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MODELING SUPPLY CHAIN SUSTAINABILITY-RELATED RISKS AND VULNERABILITY: INSIGHTS FROM THE TEXTILE SECTOR OF PAKISTAN

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Abstract:

Sustainability-related risk and vulnerability management have attained significant attention from academia and industry. Manufacturing industries in developing countries such as Pakistan are under severe economic pressure and striving to boost sustainable supply chain practices for achieving business excellence. In this context, the objectives of the present research are to examine the critical supply chain risks associated with sustainable development goals, namely social, economic, and environmental factors. The failure mode and effect analysis (FMEA) technique is employed for categorizing the risk factors and Pareto analysis for highlighting the more crucial and risky factors. For this purpose, a large-scale survey was carried out in the textile industries of Pakistan to develop a risk mitigation model for sustainability-related risks and vulnerability in a textile supply chain (TSC). It captures the input expressions of experts for risk factors, namely severity (s), occurrence (o), and detection (d) for calculating the risk priority numbers (RPNs) of identified alternatives. The results depict that endogenous environmental risks categorize as the most significant for the textile manufacturing industries, and the interfaces between the various risks associated with sustainability-related are also found very high. This study would be a toolkit for the industrial managers and policy-makers for creating sustainable manufacturing culture on organizational premises.

Keywords:

Risk mitigation, FMEA, Pareto analysis, cause and effect analysis

1. Introduction

Modeling sustainability-related risks in a supply chain (MSRSC) is an emerging concept and grabbing the attention of researchers, stakeholders, and industrial professionals. Recently, organizations are much concerned with the supply chain sustainability-related risks and vulnerability, as these impacts the overall performance and profitability of industries. Vulnerability can be defined as the possibility or potential for loss. It is a substantial concept that is broadly studied as fundamental for the development of mitigation strategies for overcoming the effects of hazards at industrial, national, and international levels. The management of risks in operations and supply chains has been developed as one of the main research domains in academia and industry [1–7]. It has emerged as a new area of research in Supply Chain Management (SCM) and operations research [1, 4, 8]. In the last decades, risk mitigation studies are focusing on a series of key basic questions such as: What types of risks are tied in a supply chain sustainability context? How are the sustainability-related risks analyzed? How industries mitigate risk and vulnerability? Why are societies becoming more vulnerable to environmental risks?

In the developing country context, textile industries are striving to pay attention to socio-economic and environmental aspects in their activities of SCM as it is required from Government, competitor, and as well as the increasing pressure of global markets [9]. The textile industries play a vital role for under-developed industrial economies in improving their living standards and employment. In the case of Apparel and textile exports to the USA, Pakistan is the fourth-largest supplier, and recently exports approach to a figure of $1.9 billion. The textile industry of Pakistan has a big contribution to the economy of the country (8.5% of GDP). The effective supply chain gives several advantages to the textile industry for example-lower inventories and costs, higher productivity, shorter lead times, gain higher profits, and customer loyalty [10, 11]. explore the sustainability-related supply chain risks, their evaluation, and the development of risk management approaches which are the main hurdles, encountered by the organizations due to less training and knowledge of managers.

The sustainable supply chain is concerned with society, the environment, and organizations. By mitigation of risks related to the supply chain, sustainability would result in better allocation of the organizational resources and it improves the performance of the enterprises significantly. Moreover, supply chain risk management not only saves the cost of the firms but also results in value addition of the products, and it results in the sustainable growth of the textile business sector. As Dyck and Silvestre [12] suggested managerial introduction

toward sustainability can be divided into two structures: firstly, the conventional business approaches which demonstrate how firms receive manageability, basically to gain extra financial incentives for investors, and secondly, increasingly progressive business approaches which elaborate how firms realize sustainability to develop socio-ecological esteem for all partners.

Various studies have been analyzed about the risks which neglect the essence of sustainability in a textile supply chain (TSC). Few of them have completely centered toward environmental risk [13] and fewer analyzed toward specific sectors (e.g., [14].). Tools of SCRM are used to determine and distinguish various risks in a manner that they can reduce the effects with minimum cost [15]. Over the past years, studies have extensively explored the supply chain risk [15–17]. Tuncel and Alpan [18] showed that SC risks harmed the performance of the organizations. The current study used failure mode and effect analysis (FMEA), based on the risk mitigation model. FMEA is a tool, utilized to provide a skeletal model in checking the fluctuation among variables by using cause and effect analysis of key faults, risks, and errors. Previously, Chin et al. [19] purposed the model for measuring risk priority numbers (RPN) in new product development. This tool is developed to identify the potential risk in solving practical problems, related to engineering, supply chain, and judgmental problems [20]. Practically, in 1963, this methodology was designed and implemented by NASA in 1963 to check the reliability requirements in their newly designed products. Later on, it was adopted by one of the most popular automobile companies, Ford Motor Company in 1977. FMEA is a popular approach, widely used for safety and reliability analysis of the products and processes in multiple companies, especially, satellites, aircraft, pharmaceutical, and automotive companies [21]. The present study calculated a risk priority number (RPN) which is obtained by multiplying the values for severity (S), occurrence (O), and detection (D). Afterward, the RPNs of identified alternatives considering the risk factors are ranked with higher risks.

