in the telecommunications products and 'volatility of price and cost' identified as the second most important causal risk factor. Contrary to our findings, many scholars did not consider this risk factor in their risk evaluation process. As an example, Rajesh and Ravi, (2015) investigated the interactions among risk drivers in an electronic manufacturing company and identified fourteen risk drivers but did not consider this risk factor in their analysis. Wang and Hao, (2016) worked on risk assessment in fresh agricultural products and listed twenty risk factors without considering 'volatility of price and cost'. Khemiri et al., (2017) evaluated risk factors in the context of an integrated procurement–production system, and this risk factor was not considered in their evaluation process. Therefore, it is mentioned that risk factors may differ from domain to domain and our findings are unique.

Next, the risk factor "fiscal changes (RF7)" got the fifth position in the final ranking with a weight of 0.1108. This factor is considered a risk factor because the variations in fiscal policy may disturb the financial concerns. In addition, it can impact on SC sustainability and effectiveness (Hossan Chowdhury and Quaddus, 2020). Therefore, this risk factor should be considered in policymaking and budgetary adjustments. Many scholars identified various types of economic risk factors such as volatility of price and cost (Tang and Nurmaya Musa, 2011), inflation and currency exchange rates (Tummala and Schoenherr, 2011), market share reduction (Afgan, 2004), brand damage or reputation loss (Sodhi et al., 2012) but did not consider the risk factor 'fiscal changes' in their assessment models. However, for the LISC, the decision-makers should consider this risk factor for developing risk mitigation strategies.

The sixth-highest ranked risk factor is "lack of machine and chemical handling training (RF3)" with a weight of 0.0669. Improper maintenance of machines and equipment may lead to serious health problems and may create a dangerous working environment. Since leather industries are significantly depended on chemicals and machines, therefore, consistent maintenance is essential to keep equipment, machines, and the work environment safe and reliable. Accordingly, chemical operations depend on the skills of the operators. Therefore, the lack of well-working machine and chemical handling training may act as a serious risk factor for LISC. To mitigate this risk factor, it is necessary to arrange a training program for the operators. It is a unique risk factor as the literature review confirmed that no one has undertaken this risk factor in their analyses. For example, Er Kara and Firat, (2018) assessed risk factors in the heavy machinery sector, considering eight dimensions of supply risk. They considered seventeen risk factors but did not consider 'lack of machine and chemical handling training' as a risk factor. Similarly, Mangla et al. (2018) investigated risk factors in north Indian plastic manufacturing firms and identified sixteen risk factors and did not take the risk factor 'lack of machine and chemical handling training' in their analysis.

The risk factor "unfitting machine efficiency (RF8)" holds the seventh position in the final ranking with a weight of 0.0569. Leather processing largely depends on the various types of machines such as rotating electrical control drum, samming machine, shaving machine, splitting machine, vacuum drying machine, and milling machine. Unfitted machine efficiency can act as a crucial risk factor for LISC as it can impact on the overall production process of finished leather. In addition, this risk factor might affect the quality of finished leather which can further impact the sustainability of the LISC. It is also a unique risk factor for the LISC as many scholars did not consider this risk factor in their risk modeling framework. As an example, Gan et al., (2019) proposed an integrated risk assessment model for supplier risk assessment and identified seven types of risk evaluation criteria under three main groups and did not consider 'unfitting machine efficiency' as a risk factor. Similarly, Yazdi et al., (2020) assessed the risk in supercritical water gasification system but did not consider it in their evaluation process. Abdel-Basset et al., (2019) used a theoretical model for quantifying risk criteria in an enterprise which sold non-perishable goods but avoid to consider this risk factor. It is articulated from the discussion that this risk factor is unique for LISC. Therefore, decision-makers should give special care on it for achieving sustainability in LISC.

Next to the risk factors "lack of eco-literacy and eco-designed system (RF11)" and "frequent machine breakdown (RF10)" are in the eighth and ninth positions with the weights of 0.0551 and 0.0466 respectively. If eco-literacy and eco-designed systems are not maintained effectively in the leather industries, it might result in ineffective disposal of wastage which can further affect the health, safety and environment. The risk factor 'frequent machine breakdown' is also an important risk factor for LISC as a frequent breakdown of machines can hamper the production flow and it may impact the timely shipment (Moktadir et al., 2018b; Wang et al., 2012b). Therefore, practitioners of the Bangladeshi leather industry should be dedicated to manage and monitor these risk factors and further formulate strategic plans accordingly. The previous studies confirmed that both risk factors are important for SC sustainability (Bello et al., 2018; Li et al., 2016).

Lastly, the risk factors "improper location of storage facilities (RF9)" and "unfriendly relation between top management and workers (RF1)" received tenth and eleventh positions with the weights of 0.0449 and 0.0427 respectively. Improper location of storage facilities can cause difficulties in production, shipping, and unloading materials. Effecetive storage facilities can help to improve the production rate by reducing difficulties in sorting of the materials (Đurić et al., 2019). Also, unfriendly relations between top management and workers might affect the work environment of the companies. Therefore, healthy communication among the management and employees is necessary to build mutual respect and the relationship.

5.2 Sensitivity Analysis

In this study, a sensitivity analysis has been performed to check the overall robustness of the attained results. To do this, the weight of the high ranked risk factor is varied from 0.1 to 0.9 and noted the ranking deviation (Mangla et al., 2015; Moktadir et al., 2018b). It is observed that a minor variation has occurred otherwise the ranking of the risk factors is the same as experimental analysis. For more clarification, we changed the weight of the risk factor "RF6" from 0.1 to 0.9 instead of a normal weight of 0.1585 and checked the deviations of the ranking of each risk factor which are presented in Table 11 and Figure 6. At a weight of 0.1 for "RF6", a minor variation of ranking is found that is the risk factor "RF2" got the third position instead of fourth, the risk factor "RF4" received the first position instead of second, the risk factor "RF5" received the second position instead of third, the risk factor "RF6" received the fifth position instead of first, and the risk factor "RF7" received the fourth position instead of fifth. No change has been noted during a weight variation of 0.2 to 0.6. Further little variation has been found for the weight variation of 0.7 that is the risk factor "RF2" got the fifth position instead of fourth, the risk factor "RF4" received the third position instead of second, the risk factor "RF5" received the fourth position instead of third, the risk factor "RF6" received the second position instead of first, and the risk factor "RF7" received the fourth position instead of fifth. The weight variation of pertinent risk factors is shown in Table 10 and Figure 5 and the resulted ranking is presented in Table 11 and Figure 6.

Table 10: Weights of the risk factors associated with the LISC during sensitivity analysis

Risk factors		Values of preference weights for risk factors associated with LISC								
	Normal (0.1585)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RF1	0.0427	0.0456	0.0406	0.0355	0.0304	0.0253	0.0203	0.0152	0.0101	0.0051
RF2	0.1370	0.1465	0.1302	0.1139	0.0977	0.0814	0.0651	0.0488	0.0326	0.0163
RF3	0.0669	0.0715	0.0636	0.0556	0.0477	0.0397	0.0318	0.0238	0.0159	0.0079
RF4	0.1427	0.1526	0.1357	0.1187	0.1017	0.0848	0.0678	0.0509	0.0339	0.0170
RF5	0.1381	0.1477	0.1313	0.1149	0.0984	0.0820	0.0656	0.0492	0.0328	0.0164
RF6	0.1585	0.1000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000
RF7	0.1108	0.1186	0.1054	0.0922	0.0790	0.0659	0.0527	0.0395	0.0263	0.0132
RF8	0.0569	0.0609	0.0541	0.0473	0.0406	0.0338	0.0270	0.0203	0.0135	0.0068
RF9	0.0449	0.0480	0.0427	0.0373	0.0320	0.0267	0.0213	0.0160	0.0107	0.0053
RF10	0.0466	0.0498	0.0443	0.0387	0.0332	0.0277	0.0221	0.0166	0.0111	0.0055
RF11	0.0551	0.0589	0.0524	0.0458	0.0393	0.0327	0.0262	0.0196	0.0131	0.0065
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table 11: Ranking of the risk factors associated in LISC via sensitivity analysis

Risk factors	**Normal (0.1585)**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
RF1	11	11	11	11	11	11	11	11	11	11
RF2	4	3	4	4	4	4	4	5	4	4
RF3	6	6	6	6	6	6	6	6	6	6
RF4	2	1	2	2	2	2	2	3	2	2
RF5	3	2	3	3	3	3	3	4	3	3
RF6	1	5	1	1	1	1	1	2	1	1
RF7	5	4	5	5	5	5	5	4	5	5
RF8	7	7	7	7	7	7	7	7	7	7
RF9	10	10	10	10	10	10	10	10	10	10
RF10	9	9	9	9	9	9	9	10	9	9
RF11	8	8	8	8	8	8	8	10	8	8