1.1 Key problem statement and research highlights

The textile sector is considered the backbone of the Pakistan economy as it is the most important industrial sector in terms of raw material import and export of finished goods. This sector is facing tough competition from regional competitors such as Bangladesh, Vietnam, India, China, and Turkey. The supply chain cost of doing business in Pakistan is high as compared to other regional competitors. Based on these reasons, the Pakistan textile industry is passing through a crucial stage [5]. The industries are using different types of chemicals in their production process which severely cause environmental emissions and occupational health problems. The textile industry is also associated with water pollution which is caused by the discharge of untreated effluents because of the use of toxic chemicals, especially, during processing. Therefore, sustainability related-risks are directly associated with the textile industry of Pakistan [2]. With increasing worldwide awareness regarding the domain of sustainability issues such as environment and pollution, economic conditions and social stability have become major factors in the dynamics of the world markets and sustainable businesses around the world. Consequently, these problems are addressed in this research study to help fill this gap in the textile perspective. Therefore, the study is aimed to investigate the risk factors of the external and internal environment which affect the firm's performance. Recently, organizations are concerned to find out ways to mitigate or reduce the effect of sustainability-related risks. The present study primarily focused on the sustainability aspects of supply chain risk and vulnerability management. Based on these problematic scenarios, this study raises three research questions (1) what types of risks are tied in the context of supply chain sustainability? (2) how are the sustainability-related risks analyzed? and (3) what are steps taken by the managers of industries to mitigate risk and vulnerability?

To address the above-mentioned research questions, this work has the following objectives:

1. To investigate and mitigate the risks related to TSC sustainability

2. To analyze the nature, the causes, and effects of sustainability-related TSC risks

3. To designate a comprehensive model for mitigating sustainability-related risks and vulnerability

This research study bridges the gap to mitigate the key risks in a sustainable supply chain. The mitigation of the risks is very important but not easy to tackle all the endogenous and exogenous risks at the same time. The mitigation of sustainability-related risk is not a common phenomenon in the textile sector of Pakistan. Some vertically oriented textile industries are trying to adopt sustainable practices which are not implemented properly. The literature on MSRSC is not well-established and it is a new approach in the context of the textile industry of Pakistan. This research would assist the companies to improve the business performance in local as well as in the global market. The proposed framework of sustainability-related activities would be helpful for practitioners and industrial experts to adopt sustainable activities in their business environment.

The rest of this paper is organized as follows. Section 2 briefly identifies the literature in a sustainable supply chain context. The proposed model for mitigation of risks is described in Section 3. The research findings and discussion of the proposed model are elaborated in Section 4. Finally, the concluding remarks along with policy implications and unique contributions are discussed in the last section.

2. Literature review

The concept of supply chain risk and vulnerability is assumed as a potential for loss, and it is not clearly expressed as to what kind of loss; either it belongs to the personal or individual potential for, or sensitivity to, losses that have both spatial and no spatial domains referred to as an individual vulnerability.

Social vulnerability comprises the vulnerability of social groups or society at large to potential losses (structural and nonstructural) from hazardous events and disasters. Environmental Vulnerability is characterized by the capacity of systems or organizations for managing, resisting, mitigating, and recovering all the problems due to environmental uncertainties. Economic vulnerability can be defined as the capacity of an organization to survive, manage the operations in exogenous shocks, arising due to economic instability or financial crises or recover from the effects of such shocks [22].

The sustainability of SCM is triggered by the internal and external activities of industrial decision-makers, Government policies-makers, and stakeholders. A significant number of studies concluded that the environmental-friendly strategy, regarding SCM, have a significant effect on the cost-efficient system and operational performance (G [23–25].). Hollos et al. [26] suggested that sustainable SCM practices empirically impact the performance of a firm [25, 27]. Kleindorfer and Saad [28] explored three types of SCM risks: natural, economic, and terrorist, etc. This study presented a conceptual methodology for risk assessment and mitigation. Huatuco et al. [29] investigated whether companies' environmental and conventional supply chain risks are associated with their economic performance or not in the USA. It was observed that SCM practices were positively associated with the financial performance of the company.

The supply chain risk can be categorized into two main groups: endogenous or internal risk triggered by firms besides their supply chain and the risk, caused by the companies through external environment interaction in which they operate is called exogenous or external risk described two types of risks that are related to the internal and external systems of organizations [30, 31]. Internal risks i.e., late delivery, surplus inventory, poor forecasting, financial risks, human mistakes, minor accidents, and errors in ERPs systems. External risks are associated outside the supply chain i.e., earthquakes, financial irregularities, hurricanes, industrial action, price changes, wars, crime, and materials shortage. The nature of risks in a supply chain are extensively investigated in the last years; the typical risks of the supply chain are involved in disruption and interruptions due to supply risks such as issues in quality management, the liquidity of supplier problem, the dependency of the supplier, change in product design and postponements in the delivery [32].