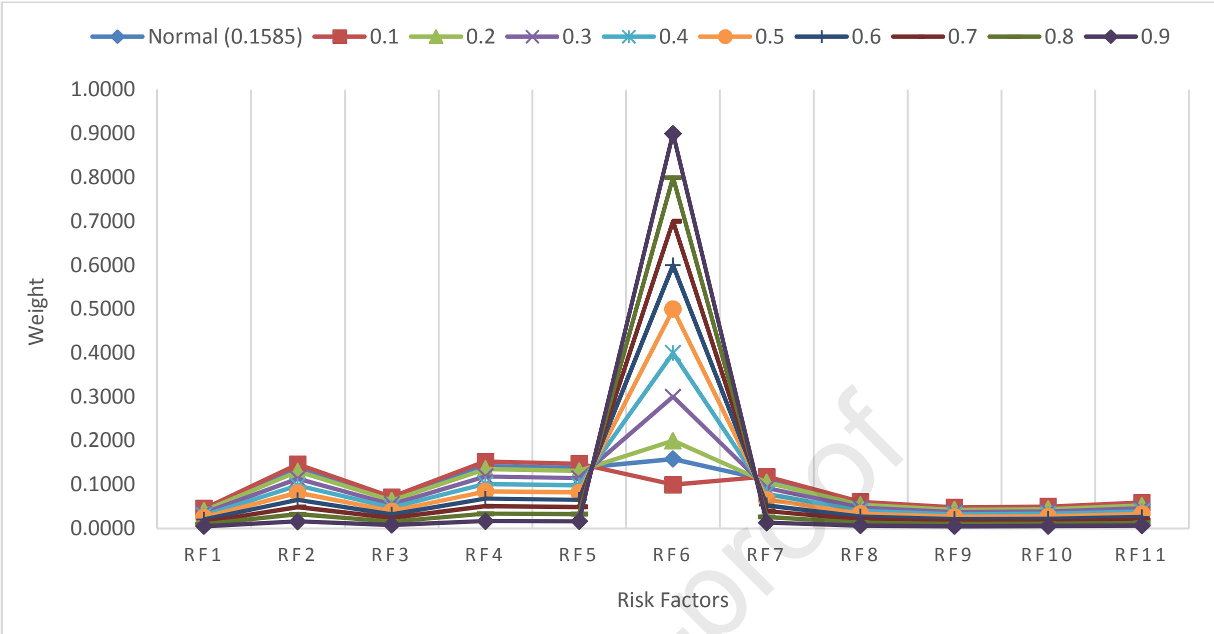


Figure 5: Weights of the risk factors during sensitivity analysis

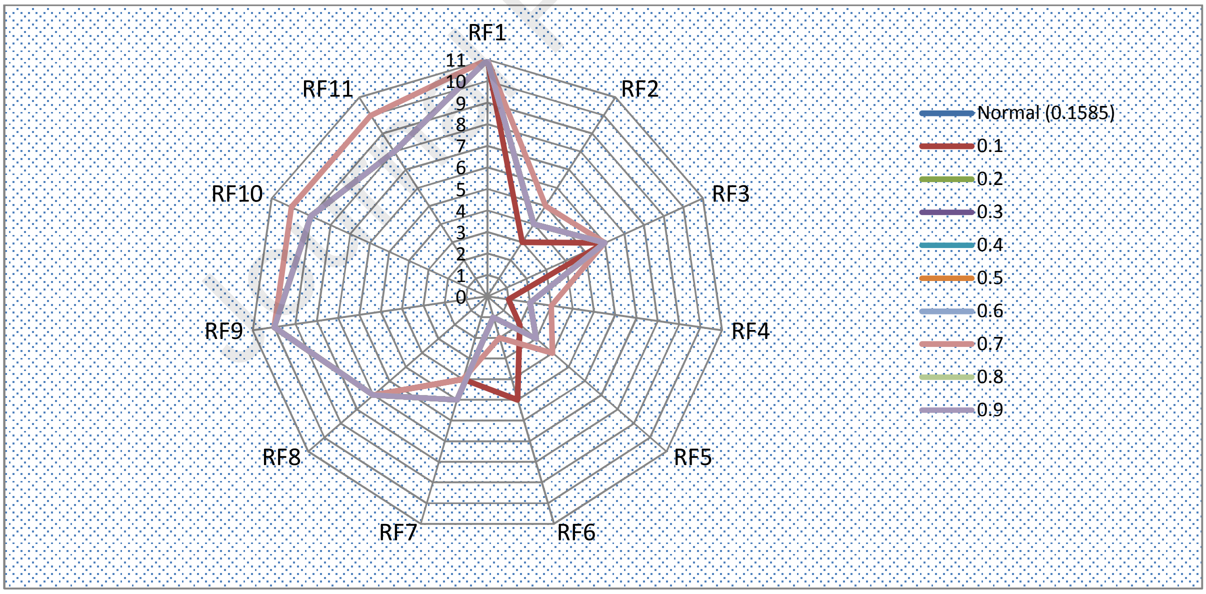


Figure 6: Ranking of the risk factors during sensitivity analysis

6. Theoretical and practical implications

The theoretical and practical implications of this study are noticeable. In the theoretical aspects, this study has made significant contributions in the literature by analyzing risk factors associated with the LISC under five-dimensions to sustainability (i.e. social, environmental, economic, technical, and institutional). From the methodological perspective, this study took the first attempt to amalgamate and implement integrated Pareto and BWM methods in the risk assessment field. This study grabbed the advantages from both methods in the following ways: i) only Pareto study cannot able to deal with the importance of the risk factors quantitatively rather than it can fix out the importance of the risk factors qualitatively. Therefore, the Pareto analysis helped to find the pertinent risk factors easily; and ii) BWM helped to examine the risk factors quantitatively and to acquire the most reliable and consistent results.

In the aspect of research findings, this is the first study that focuses on the risk assessment in the domain of the Bangladeshi leather industry and identified fourteen new risk factors and finally, five risk factors considered among them in the evaluation process. The identified and examined risk factors may then have eliminated by addressing one by one in the LISC.

In the aspect of managerial point, this study has significant contribution in the practical filed. The research findings may help practitioners to comprehend the risk factors involved in the LISC and guide the policymakers to set the pro-active, active and reactive risk mitigation strategy development to overcome the existing risk factors from the LISC. The findings may help to introduce the efficient treatment plant facility, a proper facility of solid waste disposal in the tannery areas, and building healthier relationships among industry owners and workers thus will help to accelerate the risk minimization in the LISC. Some specific managerial implications can be offered based on research findings which are listed as follows.

a. Paying attention to ensure efficient effluent treatment plant: In this study, ‘inefficient effluent treatment’ has been identified as the most crucial risk factor. An efficient treatment facility for the leather industry is required to address this risk factor as this risk factor can destroy the environment as well as it can create a negative image in the global market. Therefore, decision-makers and industrial practitioners should immediately try to build an efficient treatment plant to overcome this risk factor to sustain in the global competition.

b. Formulating strategic policies to overcome the unexpected change in consumer preferences: The findings identified ‘Change in consumer preference’ as the second most essential risk factor for LISC. Therefore, practitioners should need to follow up-to-date market demand and understand consumer preferences, values, and utilities to minimize this risk. To do these, practitioners may focus on producing environmentally friendly leather products as its demand is increasing in the world market.

c. Ensure the proper dumping facility of solid waste: The risk factor ‘improper dumping of solid waste’ also received a higher priority in the ranking. The environment can be polluted because of improper dumping as well as the buyer can raise compliance issues. Therefore, practitioners can establish a proper dumping or recycling facility to minimize this risk factor.

d. Formulating strategic policy for overcoming the unexpected economic risk factors: To mitigate the economic risk factors such as ‘volatility of price and cost’ and ‘fiscal changes’, industrial practitioners should build a resilience business strategies to sustain in the global market. It is a prerequisite to attain the resilient capability for overcoming the risk issues.

e. Ensure the agile and resilient equipment maintenance facility**:** As the leather processing largely depends on machine and equipment, therefore, practitioners should ensure proper maintenance to minimize the unexpected issues related to machine breakdown.

f. Ensure the proper storage and handling facility of chemicals and raw materials: LISC must ensure the proper storage and handling facility for chemicals and raw materials otherwise the huge loss can be made inside the LISC. The findings can aid the managers of leather processing companies to understand the technical risks and inspire them to organize awareness-raising training and workshops for chemical and machine handling.

g. Motivating experts to adopt good communication with the employees and ensure equipment efficiency: The risk factor ‘unfriendly relation between top management and workers’ also needs proper attention as these can affect the employee performance and productivity of the organization. Decision-makers should develop a policy to ensure a friendly working environment for smooth and efficient leather processing.