A significant number of scholars characterized the risks in different ways, such as risks related to procurement exchange rates, stock out and inventories risks, transportation risk and logistics risks, relational risk of the supply chain (moral hazard and holdup risk), risks of demand such as volatility of demand and wrong forecasting, distortion of information and accumulation of stock due to the effect of the bullwhip effect, breakdown of equipment, and risks related to infrastructure and systematic break-down [15, 33, 34]. Xie et al. [35] categorized the supply chain risks into delay risks, demand risks, inventory risks, disruption risks, manufacturing risks (process) breakdown risks, physical plant capacity risks, supply procurement risks, system risks, transportation, and sovereign risks. Karakayaa and Ghorbanib [36] prioritized the supply chain risks regarding information technology, human, financial, and physical resources. The scholars claimed that environmental risk is the most influential and important due to the governmental policies and regulations.

According to [37], the regular risks, related to sustainability for many industries are ozone harming substance outflows, natural disasters events, mishaps, energy utilization, bundling waste, logistics, and ecological harm in transportation. Interruption risks are caused by occasions that create a supply deficiency for a specific period [38]. The risky occasions identified with society, for example, child/forced labor, animal immoral treatment, natural practices, prizes, pay off claims or bribery, misrepresentation, and patent encroachment [11]. In such circumstances, the risk management action plans can be developed preferably to avoid the identified risks, or if not possible, at least to mitigate, contain, and control them.

In SCM, the risk would be the likelihood of an incident, related to inbound supply, negatively affecting the purchasing capacity of the company to give value to the demand of the clients. Various studies have analyzed the risks, carried by the absence of supply chain sustainability which is directly linked with environmental risk [13] and some risks are evaluated according to the specific sectors [14]. Tools of SCRM are used to determine and distinguish various risks in a manner that they can reduce the effects with the minimum cost [15]. Over the past years, the studies have extensively explored the supply chain risk [15–17]. Tuncel and Alpan [18] showed that SC risks harmed the performance of the organizations. This study used Failure Mode Effect Model for the analysis purpose. Heckmann et al. [39] examined that the frequency of risks, related to the supply chain is increasing significantly, owing to a lack of knowledge regarding identification/assessment, evaluation, and monitoring of risk.

3. Research methodology

Failure mode and effects analysis (FMEA) is an effective reliability analysis technique utilized in a wide scope of industries for improving the reliability of frameworks, products, procedures, and services. It is a well-organized analysis tool that is employed to study the problems in a systematic way that might arise in a running system. This method not required advanced knowledge of statistical tools and complex statistical techniques for analyzing and measuring the risk factors. In the FMEA approach the survey participants were asked to evaluate the level of severity (S), probability of occurrence (P), and ease of detection (D) of each risk factor [18]. A risk mitigations structure for sustainability related-risks in a TSC is shown in Figure 1.

3.1 Data collection

The data has been collected from the experts of SCs and academia members with relevant experience, knowledge, and education. The experts hail from from the relevant fields, such as spinning, knitting, dyeing and finishing, apparel

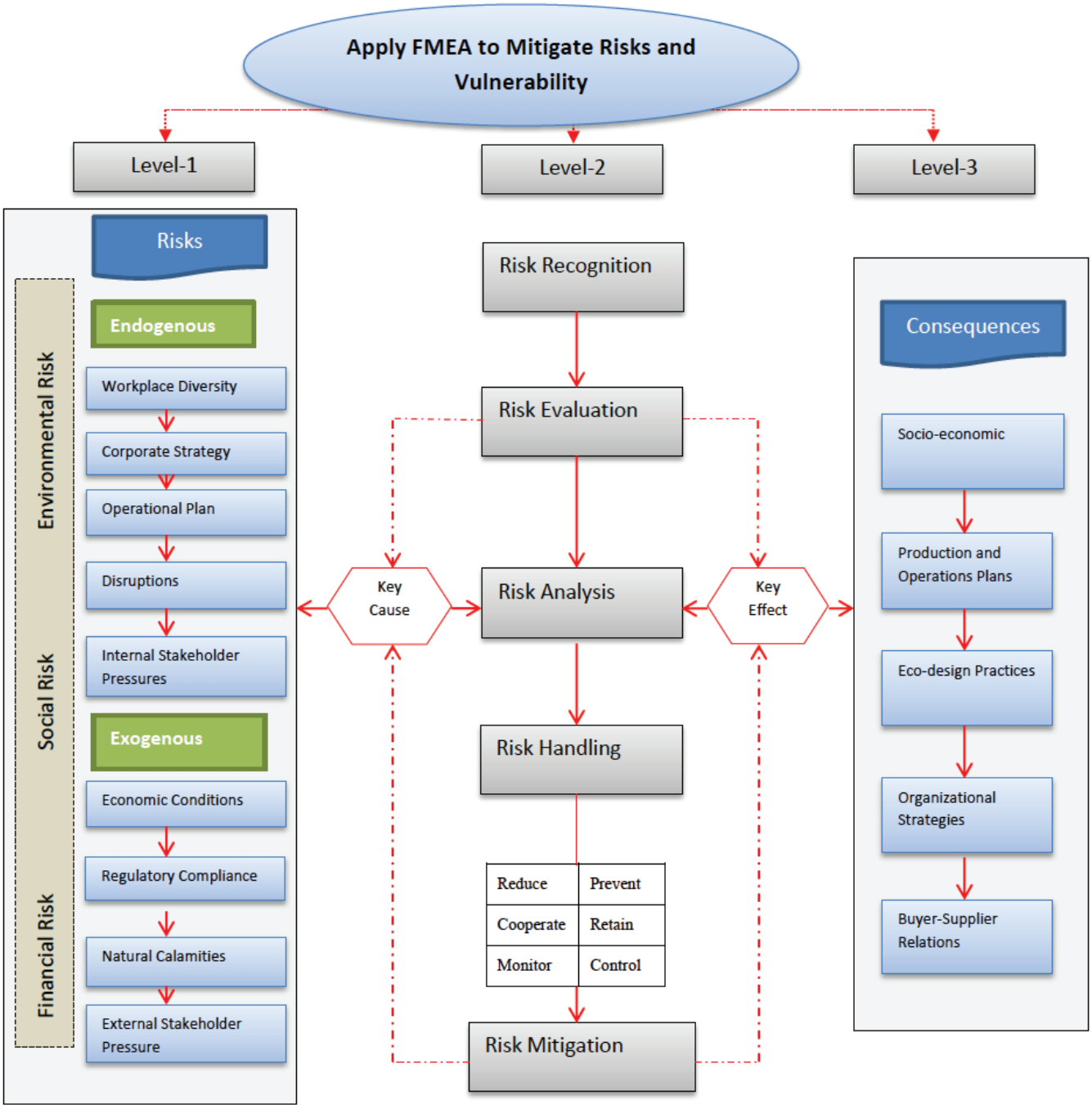

Figure 1. A risk mitigations model for sustainability related-risks in a TSC. TSC, textile supply chain.

manufacturing, and garments and have more than 10 years' experience. The data was collected through a structured questionnaire communicated via e-mail and physical meetings with experts from the period 17 March 2019 to 15 December 2019. For risk recognition, this study used extensive literature review and the list was finalized by consent of experts from the textile industry to detect whether sustainability risks are evident or not in the supply chains of their organizations. Research objective 1 (risks related to sustainability) was explored through a comprehensive study from the literature review. In this phase, we approached 71 experts from different textile industries located in different industrial cities of Pakistan. Similarly, at the second phase, to develop a risk management framework (Research Objective 2), data was collected via a structured questionnaire survey from 29 textile industrial professionals (Director of Operations, General manager, Supply Chain Manager, Deputy general manager, logistics, Deputy general operations, Supply chain manager) who are involved in operations and SCM activities of different textile industries of Pakistan. The simple random sampling and convenient snowball sampling technique were employed for contacting industrial professionals.

The presented study is examined from industrial expert's opinions that are involved in operations and SCM activities. The sample size of responses of persons influences the quality of results, and decision-making becomes unrealistic. Furthermore, it also leads to a high level of inconsistency. The industrial-experts team consisting of 30 experts was organized based on their professional expertise in the leading textile industries

of the country and two experts from the academia side. The average experience of industrial experts was between 24 and 30 years and academia professionals (Assistant Professor of operations and SCM) was 7 and 8 years respectively.

3.2 Data analysis

To evaluate the risks, the FMEA technique was used for risk assessment and risk analysis. Following the FMEA technique, "the survey participants were asked to evaluate the level of severity (S), the probability of occurrence (P) and ease of detection (D)" of each risk factor [18] on a 7-point Likert scale. The managers were assigned a probability level to identify risk causes and effects. After the recognition of risks, they were asked to evaluate the key causes and effects using Pareto analysis to find out the most important risk factors. Data was analyzed through the FMEA technique, and for each possible key risk, this technique calculates risk priority numbers (RPN). RPN number is calculated when the severity, event occurrence, and detectability were multiplied for each respondent and then the responses of the respondents were averaged out. The RPN calculated (by multiplying the risk severity, chances of an event occurrence, and ease of risk detection factor) is shown in Table 1.

4. Research findings and results discussion

The descriptive statistics results in Table A1 in Appendix show that, as a whole, the risk factors related to sustainability are considered as major consequences for textile industries (mean = 5.22); they happen from time to time (mean = 4.57) and are moderately difficult to detect (mean = 3.89). In contrast, social-related risks are perceived as high-risk factors as compared to environmental and social factors, while environmental (exogenous) related issues also have more prominent. Furthermore, the perceived priority numbers of financial (exogenous) are riskier as compare to environmental (exogenous) and social (exogenous), while social (endogenous) perceived priority numbers are higher than financial (endogenous) and environmental (endogenous).

4.1 Pareto analysis

The Pareto analysis technique is used for highlighting the most critical and risky factors (Figure 2). It is a very helpful tool for prioritizing potential causes of a research issue and identifying improvement opportunities. The experts from different textile industries who took part in this research made more valuable results related to sustainability-related risks and increase the importance of the selected risks. Social instability is ranked as the most weighing social risk, mainly due to its severity, and frequency of occurrence, rather than its difficulty in detection. This shows the difficulty to manage the sustainable processes of the supply chain at the domestic and global level as well and also point out the need to make serious consideration for improving supply chain processes. Concerns about social risks, such as social instability, unfair wages, excessive working time demographic changes, discrimination, and inhuman treatment prevail the most important perceived risk factors. Among the economic risks, energy prices volatility, tax avoidance/ evasion are perceived as almost close to equally impactful as financial crises, "reflecting both an economic as well as a social phenomenon; the rising awareness of the social responsibility of businesses in light of the increasing socio-economic equality that is experienced in developed as well as developing economies" [7]. Among the financial risks, tax avoidance and energy price volatility are perceived as close to equally impactful as social and environmental risks. The current Government is very concerned about the taxation factor and trying to take the business persons into the tax circle.

4.2 Key causation and effects of sustainability-related risks

Cause and effect analysis is used for exploring the root causes of high ranking factors with the help of data collected from industrial exports. The interviewed experts were asked to share the information of key causes and effects of each factor related to sustainability. The analysis results are presented in Table 1. The findings of the research depict the environmental (endogenous) risk factors as a group risk related to sustainability perceived as the potential risk have major impacts on organizations with (mean = 4.54), risk occurring occasionally have mean value (mean = 4.46) and risk with moderate effect have mean value (mean = 4.44). These findings indicate that social risk factors i.e., social instability have higher RPN numbers as compared to the other risk factors, which indicates that social instability needs to consider as the first preference level by the policymakers.

The findings in Table 1 show that social risk factors (endogenous) as a group risk related to sustainability perceived as the risk have major impacts on organizations with (mean = 4.47), risk occurs occasionally have mean value (mean = 4.09) and risk with moderate effect have mean value (mean = 3.46). These findings indicate that social risk factors having RPN number for most of the risk factors is less than a hundred, which indicates that social risks are a minor risk for organizations. While in case of social risk factor (exogenous) as a group related to sustainability perceived as a risk have major impacts on organizations with (mean = 4.01), risk occurring occasionally have mean value (mean = 3.91) and risk with moderate effect have mean value (mean = 3.64).

In Table 1 The findings show that financial economic (endogenous) risk factors as a group risk related to sustainability perceived as the risk have major impacts on organizations with (mean = 4.42), risk occurring occasionally have mean value (mean = 4.42) and risk with moderate effect have mean value (mean = 4.29). These findings indicate that economic risk factors having RPN number for most of the risk factors is less than a hundred, which indicates that social risks are a minor risk for organizations. While in case of financial-economic (exogenous) risk with severity (mean = 3.87), occurrence (mean = 4.19) and risk with moderate effect have (mean = 4.11)

The findings indicate that social risk is supposed as considerably minor risks as compared to financial or environmental risks because their RPN number is less than a hundred for most of

Table 1. Priority risk factor number for environmental risks.

Risk	Sub-risks	Liker scale: Min = 1, Max = 7			
		Severity	Easy of occurrence	Easy of detection	RPN
Environmental (endogenous)	Energy consumption	6.04	6.76	4.67	188.14
	Environmental accidents	3.67	4.2	4.05	62.43
	Non-compliance with sustainability laws	3.13	2.07	3.33	21.57
	Pollution (air, water, soil)	7.04	7.1	3.33	166.45
	Product waste	3.67	2.2	2.33	18.81
	Unnecessary packaging	4.33	4.17	2.07	37.38
	Mean	4.64667	4.41667	3.29667	82.4633
	SD	1.54776	2.15498	0.98944	
Environmental (exogenous)	Heat waves, droughts	6.011	6.08	4.33	160.85
	Water scarcity	5.09	4.33	3.1	66.34
	Mean	5.5505	5.205	3.715	113.595
Social (endogenous)	SD	0.65125	1.23744	0.86974	
	Child/forced labor	2.33	3.15	2.05	15.05
	Discrimination (race, sex, religion, age, politics)	5.67	5.33	3.03	91.57
	Unhealthy/dangerous working environment	4.67	4.67	2.33	50.81
	Inhumane treatment/harassment	5.04	3.33	5.03	84.42
	Unfair wages	5.01	6.33	4.67	148.1
	Excessive working time/work-life imbalance	5.67	6.33	3.67	131.72
	Mean	4.73167	4.85667	3.46333	86.945
	SD	1.24139	1.40312	1.21844	
Social (exogenous)	Demographic challenges/ageing population	6.11	4.23	3.67	94.85
	Social instability/unrest	7.15	5.67	5.06	205.13
	Mean	6.63	4.95	4.365	149.99
	SD	0.73539	1.01823	0.98288	
Financial/economic (endogenous)	False claims/dishonesty	3.67	4.33	5.17	82.16
	Patent infringements	2.03	3.05	2.12	13.13
	Tax avoidance/evasion	5.67	5.67	5.33	171.35
	Antitrust claims	3.06	2.33	3.33	23.74
	Bribery allegations/corruption	4.01	4.33	4.05	70.32
	Price fixing	4.67	4.33	4.33	87.56
	Mean	3.85167	4.00667	4.055	74.71
	SD	1.26327	1.16677	1.2012	
Financial/Economic (exogenous)	Boycotts	5.67	3.09	4.67	81.82
	Energy prices volatility	6.01	5.18	4.14	128.89
	Financial crisis	6.33	5.07	5.33	171.06
	Litigation claims	5.67	2.67	3.67	55.56
	Mean	5.92	4.0025	4.4525	109.333
	SD	0.31686	1.30821	0.71351	
Over all mean		5.22	4.57	3.89	

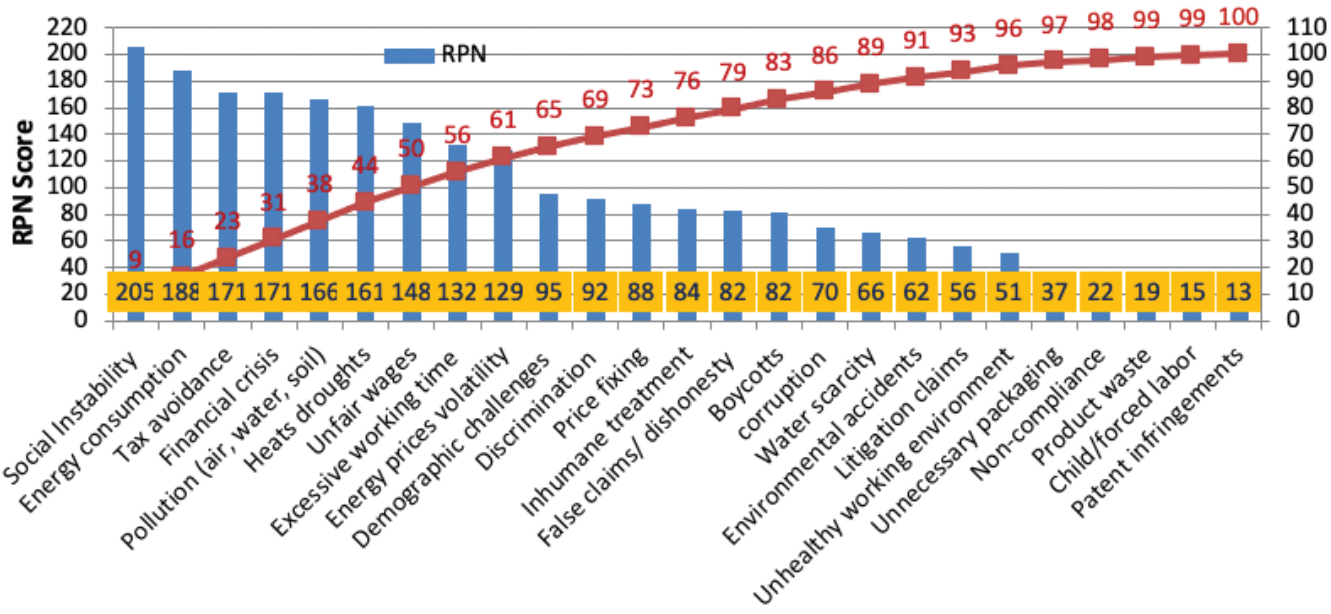

Figure 2. Pareto diagram for RPN of risk factors related to sustainability.

the factors. Though the environmental (exogenous) and social risks have higher exposure to media, the result of the survey indicates that the perceived high priority number for risks type such as economic and environmental risk (endogenous) is high as compared to social risk factors. The results provide an interesting insight regarding risk factors such as endogenous risk considered as more "important" than exogenous risks. The endogenous risks usually originated from the action or lack of actions by organizations and suppliers. These actions have direct responsibility for the control or mitigation of risks. The last step of the risk mitigation process recommended as a strategy to reduce or mitigate the factors of risk. The study also discusses uncontrollable risks or risks with lesser control. Finally, the results suggest that the organization needs to develop strategies of risk mitigation for tackling the issues related to sustainability in the supply chain environment. Organizations should focus on sustainable manufacturing and the implementation of lean thinking for reducing operational risks. The proposed model can lead the industry for overcoming the highlighted issues which are identified in the cause and effect diagram, and recommendations in Table A1 in Appendix.

4.3 Managerial implications

The study supports textile industries with environmental, social, and economic operations and recommendations for supply chain risk and vulnerability evaluation. Textile and apparel industries, in particular, can utilize the proposed model as a way forward to improve their supply chain sustainability efforts. It is difficult to control external risks and develop risk mitigation strategies. Sinha et al. [40] discuss that organization has no benefit with an attempt to deal with exogenous risks without mitigating the endogenous risks because the organizations have no control over the outside risks. However various strategies for identified risks are proposed and mention in Table A1 in Appendix. Each defines diverse strategies based on their high or low impact on the organization. In this context, sustainable strategies should be designed through an identification process and assess them relating to sustainability and after that analyze their effect in terms of financial, social, and environmental risks. This tactic helped as a springboard to recommend an alternate theorizing of the economic activities of the textile firm which helps in the resource allocation to the supply chain process. However efficient treatment and appreciation for various types of risks that lead to economic or financial uncertainty should be addressed.

The perceived most important nine key risk factors explored by the research survey like social instability, energy consumption, tax avoidance, financial crises, pollution, heat droughts, unfair wages, excessive working time, and energy price volatility (See Figure 2). The analysis of this study reflects the environmental, social, economic, and regulative contexts that exist in the scenario of Pakistan. Therefore, risk factors such as child labor, product waste, demographic challenges, non-compliance with laws, water scarcity, patent infringements, antitrust claims, and bribery allegations are ranked at a low level, and subsequently, these factors are not perceived as sensitive issues for the textile industries operating in Pakistani geography. The detailed managerial implications are tabulated in Table A1 in Appendix and briefly outlined here.

Environmental Risks

The three key risks like energy consumption, pollution, and heat and drought fall into the environmental domain of sustainability. For overcoming these key risks and vulnerability the industrialists and the Government can play a very important role by investing in a cheap source of energy such as wind and solar technologies, and environmentally friendly processes and products should be adopted by the industries and work with ISO certified supplier.

Social Risks

The three key risks like unfair wages, excessive working time, and social instability or unrest fall into the social domain of sustainability. For overcoming these key risks and vulnerability, there is a need to create a strong relation between Government and industry stakeholders for gaining the trust of industrial stakeholders and implementing the long-time textile policies in true letters. In this scenario, social instability is a serious issue in Pakistan and considered a big hurdle for capturing more investment and achieving sustainable supply chain performance.

Economical/operational Risks

The three key risks like Tax avoidance, energy prices, and financial crises fall into the economic domain of sustainability. For overcoming these risks and vulnerability, the Government has to pay intention and support the industries for future growth. It can be done by introducing an easy and online way of tax payments, motivate the industrialist to come into the taxation circle, encourage the exports by decrease export duties, control the energy prices and engage the financial institution to jointly support liquidity.

5. Concluding remarks

The purpose of this research was to recognize the sustainability-related risks and proposed a risk mitigation model and a systematic framework of strategies for handling the risks. For this purpose, a total of 26 sustainability-related risks have been recognized and categorized into six thematic groups through a detailed review of the literature. This study develops a detailed process for managing risk and managerial implications. The given risk management process is a good source of useful and strategic nature information related to sustainability risks associated with a TSC. Supply chain sustainability can be enhanced through the development of effective and appropriate strategies for the treatment of risk and the negative impact of these risks might be controlled. The present research examined the critical supply chain risks associated with sustainable development (social, economic, and environmental aspects). The major contributions of this study are to a) develops a comprehensive model as an output to categorize the overall risk in terms of supply chain sustainability b) the recognition, evaluation and handling practices of risk gives a good understanding of the overall supply chain sustainability risk and vulnerability in textile industry c) distinguishing the high-prioritized risks is crucial for the consequent risk management stage d) the current study of risk management is validated and presented for highlighting real issues related to sustainability specifically in Pakistan, and finally e) this study would be beneficial for the policymakers to find out the most possible risks facing by the textile industries and make better policies for solving these issues with preferences. The model developed in this study could be applied in other industries including, plastics, pharmaceuticals, and agriculture industry to study drivers to sustainable manufacturing practices. This study used extant literature review and experts' opinion for listing sustainability-related risks and employed FMEA for prioritizing these risks. In the future, Fuzzy Analytic Hierarchy Process (FAHP), VIKOR, ELECTRE, TOPSIS, or Hybrid techniques could be used to rank the factors.

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Appendix

Table A1. Treatment of sustainability-related risk and vulnerability.

Risk	Sub-risk	Risk response	Practices/recommendations
Environmental (Endogenous)	Energy consumption	Mitigate Prevent	For efficient production, need to invest in cheap source of energy like wind and solar technologies.
	Environmental accidents	Prevent Mitigate Reduce cooperate Insure	To avoid any catastrophic accident related to production a regular maintenance is compulsory. Establish manufacturing plant in less populated area to safely rescue workers in case of emergency. Develop sustainable relationship with suppliers to identify risk with solid solution. Maintain liaison with forestry department of Govt. and media cell for quick reporting.
	Non-compliance with sustainability laws	Prevent Control Share	Get certification of ISO 9001, 14001 standards and ISO 31000. For export products firms must need to be certified with international standards. Like financial audit, sustainability audit must be compulsory before taking any order from buyer.
	Pollution	Avoid Prevent Reduce	Good ventilation, carefully handling of chemicals, and properly place the safety equipment. Reduce the amount of waste generated by textile units' process prior to off-site recycling, treatment, or disposal of waste. Comprehensive assessment should be done at operational facilities. Manufacturing facilities should be located away from urban areas. Now days, textile sector has work on it and maintain a very good system of draining, exhausting and wastage pipelines.
	Excessive product waste	Mitigate Prevent	Organizations should focus on sustainable manufacturing and the implementations of lean thinking for reducing operational process wastes Apply lean six sigma principles Focus on recyclability patterns Excessive product waste should be disposed off timely.
	Unnecessary packages	Prevent Cooperate	Reduce plastic element in packaging. Establish packaging department for producing the finest quality packaging stuff. Use environment friendly material in the packaging.
Environmental (Exogenous)	Natural disasters	Mitigate Cooperate Reduce Insure	Develop contingency plans to cope up with natural calamities. A disruption alert message should be sent to industries by the National disaster cell of Govt.
	Water scarcity	Prevent Mitigate Cooperate	Need to install water treatment plant to reuse the waste water. Water recycling is necessary component to enhance the water level.
Social (Endogenous)	Child/forced labor	Avoid Insure Mitigate	Minors should not allowed to work in the facilities or plants. Govt. policies regarding child labor should be shared and implemented in true sense.
	Discrimination	Prevent Mitigate Transfer	Promote the corporate culture. Discourage the discrimination level at all management levels. Equal opportunity employers should get special tax rebate from Govt.

Risk	Sub-risk	Risk response	Practices/recommendations
	Unhealthy/dangerous working environment	Prevent Mitigate Reduce Insure	Precautionary measures can be adopted like employees use mask, special uniform, gloves and shoes etc., Provide medical insurance to employees. Provide safety guideline to employees as suggested by ISO standards.
	Inhumane treatment/ harassment	Prevent Mitigate	Fear of job security is a big issue in the private sectors. Establish complaint handling cells to listen the queries of employees. In case of harassment one window operation should be done.
	Unfair wages	Prevent Cooperate	Govt. laws should be implemented for the fair wages and monitoring system for ensuring it by engaging with industries.
	Excessive working time	Reduce Mitigate Prevent Insure	Excessive working hours should not be forcefully employed on employees and encourage the flexible timing system in industries. Offer employees health insurance. Monitor productivity levels and give incentives.
Social (Exogenous)	Demographic challenges		To cope up the political instability, the Government should make long term strategies for controlling energy and gas crises, fluctuating yarn prices, law and order situation, and devaluation of Pakistani currency. Need to introduce new updated technologies for reducing production cost and trained the employees for bring innovations in textile industries.
	Social instability/unrest	Mitigate Reduce Insure	Good relationship between leadership and workers. Proper contingent planning for ensuring resilience in operational activities. Stability in social and political matters. Proper health facilities for ensuring employees health.
Financial/ economic (Endogenous)	Antitrust claims	Avoid Reduce Mitigate	Establish good relationship with local communities, Monitor flow of resources/material from unstable areas. Build flexibility in capacity.
	Bribery/corruption	Prevent	Adopt antitrust principles to recognize when an problem is possible. Work with potential suppliers to interpret law.
	False claim	Prevent Avoid Mitigate -	Maintain the proper record of claims. Avoid the clients who don't have good transparent record system. Educate the employees about the claim policy and Government laws in case of any false claim. Apply compliance cell to observe.
	Price fixing	Prevent Insure	Identify the source of license product. Insure against infringements from customers/suppliers.
	Tax avoidance/evasion	Mitigate Cooperate Transfer	Implement compliance with FBR laws. Make the easy way of tax payments. Motivate the industrial persons to come in taxation system.
Financial/ economic (Exogenous)	Boycoatts	Cooperate	Strengthen the relationship between industrial leadership and employees' unions. Strengthen the relationship between industrial representatives and Government authorities. Timely identity and fix the issues of employees and industries. Provide subsidy.

Risk	Sub-risk	Risk response	Practices/recommendations
	Energy prices volatility	Mitigate Cooperate Transfer	This is the major dilemma now days, especially in Pakistan. Government control on energy prices and create good relation with industry.
	Financial crises	Mitigate Transfer	Encourage the textile exports. Secure liquidity through insurance for example securitization. Engage financial institutions to jointly support liquidity.
	Litigation	Prevent Avoid Insure	Start a comprehensive review system that will track and assess litigation exposure. Establish a good internal information system that disseminate the information timely and quickly to industrialist about existing and pending litigations.