7. Conclusion, limitations and future research agenda

The technological advancement in the industries has resulted in increased waste and pollution. Sustainable practices can integrate environmental protection, economic gains, and social improvement in organizations. The adaption sustainable practice in manufacturing firms is very essential both from Government perception and industry point of view. To attain sustainability, the leather industry in developing countries like Bangladesh must improve its SC operations with innovative methods. This study highlights the importance of understanding the sustainability of LISC. To improve sustainability practices, industries should recognize potential risk factors and threats in the business environment. In this study, forty-four potential risk factors related to the Bangladeshi leather industry were recognized through extensive literature review and expert survey. Further, risk factors were confirmed through the recommendations of the experts. The finalized risk factors of LISC were categorized under five-dimensions to sustainability. The Pareto study was then performed to determine the pertinent risk factors for LISC. Further, the weights of the identified relevant risk factors and their importance were investigated by adopting BWM.

The findings from the study suggest that the most important five important risk factors are ‘inefficient effluent treatment (RF6)’, ‘change in consumer preference (RF4)’, ‘improper dumping of solid waste (RF5)’, ‘volatility of price & cost (RF2)’, and ‘fiscal changes (RF7)’. A large amount of amount effluents in form of contaminating chemicals and bio-logical residues is generated during the leather manufacturing process. This can be seen as a major risk factor and a threat in the path of achieving sustainable LISC. There is an urgent requirement for treating the generated effluent effectively. The leather industry should focus on adopting effluent treatment techniques to overcome the generated inefficient effluents. In the rapidly changing markets, customers have been shifting toward customized products. The leather industry needs to meet the demand of consumer preferences and their customized demand. This can be seen as a challenging risk factor for the leather industry. The leather industry is responsible for producing a vast amount of solid waste and it poses a huge risk to public health and the environment. In Bangladesh, the major portion of the solid waste has been disposed to landfill, but there is an acute shortage of landfill sites. Therefore, solid waste produced in the leather industry can be processed to produce different types of other products. The leather industry should formulate business strategies to meet the challenges of fiscal changes. The Government should also promote the investment-friendly environment and fiscal incentives to improve competitiveness in the leather sector. The risk factors examined in this study together with their weights will help practitioners to determine the crucial risk factors and to formulate a risk mitigation strategy to achieve sustainability in LISC.

The contributions of this study can be explained in four phases. Firstly, this study identified potential risk factors for the sustainable LISC in the context of an emerging economy which is hardly investigated in the existing literature. This is the first study that has studied the risk factors under five-dimensional (social, environmental, economic, technical and institutional) approaches to sustainability. Second, the data gathered from experts and practitioners of different case companies disclose rich outcomes that further enhance our considerate towards sustainable studies. Thirdly, a Pareto analysis was adopted to finalize the pertinent risk factors which helped to avoid complexities in the final evaluation process. Finally, a newly developed method BWM was adopted to determine the significance of the pertinent risk factors obtained from the Pareto analysis.

The study has some limitations. The eleven most relevant risk factors were considered for the analysis using BWM. The risk mitigation strategies for overcoming the identified risk factors were not investigated. The data for the study was gathered from twelve representative case companies and one educational institute. The analysis can be extended to identify and analyze risk mitigation strategies for the most important risk factors. In addition, supply chain disruptions can hamper to attain sustainability (Ali and Nakade, 2017). Further, this study can be extended by considering disruption risk factors and optimization tools and techniques can be applied to analyze them. The present study can also be extended to investigate the interactions between the LISC risk factors by adopting Fuzzy DEMATEL, Grey-DEMATEL, rough-DEMATEL, or Total Interpretive Structural Modelling (TISM).

Appendix-A: Survey Questionnaires

In this step, a set of survey questionnaires is provided to different experts of leather processing companies to give feedback using yes or no options.

Survey Questionnaires: (Please fill up the following questionnaires)

Questions	Answer
Q1.Name	
Q2.Email Address	
Q3.Industry Name	
Q4.Your Working Area	
Q5.Role	
Q6.Years of experience	

Q7. In your opinion, which risk factors can directly or indirectly affect the supply chain sustainability of the Leather Industry? If you think the risk factors directly or indirectly affect the supply chain sustainability of the Leather Industry please write "Yes" otherwise write "No". Besides, if you have any suggestions regarding new risk factors associated with the LISC please include it in Table A1.

Table A1: Initial identification of risk factors under five-dimensions of sustainability

Dimension to sustainability	Risk factor	Yes/No
A. Social dimension	Dangerous working condition	
	Inadequate personal protective equipment	
	Unfriendly relation between top management and workers	
	Lack of work culture	
	Lack of healthy partnership among supply chain partners	
	Business ethics nonconformity	
B. Environmental dimension	Natural disasters	
	Tannery effluent	
	Poor ventilation	
	Hazardous air emission	
	Discharge of hexavalent chromium	
	Explosions, fires, chemical accidents	
C. Economic dimension	Volatility of price and cost	
	High cost for disposing of hazardous wastes	
	High maintenance cost	
	Fiscal changes	
	Lack of technical expertise	
	Frequent machine breakdown	
	Damage of products in handling and shipping	
	Poor process output at the supply source	

D. Technical dimension	Change in consumer preference	
	Supplier failure	
	Raw materials scarcity	
	Wrong supplier selection	
E. Institutional dimension	Carelessness of top management in policymaking	
	Absence of strategic planning	
	Lack of laws and legislation	
	Lack of health and safety management facility	
	Lack of eco-literacy and eco-designed system	
	Lack of internal auditing programs	

Appendix-B: BWM analysis

Table B1: Best risk factor over the other risk factors determined by experts' E3, E7, E8, and E9

Best to others		RF1	RF2	RF3	RF4	RF5	RF6	RF7	RF8	RF9	RF10	RF11
Expert-3 (E3)	Best risk factor (RF2)	7	1	6	3	4	5	2	5	9	8	4
Expert-7 (E7)	Best risk factor (RF5)	7	3	4	6	1	2	5	7	8	6	9
Expert-8 (E8)	Best risk factor (RF4)	7	3	4	1	6	5	2	8	5	9	6
Expert-9 (E9)	Best risk factor (RF6)	8	4	9	3	2	1	4	6	7	6	5

Table B2: Other risk factors to the worst risk factor constructed by experts' E3, E7, E8, and E9

Others to worst	Expert-3 (E3)	Expert-7 (E7)	Expert-8 (E8)	Expert-9 (E9)
	Worst risk factor			
	RF9	RF11	RF10	RF3
RF1	3	5	4	2
RF2	9	8	7	7
RF3	4	4	6	1
RF4	7	2	9	5
RF5	5	9	5	6
RF6	8	3	8	9
RF7	6	6	3	6
RF8	6	5	2	3
RF9	1	8	5	4
RF10	5	7	1	8
RF11	2	1	4	4

Table B3: Optimal weights of identified risk factors computed with experts' E3, E7, E8, and E9 responses

Risks factors	Expert-3 (E3)	Expert-7 (E7)	Expert-8 (E8)	Expert-9 (E9)
	Optimal weights			
RF1	0.0480	0.0524	0.0509	0.0427
RF2	0.2527	0.1222	0.1187	0.0854
RF3	0.0560	0.0917	0.0890	0.0182
RF4	0.1120	0.0611	0.2678	0.1138
RF5	0.0840	0.2658	0.0593	0.1708
RF6	0.0672	0.1558	0.0712	0.2527
RF7	0.1680	0.0733	0.1481	0.0854
RF8	0.0672	0.0524	0.0445	0.0569
RF9	0.0188	0.0458	0.0712	0.0488
RF10	0.0420	0.0611	0.0199	0.0569
RF11	0.0840	0.0183	0.0593	0.0683
ξ^{L*}	0.0833	0.1008	0.0883	0.0888

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Highlights:

1. Forty-four risk factors in the context of Leather Industry Supply Chain (LISC) are identified.
2. The identified risk factors of LISC are segregated into five-dimensional approaches to sustainability.
3. Pareto based best-worst method is used to identify and assess the importance of the risk factors.
4. 'Inefficient effluent treatment' identified as the most crucial risk factor to SSCM practices in the LISC.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: