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A supply chain risk assessment index for small and medium enterprises in post COVID-19 era

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ABSTRACT

Supply chain networks worldwide were disrupted substantially during covid-19 pandemic. More specifically, the supply chain networks for Small and Medium Enterprises (SMEs) were exposed to various risks and disrupted more significantly than large organisations during and after the covid-19 era due to these disruptions and limited resources. This study uses the fuzzy set theory to present a conceptual framework for a comprehensive supply chain risk assessment in SMEs during uncertain times. A case study illustrates the efficacy of the proposed conceptual framework for post-covid-19 risk assessment in SMEs in a developing country. The proposed framework evaluates the overall risk index in SMEs based on seven Supply Chain Risk (SCR) factors and 42 associated attributes. In addition, twenty SCR attributes are identified as the main SCR obstacles according to their fuzzy supply chain risk index.

1. Introduction

Small and Medium-Sized Enterprises (SMEs) play a crucial role in the economic development of most nations [43,63]. SMEs are thought to be the backbone of the economy because they make up about 90% of the businesses and 50 % of the employment worldwide. These employments are created both in cities and in rural areas [46]. Formal SMEs are contributing almost 40 % of the Gross domestic product (GDP) in emerging economies. In other words, SMEs are integral part of economy in terms of its contribution towards employment generation, GDP, export and lending. With the presence of this scale, when an event disrupts the supply chain of SMEs, it not only affects the supply of organisation but also negatively affect entire economy of the country. The Covid-19 pandemic affected both the domestic and international supply chain networks, globally, the COVID-19 pandemic imposed numerous risks and nearly brought the global market to a standstill [1,54]. It was also noticed that the small and medium-sized enterprises around the world were hit the hardest [11,12,19]. In addition, Global GDP is likely to be affected by 2.3–4.8 % [49]. The major reasons for these losses are raw material shortage, uncertainty in the demand, disruptions in supply chain network and other transportation problems. Large enterprises are capable of dealing with these problems to some extent, but due to limited resources SMEs are not in a position to deal with these issues [35]. Covid-19 pandemic posed an existential threat to the SMEs [25,68] and the damages to SMEs due to Covid pandemic are not over yet and expected to last longer as compared to the large enterprises [6,41].

Rao et al. [45] noted that during the nationwide lockdown, a large number of small and medium-sized enterprises in the manufacturing and retail sectors are forced to temporarily close their doors. In addition, due to the loss of jobs and non-payment of wages and salaries by small and medium-sized businesses, many people migrated from urban to rural areas, which exacerbated the situation following the pandemic. Due to national complete lockdown imposed by several Governments around the world Manufacturing SMEs had halted their trade activities. Consequently, their supply chain networks were disrupted during and post pandemic. The relief packages provided by the governments were not sufficient in comparison with the loss incurred by the pandemic to SMEs. The growth of SMEs is critical for all countries in this age of globalisation [42,45]. SMEs sector faced high economic losses during pandemic and this sector is still trying to recover from the losses due to these disruptions. Several studies, including Dahles and Susilowati [14], Wedawatta and Ingirige [64], and Chang and Falit-Baiamonte [10], have assessed the effects of disasters on small and medium-sized enterprises (SMEs) and the policies that should be put in place after a disaster. Most of these studies focused on disasters like earthquakes, floods and Tsunami etc., but a study that focuses on post-pandemic scenario is rare specially in manufacturing SMEs sector.

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The kind of impact which a pandemic has on SMEs is different than from the natural disaster like earthquakes, floods and Tsunami etc. The natural disasters like earthquakes, floods and tsunami can cause immediate damage to a country's infrastructure, the effects of an epidemic can be much more severe and last much longer [32,48]. In such dynamic business environment, manufacturing SMEs have to realise the importance of Supply Chain Risk Management (SCRM) to make their supply chain robust against disruptions. To implement the SCRM, organisations must examine the risk-level of their supply chain, main Supply Chain Risk (SCR) variables and their attributes. Assessment of the risk-level is essential to understand the current risk exposure of the organisation's supply chain.

Based on the literature review on SCRM and expert opinion, this study identifies seven major risk variables in the post-covid era associated with the case organisation. A conceptual framework is proposed to determine the overall Risk Index of the organisation's supply chain using fuzzy logic approach. To ensure consistency and reliability of the data, fuzzy logic approach is used into this framework for assessment of risk index of supply chains [61]. This paper is primarily concerned with SCRM and risk variables in the context of manufacturing SMEs post-Covid. Identifying the relevant risk variables and prioritising these risk variables prepares the organisation to manage any future risk. The fuzzy-logic based approach followed in the article provides flexibility to respondents to capture the nuances of their opinion without losing the accuracy and comprehensiveness. In comparison to traditional questionnaires, fuzzy logic-based questionnaires can handle incomplete or noisy data more effectively. Fuzzy methods are also helpful when dealing with uncertainty, imprecision, subjective information, complex systems, expert knowledge, in order to capture and represent the inherent ambiguity and provide more flexible and nuanced analysis. The primary aims of this study are:

- to examine the key SCR variables related to manufacturing SMEs that significantly affect SCRM decision-making in the post-Covid era;
- to develop a conceptual framework for evaluation of the overall Risk Index of organisation's supply chain using Fuzzy-logic approach
- to assess all identified SCR variables/attributes and identify the main obstacles of SCRM on the basis of their fuzzy performance importance index in post Covid era.

The research is structured into following sections: Section 2 describes a brief discussion of the literature review on supply chain risk management, SCR variables, and their attributes as a result of the pandemic. Section 3 briefly explained the research methodology and proposed conceptual framework for evaluating Risk Index using fuzzy logic approach. Section 4 presented a practical case of a manufacturing SMEs. Results are presented in Section 5, finally, in Section 6, the research findings are concluded, along with the limitations of this study and the scope of future work.

2. Literature review

Supply chain risks arise from adverse incidents or activities which expose the supply chain to the threats and vulnerabilities which may adversely affect the product or services delivery of the supply chain or risk is a situation which pauses danger to the smooth functioning of the supply chain [40]. The uncertainty in global supply chain network activities, complicated government rules and financial crises have made the supply chains prone to different supply chain risks. The process of identification, assessment and mitigation of the supply chain risks is known as Supply chain risk management (SCRM) [4]. In Jan 2020, the World witnessed to Covid-19 pandemic, World Health Organisation (WHO) issued several advisories to deal with the pandemic. Governments around the world reacted to the pandemic in various ways, with the majority imposing new restrictions in order to control the virus's spread. But unfortunately, these measures were not able to control the spread of the disease. Approximately 578 million people were infected and 6.4 million people lost their lives due to the pandemic by July 2022 [65]. The restrictions which were setup to control the virus posed a problem to the supply chains as well. When the world is coming back slowly to normalcy, identifying and accessing the various risks to the supply chain (especially for SMEs) is of utmost importance. Covid-19 is a new type of environmental risk that causes supply chain interruptions, shortage of raw materials, uncertainty in demand, shortage of skilled manpower and increased lead time [17,20,22,44]. This study has been conducted to access all these risk factors in the light of Covid-19.

A few research studies have carried out on SCRM during Covid-19 on the different sectors, such as Ali et al. [2] studied the risk and resilience of the SMEs agri-food supply chains (AFSCs). Sharma et al. [51] proposed a supply chain vulnerability assessment (SCVA) framework for assessment of supply chain vulnerability drivers. [34] explained the term risk and vulnerability, they defined the risk is an outcome of a negative event, while vulnerability is driving force behind the risk. However, no study has focused on evaluation/assessment of risk index of organisational supply chain of manufacturing SMEs post-pandemic.

There are number of studies which focused on supply chain risk management during Covid-19 and these studies were from different domains. Ali et al. [2] studied the supply chain risk and resilience of the SMEs of agri-food supply chains and found that these supply chains are more vulnerable to disruptions due to their unique operational challenges. The qualitative research was conducted through the perspective of developed and developing countries. Shafiee et al. [50] highlighted the need of risk assessment as a tool to forecast the side-effects of Covid-19 on different supply chains. They identified the most important risks to the perishable product supply chains. Warasthe et al. [62] reviewed the literature regarding the risk management along with the issues of sustainability in the textile and apparel industry. Vali-Siar et al. [58] addressed the problem of disruption risks by adopting a number of different resilient strategies including multiple sourcing, facility fortification, adding extra production capacity, multi-channel distribution, and pricing. They developed a mathematical model based on two-stage stochastic approach to maximise the profit. They solved the model with the help of improved genetic algorithm (IGA) and an improved particle swarm optimisation (IPSO). SCRM was emphasised by de Oliveira et al. [15] to achieve long-term business sustainability. They conducted a field study for a Brazilian company to evaluate and identify potential risks in health services. Nimmy et al. [38] cited the importance of Artificial Intelligence (AI) in supply chain operational risk management. Bui et al. [9] cited the importance of Blockchain in the SCRM, they suggested that the blockchains can find application in authenticating the subjective information. Sajid [47] assessed the supply chain risks due to Covid-19 to a United States based biomass company. He predicted that it would take one year to recover from the maximum damage and five years to completely recover. Jomthanachai et al. [24] studied the supply chain risks from the perspective of global supply chain. They studied the case of 6 ASEAN countries and concluded that In terms of supply chain risks, Thailand was the most vulnerable, while Vietnam was the most resilient. According to their research, trading partners with lower risk and the ability to quickly recover their import volume reflect less vulnerable supply chains. El Baz and Ruel [18] studied the role of supply chain risk management (SCRM) in mitigating the effects of supply chain disruptions. Their findings revealed the mediating role of SCRM practices and the prominent role they play in fostering supply chain resilience and robustness. Kumar et al. [29] identified and analysed the risk mitigations strategies during Covid-19 for perishable food supply chains (PFSC). They discussed the uncertainties and risks related to the pandemic and then identified the risk mitigations strategies as well. They used the fuzzy extension of best worst analysis method for the study. Jana [23] explored the impact of supply chain risk on efficiency during Covid-19. He also developed two models namely the expected value model (EV model) and chance constrained model (CC model) using uncertain interval programming techniques. Oehmen et al., [39] proposed the system-oriented view for the SCRM. They implemented SCRM in their study through two models; a Supply Chain Risk Structure Model which describes the system that determines the causes and effects of supply chain risks. The second model, the Supply Chain Risk Dynamics Model, is used to model the possible dynamics of the risk development. They demonstrated the feasibility of these models through a case study comprising three companies. Kern et al. [26] made a model for managing risks in the upstream part of the supply chain. Their model linked risk identification, risk assessment, and risk mitigation to risk performance. They also checked the model by looking at 162 large and medium-sized German factories. Alkhalidi et al. [3] used Analytic Hierarchy Process (AHP) to come up with a model for figuring out how risky wind energy projects are. They used the model to figure out how risky two wind energy projects in Jordan were. Their model helped the people making the decisions come up with reasonable budgets and goals that could be reached for the project. Kumar Pradhan and Routroy [28] did study on the risks in the manufacturing supply chain, and they came up with a plan for managing risks in all manufacturing supply chains. Through a brainstorming session with managers and engineers, they found out about the different risks that manufacturing companies face. Lastly, these risks were put into groups based on the type of risk they were for further analysis, and management lessons were learned based on how much each risk affected the business. Venkatesh et al. [59] looked into the risks in retail supply chains for clothes. Using the Delphi method, they found expert opinions that could be controlled. They then used several other methods, including the principles of fuzzy logic, to figure out how these expert opinions depended on each other.

Moktadir et al. [37] came up with a model based on AHP to look at the risks of pharmaceutical supply chains. They came up with four major risks and sixteen smaller risks. Then, they used a case study of five pharmaceutical companies in Bangladesh to prove that these risks were real. They came to the conclusion that operational risks should be less important than supply-related risks. Macdonald et al. [33] found risk factors and the effects of identified risks and disruptions on performance. They used a structured experimental design with discrete-event simulations of SCs to learn more about the factors that link a disruption to its effect on SC performance through both direct and interaction effects. Since fuzziness in decision-making is not addressed by the traditional AHP technique, so Singh et al. [52] used fuzzy AHP to address the selection problem of parameter-influencing test in software development.

3. Research methodology and model development

Most of the conventional assessment tools are crisp and dichotomous such as true-or-false, yes-or-no. Whereas Fuzzy theory is opposite to the crisp system. This theory was introduced in 1965 by Lotfi A. Zadeh[66]. Empirical researches are mainly dependent on the expert's opinion, which may be ambiguous and imprecise. Vagueness of estimation can be reduced by using the fuzzy logic approach. Fuzzy logic is a problem solving and data mining tool, which is comparatively superior and efficient to conventional methods. Since its inception, this methodology became popular among researchers for development of different models in different fields of study such as artificial intelligence, social science, technology and management science. Several types of fuzzy numbers are available such as, Trapezoidal, Triangular and Gaussian fuzzy number.

In the present dynamic business environment, small manufacturing organisations have realised the importance of SCRM to make their supply chain robust against disruptions. To implement the SCRM, organisations must examine the risk-index of their supply chain, main SCR variables and their attributes. Assessment of the risk-index is essential to understand the current risk exposure of the organisation's supply chain. In this research, a conceptual framework is proposed to evaluate the risk-index of the supply chain using fuzzy logic approach as a research methodology. This study involves the evaluation of risk-level of the supply chain. A flow chart of proposed conceptual framework for risk-index evaluation process is shown in Fig. 1. Figure shows that a Fuzzy Logic Approach (FLA) was used to find the risk-index of the supply chain of case organisation. Experts' opinions were sought to determine the risk-index of the supply chain. Lin et al. [30] developed a fuzzy agility index (FAI) of the supply chain of a manufacturing organisation and also asserted that Fuzzy Logic is the most informative and reliable tool for decision making for complex and vague problems. Fuzzy Logic Approach (FLA) due to Lin et al. [30] was adopted to evaluate the risk-index and to identify the main obstacles of SCRM.

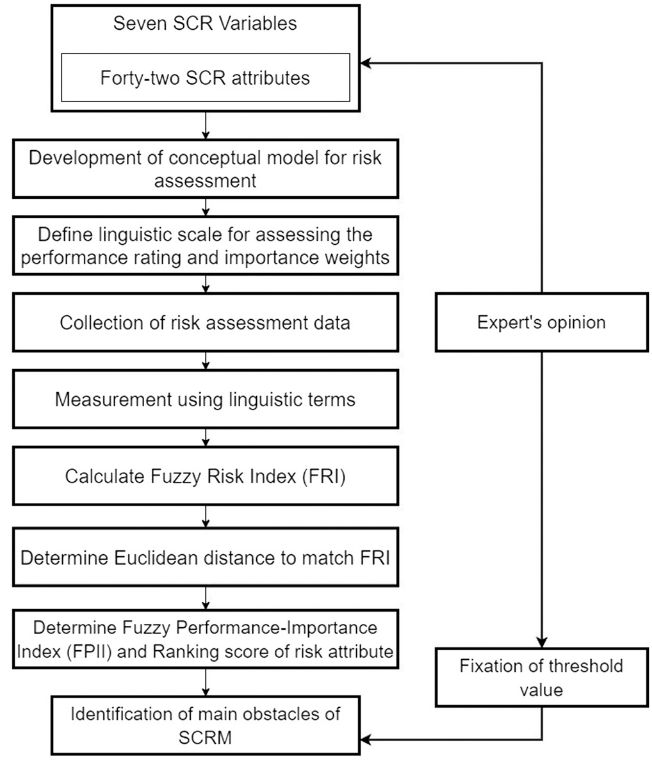

Fig. 1. Flowchart for evaluation of risk-level by Fuzzy Logic Approach (FLA).

3.1. Case study

The proposed conceptual framework has been demonstrated and verified on the Indian manufacturing SME to evaluate the Supply Chain Risk Index in post-covid-19 era. Due to confidentiality clause of the case organisation, it is referred as "ABC". The conceptual framework was discussed with Five Experts from the case organisation. The proposed conceptual framework has been demonstrated and validated on Indian manufacturing SMEs in order to evaluate the Supply Chain Risk Index in the post-covid-19 era. It is referred to as "ABC" due to the case organisation's confidentiality clause. The conceptual framework was discussed with Five Case Organisation Experts. Three of the five experts have master's degrees, one has a bachelor's degree, and one has a doctorate. One expert is the company's vice president, another is the chief of operations, and three are mid to senior level managers. Each expert has more than 18 years of experience in the industry. Despite the fact that experts are masters of their field, some biases may be possible to exist in their responses. With the help of linguistic scale, the fuzzy rating and weights were determined by these experts committee. Based on the experts committee opinion, the Risk Index of the case organisation's supply chain and the main obstacles of SCRM were finalised. The process of evaluation of risk-index and identification of main obstacles of SCRM is explained in the following sections:

Table 1
SCR variables and their attributes for evaluation of risk-level.

S.N.	SCR Variables	SCR attributes	Reference
1	Environmental Risk (ER)	ER1- Change in government regulation ER2- Natural disaster ER3- Seasonal production ER4- Political instability and Man-made disaster ER5- Economic imbalances ER6- Effect of pandemic such as Covid-19	Kersten[27], Hachicha and Elmsalmi,[21], Tang and Tomlin[55], Blome and Schoenherr[8], Babu et. al [5](2021b)
2	Information Technology Risk (IR)	IR1- IT system failure IR2- Distortions in information sharing IR3- Hacking, Virus and Cyber-attacks, etc. IR4- Physical damage in computer network	Chopra and Sodhi,[13] Diabat et al.[16], Babu et. al [5](2021b)
3	Supply Risk (SR)	SR1- Supplier fulfilment errors SR2- Financial failure of supplier SR3- Mismanagement in supplier selection SR4- Inflexible supply source SR5- Sluggish attitude in delivery performance SR6- Supply shortage due to Covid-19 restrictions	Zsidisin[67], Tummala and Schoenherr,[57], Blackhurst et al.[7], Babu et. al [5](2021b)
4	Process Risk (PR)	PR1- Internal labour strikes or shortages due to Covid-19 restrictions PR2- Lack of production planning and quality failures PR3- Lack of skilled employees PR4- Poor inventory management PR5- High production cost PR6- Inflexible manufacturing process PR7- Frequent changes in product/process designs	Tummala and Schoenherr,[57], Hachicha and Elmsalmi,[21], Babu et. al [5](2021b)
5	Transportation Risk (TR)	TR1- Higher freight charges TR2- Limited Port capacity TR3- Transporters issues/strikes TR4- Exorbitant paperwork and poor scheduling TR5- Selection of wrong transportation mode	Tummala and Schoenherr,[57], Soni and Kodali,[53], Babu et. al [5] (2021b)
6	Delay Risk (DE)	DE1- Delay due poor information/material flow DE2- Excessive handling due to border crossings DE3- Delay due to system failure DE4- Limited Port capacity DE5- Insensitiveness suppliers during Covid-19 DE6- Lengthy Custom clearance process DE7- Mismanagement in production processes	Tummala and Schoenherr,[57], Mohammaddust et al.[36], Babu et. al [5](2021b)
7	Demand Risk (DR)	DR1- Information distortion due to Bullwhip effect DR2- Unpredictability of Demand DR3- Inaccuracy in demand forecasting DR4- Shorter product life cycle DR5- Expansion in product range DR6- Exaggeration in Demand during Covid- 19 DR7- Information distortion due to Sales promotion	Chopra and Sodhi,[13], Babu et. al [5](2021b)

3.2. Identification of relevant SCR variables

Identification of relevant SCR variables is a crucial task when prioritising supply chain risk variables. For identifying relevant SCR variables for SMEs, the authors have utilised two methodologies (namely, primary and secondary research). Primary research includes survey methods and the like, while secondary research includes literature reviews and the like. The authors relied exclusively on peer-reviewed journal articles published between 2001 and 2022 to identify the pertinent risks for SMEs. Since the authors used both primary and secondary methodologies to identify relevant variables, the problem was discussed with industry and academic experts following a review of the literature. To obtain expert opinion, a pilot study was conducted with a panel consisting of one author of this paper, three academic experts, and eight industry experts. On the basis of the literature review, seven significant SCR variables and forty-two SCR attributes related to the case organisations' supply chain were identified.

Table 1 provides a deeper comprehension of the identified SCR variables and their attributes. A greater comprehension of SCR variables and SCR attributes reduces the SC's susceptibility. The table was compiled based on a review of the relevant literature, specifically Chopra and Sodhi [13], Tang and Tomlin [55], Tummala and Schoenherr [57], and Babu et al. [4,5].

3.3. Conceptual model for evaluation of the risk-level

With already identified seven SCR variables and their forty-two attributes, a conceptual model is developed with the help of industry experts for evaluation of the risk-level of the supply chain. This conceptual model is shown in Fig. 2. Fig. 2 shows the objective first followed by the SCR variables associated with problem. SCR variable divided into SCR attribute and is shown below each such variable. Nomenclature for SCR variable and associated attribute is also shown in Table 1.

3.4. Collection of data

The expert's judgements play a major role for assessment of importance weights and performance ratings of SCR variables and their attributes. For assessment of importance weights and performance ratings, linguistic terms are required to capture the expert's judgements [31]. Determination of linguistic scale is an important aspect of an

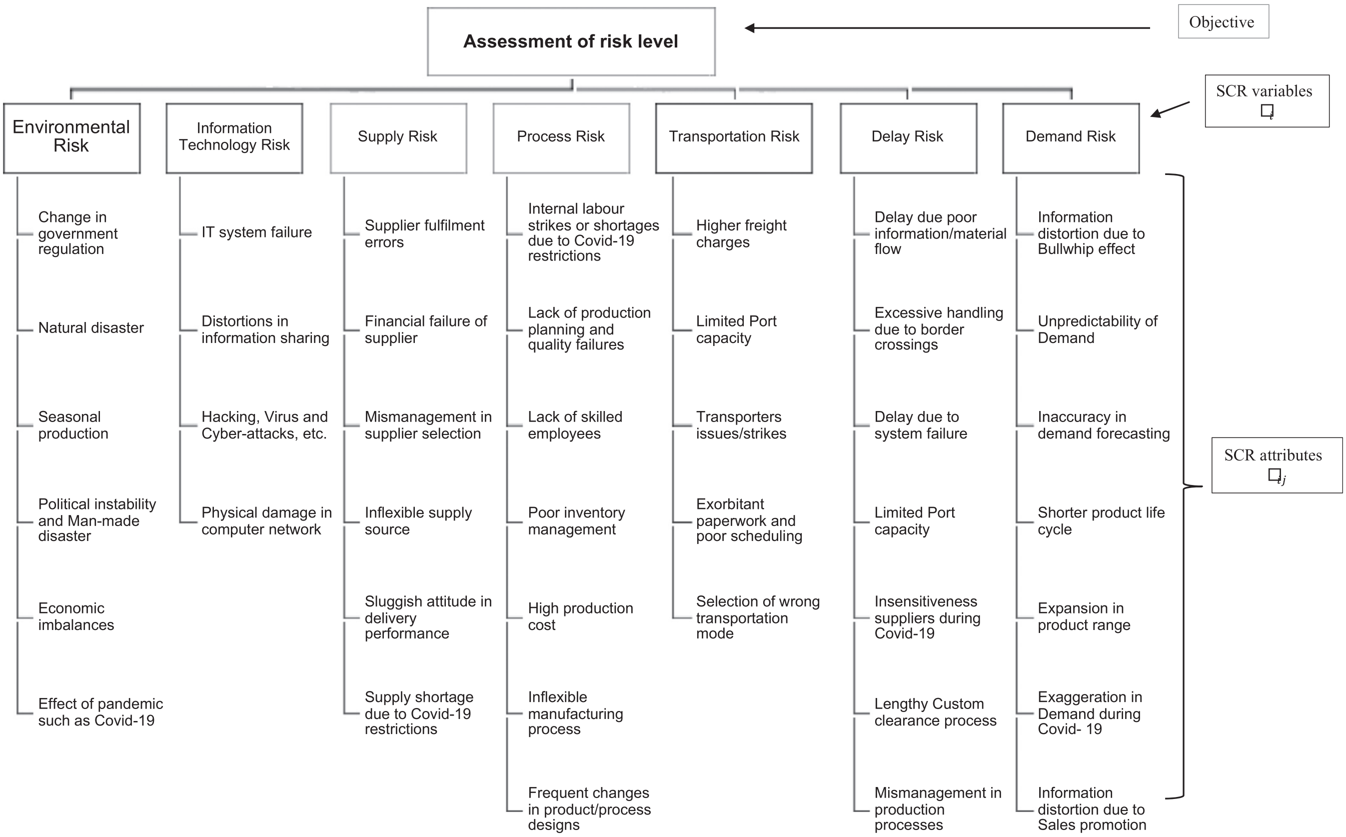

Fig. 2. Conceptual SCRM model for assessment of risk-level.

Table 2
Linguistic terms and fuzzy numbers (Lin et al., 2006b).

Performance ratings		Importance weights	
Linguistic variable	Fuzzy number	Linguistic variable	Fuzzy number
Worst (W)	(0, 0.5, 1.5)	Very low(VL)	(0, 0.05, 0.15)
Very poor (VP)	(1, 2, 3)	Low (L)	(0.1, 0.2, 0.3)
Poor (P)	(2, 3.5, 5)	Fairly low (FL)	(0.2, 0.35, 0.5)
Fair (F)	(3, 5, 7)	Medium (M)	(0.3, 0.5, 0.7)
Good (G)	(5, 6.5, 8)	Fairly high (FH)	(0.5, 0.65, 0.8)
Very good (VG)	(7, 8, 9)	High (H)	(0.7, 0.8, 0.9)
Excellent (E)	(8.5,9.5, 10)	Very high (VH)	(0.85, 0.95, 1.0)

empirical research to deal with impreciseness and ambiguity. Linguistic scale deals with conversion of qualitative data into quantitative data. For this purpose, a linguistic scale is obtained from the previous studies [31,56,60], which is exhibited in Table 2.

Experts were apprised about this linguistic scale. After determination of linguistic scale, the next step is to collect the data from the experts. In this study, five experts from the case organisation were approached to assess the performance ratings and importance weights of SCR variables and their attributes. The data is collected from the expert's opinion in the form of linguistic variables. Tables 3 and 4 reproduce such data as a sample. Table 3 shows the experts responses in linguistic terms for performance rating of the SCR Variable 'Environmental Risk' (ER). Similarly, Table 4 shows for importance weights of the SCR variable 'Environmental Risk' (ER). The linguistic data is collected from the experts are shown in Tables 3 and 4 by have the following notations:

W_i importance weight of SCR variable i.
R_{ij} performance rating of j^{th} SCR attribute of i^{th} variable.
W_{ij} importance weight of j^{th} SCR attribute of i^{th} variable.

Table 3
Performance rating of SCR variable 'Environmental Risk (ER)' in linguistic terms.

SCR Variables	SCR Attributes	R_{ij1}	R_{ij2}	R_{ij3}	R_{ij4}	R_{ij5}
ER	ER1	G	G	VG	G	VG
	ER2	VG	VG	G	G	G
	ER3	G	G	G	VG	G
	ER4	VG	G	G	G	G
	ER5	G	G	F	G	G
	ER6	G	F	G	F	F

Table 4
Importance weight of SCR variable 'Environmental Risk (ER)' in linguistic terms.

SCR Variables	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}	SCR Attributes	W_{ij1}	W_{ij2}	W_{ij3}	W_{ij4}	W_{ij5}
ER	VH	VH	H	VH	H	ER1	H	H	VH	H	VH
						ER2	VH	VH	H	VH	H
						ER3	FH	FH	H	H	H
						ER4	H	H	H	H	FH
						ER5	FH	M	M	FH	FH
						ER6	M	M	FH	FH	M

Table 5
Performance rating of SCR variable 'Environmental Risk (ER)' in Fuzzy numbers.

SCR Variables	SCR Attributes	R_{ij1}	R_{ij2}	R_{ij3}	R_{ij4}	R_{ij5}
ER	ER1	(5, 6.5, 8)	(5, 6.5, 8)	(7, 8, 9)	(5, 6.5, 8)	(7, 8, 9)
	ER2	(7, 8, 9)	(7, 8, 9)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)
	ER3	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)	(7, 8, 9)	(5, 6.5, 8)
	ER4	(7, 8, 9)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)
	ER5	(5, 6.5, 8)	(5, 6.5, 8)	(3, 5, 7)	(5, 6.5, 8)	(5, 6.5, 8)
	ER6	(5, 6.5, 8)	(3, 5, 7)	(5, 6.5, 8)	(3, 5, 7)	(3, 5, 7)

R_{ijk} performance rating of j^{th} SCR attribute of i^{th} variable given by expert k.
W_{ijk} importance weight of j^{th} SCR attribute of i^{th} variable given by expert k.

With the help of Table 2, the expert's opinion in the form of linguistic terms is converted into fuzzy numbers. Sample data of such converted values are shown in Tables 5 and 6 for Tables 3 and 4 respectively. After completion of conversion, this data is used for determination of average fuzzy importance weights and average performance ratings.

3.5. Determination of fuzzy importance weights and performance ratings

In this study, the performance ratings and importance weights are collected from the five experts of case organisation. Therefore, aggregation of data is essential step to get the final fuzzy importance weight and performance rating of each SCR variable. Arithmetic mean method is used in the present research to aggregate the opinion collected from 'n' number of expert's. The calculation of average performance ratings (R_{ij}) and average importance weights (W_{ij}) of SCR attributes and average importance weights (W_i) are carried using the following equations [30,61].

$$R_{ij} = \frac{R_{i1} + R_{i2} + ...+R_{in}}{n} \tag{1}$$

$$W_{ij} = \frac{W_{i1} + W_{i2} + ...+W_{in}}{n} \tag{2}$$

$$W_{i} = \frac{W_{1} + W_{2} + ...+W_{n}}{n} \tag{3}$$

Where,
W_i = importance weight of SCR variable i;.
R_{ij} = Performance rating of j^{th} SCR *attribute of* i^{th} *SCR variable;*.
W_{ij} = importance weight of j^{th} SCR *attribute of* i^{th} *SCR variable;*.

As a sample calculation, average fuzzy performance rating of the SCR-attribute *'Change in Government regulation' (ER1)* is calculated as follows:

$$R_{11} = \frac{[G + G + VG + G + VG]}{5}$$

$$R_{11} = \frac{[(5, \quad 6.5, \quad 8) + (5, \quad 6.5, \quad 8) + (7, \quad 8, \quad 9) \quad + (5, \quad 6.5, \quad 8) \quad + (7, \quad 8, \quad 9)]}{5}$$

$$R_{11} = (5.80, 7.10, 8.40)$$

Similarly, average fuzzy importance weight of the SCR-attribute *'Change in Government regulation (ER1)* is calculated as follows:

$$W_{11} = \frac{[H + H + VH + H + VH]}{5}$$

$$W_{11} = \frac{[(0.7,0.8, \quad 0.9)+ (0.7,0.8, \quad 0.9) \ + (0.85, \quad 0.95, \quad 1.0)+ (0.7,0.8, \quad 0.9)+(0.85,0.95,1.0) \quad]}{5}$$

$$W_{11} = (0.76, 0.86, 0.94)$$

The average fuzzy importance weights and average fuzzy performance ratings of SCR variable 'Environmental Risk' (ER) are shown in Table 7. Similarly, average fuzzy importance weights and average fuzzy performance ratings of all the SCR variables and their attributes is calculated, which is exhibited in Table 8.

3.6. Calculation of fuzzy risk index (FRI)

The Fuzzy Risk Index (FRI) of the organisation is calculated by considering SCR attributes then SCR variables. It consolidates the fuzzy weights and fuzzy ratings for all the SCR variables and SCR attributes. In order to compute *FRI*, the risk index (*RI*) of each SCR variable [30,61] is calculated at as follows.

$$RI_i = \frac{\sum_{j=1}^{n} (W_{ij} \times \quad R_{ij})}{\sum_{j=1}^{n} W_{ij}} \tag{4}$$

where,
RI_i = Risk index of i^{th} SCR variable; W_i = importance weight of i^{th} SCR variable;.
R_{ij} = Performance rating of j^{th} SCR attribute of i^{th} SCR variable;.
W_{ij} = Importance weight of j^{th} SCR attribute of i^{th} SCR variable;

$$FRI = \frac{\sum_{i=1}^{n} (W_i \times \quad RI_i)}{\sum_{j=1}^{n} W_i} \tag{5}$$

Using the Eq. 4, Calculation of Risk Index of SCR variable 'Environmental Risk' (ER) is as follows;

Table 6
Importance weight of SCR variable 'Environmental Risk (ER)' in Fuzzy numbers.

SCR-V	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}	SCR-A	W_{ij1}	W_{ij2}	W_{ij3}	W_{ij4}	W_{ij5}
ER	(0.85, 0.95, 1.0)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	ER1	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)
						ER2	(0.85, 0.95, 1.0)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)
						ER3	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
						ER4	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.5, 0.65, 0.8)
						ER5	(0.5, 0.65, 0.8)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)
						ER6	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)	(0.3, 0.5, 0.7)

SCR-V: SCR-Variable, SCR-A: SCR-Attribute

$$R_{i1} = \begin{bmatrix} (0.76,\ 0.86,\ 0.94) \times (5.80,\ 7.10,\ 8.40)+ \\ (0.79,\ 0.89,\ 0.96) \times (5.80,\ 7.10,\ 8.40)+ \\ (0.62,\ 0.74,\ 0.86) \times (5.40,\ 6.80,\ 8.20)+ \\ (0.66,\ 0.77,\ 0.88) \times (5.40,\ 6.80,\ 8.20)+ \\ (0.42,\ 0.59,\ 0.76) \times (4.60,\ 6.20,\ 7.80)+ \\ (0.42,\ 0.59,\ 0.76) \times (3.80,\ 5.60,\ 7.40) \end{bmatrix} \Big/ \begin{bmatrix} (5.80,\ 7.10,\ 8.40)+ \\ (5.80,\ 7.10,\ 8.40)+ \\ (5.40,\ 6.80,\ 8.20)+ \\ (5.40,\ 6.80,\ 8.20)+ \\ (4.60,\ 6.20,\ 7.80)+ \\ (3.80,\ 5.60,\ 7.40) \end{bmatrix}$$

$R_{i1} = (5.31,\ 6.69,\ 8.10)$

Similarly, Risk index for other SCR variables are calculated, and shown in Table 9.

Using the Eq. 5, calculation of Fuzzy Risk Index (FRI) is as follows:

$$FRI = \begin{bmatrix} (0.79,\ 0.89,\ 0.96) \times (5.31,\ 6.69,\ 8.10)+ \\ (0.76,\ 0.86,\ 0.94) \times (5.23,\ 6.66,\ 8.08)+ \\ (0.72,\ 0.86,\ 0.92) \times (6.30,\ 7.51,\ 8.65)+ \\ (0.73,\ 0.83,\ 0.92) \times (6.06,\ 7.31,\ 8.52)+ \\ (0.69,\ 0.80,\ 0.90) \times (5.29,\ 6.68,\ 8.10)+ \\ (0.58,\ 0.71,\ 0.84) \times (4.71,\ 6.25,\ 7.82)+ \\ (0.72,\ 0.83,\ 0.92) \times (5.94,\ 7.21,\ 8.46) \end{bmatrix} \Big/ \begin{bmatrix} (5.31,\ 6.69,\ 8.10)+ \\ (5.23,\ 6.66,\ 8.08)+ \\ (6.30,\ 7.51,\ 8.65)+ \\ (6.06,\ 7.31,\ 8.52)+ \\ (5.29,\ 6.68,\ 8.10)+ \\ (4.71,\ 6.25,\ 7.82)+ \\ (5.94,\ 7.21,\ 8.46) \end{bmatrix}$$

$FRI = (5.57,\ 6.92,\ 8.25)$

This *FRI* is now matched with the appropriate linguistic level.

3.7. Matching fuzzy risk index (FRI) with the corresponding linguistic level

After obtaining the FRI, it is matched with the natural linguistic risk level(RL_i) by identifying the closest membership function of fuzzy risk index. In the literature, several methods are available to match the fuzzy index with linguistic terms such as successive approximation and Euclidean distance. Euclidean distance method is recognised as most intuitive method for perceiving proximity [30], hence the same method is used in the present research. The Euclidean distance $D(FRI, RL_i)$ from the fuzzy risk index to linguistic risk level is calculated by using Eq. 6 [56,61].

$$D(FRI, RL_i) = \left\{ \sum_{x \in p} (U_{FRI}(x)) - U_{FLi}(x))^2 \right\}^{1/2} \tag{6}$$

Where, $U_{FLi}(x)$ represent the membership functions of the *FRI*.

$U_{FRI}(x)$ represent the membership functions of linguistic risk level.

Sample calculation of Euclidean distance using the formula 6 for the linguistic term 'High risk level' shown as (5.5, 7.0, 8.5) is calculated as follows:

$D(FRI, High) = \{(5.57 - 5.5)^2 + (6.92 - 7.0)^2 + (8.25 - 8.5)^2\}^{1/2}$

$D(FRI, High) = 0.27$

The linguistic variable and their Euclidean distance to FRI for each linguistic variable for the case organisation are calculated and shown in Table 10.

After matching the *FRI* to the linguistic level, the risk-level of supply chain of the case organisation is analysed. Table 10 shows that minimum Euclidean distance is 0.27 i.e., FRI (5.57, 6.92, 8.25) is closely matching with the linguistic variable 'High' (5.5, 7, 8.5). This has been graphically shown in Fig. 3. Knowing the risk level as 'High' for the case organisation, an effort has been made to identify the important SCR attributes contributing to this risk-level by calculating FPII.

3.8. Determine fuzzy performance-importance index (FPII)

The risk-level of the supply chain of case organisation is found to be "High", which is very far away from risk-level 'Low'. Some SCR attributes have a high impact while determining the risk level. These SCR attributes can be treated as the main obstacles and the same can be identified by using the fuzzy performance importance index (FPII). FPII

Table 7
Average fuzzy weights and fuzzy ratings of SCR variable 'Environmental Risk' (ER).

SCR Variables	Average fuzzy weight	SCR Attributes	Average fuzzy weight	Average fuzzy rating
ER	(0.79, 0.89, 0.96)	ER1	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		ER2	(0.79, 0.89, 0.96)	(5.80, 7.10, 8.40)
		ER3	(0.60, 0.74, 0.86)	(5.40, 6.80, 8.20)
		ER4	(0.66, 0.77, 0.88)	(5.40, 6.80, 8.20)
		ER5	(0.42, 0.59, 0.76)	(4.60, 6.20, 7.80)
		ER6	(0.38, 0.56, 0.74)	(3.80, 5.60, 7.40)

can be calculated by using the following equations [30,61].

$$FPII = W'_{ij} \times R_{ij} \tag{7}$$

$$W'_{ij} = [(1,\ 1,\ 1) - W_{ij}] \tag{8}$$

Where,

R_{ij} = Performance rating of j^{th} SCR attribute of i^{th} SCR variable;.

W_{ij} = Importance weight of j^{th} SCR attribute of i^{th} SCR variable;.

Using above equations, Calculation of FPII of SCR attribute '*Change in Government regulation*' (ER1) is as follows;

$$FPII_{ER1} = \{(1,\ 1,\ 1) - W_{ij}\} \times R_{ij}$$

$$FPII_{ER1} = \{(1,\ 1,\ 1) - (0.76,\ 0.86,\ 0.94)\} \times (5.80,\ 7.10,\ 8.40)$$

$$FPII_{ER1} = (0.24,\ 0.14,\ 0.06) \times (5.80,\ 7.10,\ 8.40)$$

Table 9
Risk index for each SCR Variable.

SCR Variable	Importance weight ($\boldsymbol{W_i}$)	Performance rating ($\boldsymbol{RI_i}$)
Environmental Risk (ER)	(0.79, 0.89, 0.96)	(5.31,6.69,8.10)
Information Technology Risk (IR)	(0.76, 0.86, 0.94)	(5.23,6.66,8.08)
Supply Risk (SR)	(0.72, 0.86, 0.92)	(6.30,7.51,8.65)
Process Risk (PR)	(0.73, 0.83, 0.92)	(6.06,7.31,8.52)
Transportation Risk (TR)	(0.69, 0.80, 0.90)	(5.29,6.68,8.10)
Delay Risk (DE)	(0.58, 0.71, 0.84)	(4.71,6.25,7.82)
Demand Risk (DR)	(0.72, 0.83, 0.92)	(5.94,7.21,8.46)

Table 8
Average fuzzy weights and fuzzy ratings of SCR variables/SCR attributes.

SCR Variables	Average fuzzy weight	SCR Attributes	Average fuzzy weight	Average fuzzy rating
Environmental Risk (ER)	(0.79, 0.89, 0.96)	ER1	(0.76, 0.86, 0.94	(5.80, 7.10, 8.40)
		ER2	(0.79, 0.89, 0.96)	(5.80, 7.10, 8.40)
		ER3	(0.62, 0.74, 0.86)	(5.40, 6.80, 8.20)
		ER4	(0.66, 0.77, 0.88)	(5.40, 6.80, 8.20)
		ER5	(0.42, 0.59, 0.76)	(4.60, 6.20, 7.80)
		ER6	(0.38, 0.56, 0.74)	(3.80, 5.60, 7.40)
Information Technology Risk (IR)	(0.76, 0.86, 0.94)	IR1	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		IR2	(0.79, 0.89, 0.96)	(6.10, 7.40, 8.60)
		IR3	(0.54, 0.68, 0.82)	(4.20, 5.90, 7.60)
		IR4	(0.54, 0.68, 0.82)	(4.20, 5.90, 7.60)
Supply Risk (SR)	(0.72, 0.86, 0.92)	SR1	(0.76, 0.86, 0.94)	(7.20, 8.30, 9.20)
		SR2	(0.79, 0.89, 0.96)	(6.90, 8.00, 9.00)
		SR3	(0.62, 0.74, 0.86)	(4.20, 5.90, 7.60)
		SR4	(0.79, 0.89, 0.96)	(6.50, 7.70, 8.80)
		SR5	(0.79, 0.89, 0.96)	(7.60, 8.60, 9.40)
		SR6	(0.50, 0.65, 0.80)	(4.20, 5.90, 7.60)
Process Risk (PR)	(0.73, 0.83, 0.92)	PR1	(0.50, 0.65, 0.80)	(3.80, 5.60, 7.40)
		PR2	(0.79, 0.89, 0.96)	(7.60, 8.60, 9.40)
		PR3	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		PR4	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		PR5	(0.82, 0.92, 0.98)	(7.20, 8.30, 9.20)
		PR6	(0.65, 0.77, 0.88)	(5.40, 6.80, 8.20)
		PR7	(0.72, 0.83, 0.92)	(5.80, 7.10, 8.40)
Transportation Risk (TR)	(0.69, 0.80, 0.90)	TR1	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		TR2	(0.58, 0.71, 0.84)	(4.60, 6.20, 7.80)
		TR3	(0.53, 0.68, 0.82)	(3.80, 5.60, 7.40)
		TR4	(0.79, 0.89, 0.96)	(6.20, 7.40, 8.60)
		TR5	(0.62, 0.74, 0.86)	(5.40, 6.80, 8.20)
Delay Risk (DE)	(0.58, 0.71, 0.84)	DE1	(0.50, 0.65, 0.80)	(4.20, 5.90, 7.60)
		DE2	(0.38, 0.56, 0.74)	(3.40, 5.30, 7.20)
		DE3	(0.69, 0.80, 0.90)	(5.80, 7.10, 8.40)
		DE4	(0.46, 0.62, 0.78)	(3.80, 5.60, 7.40)
		DE5	(0.46, 0.62, 0.78)	(5.40, 6.80, 8.20)
		DE6	(0.66, 0.77, 0.88)	(4.20, 5.90, 7.60)
		DE7	(0.61, 0.74, 0.86)	(5.40, 6.80, 8.20)
Demand Risk (DR)	(0.72, 0.83, 0.92)	DR1	(0.79, 0.89, 0.96)	(5.80, 7.10, 8.40)
		DR2	(0.79, 0.89, 0.96)	(6.20, 7.40, 8.60)
		DR3	(0.82, 0.92, 0.98)	(7.60, 8.60, 9.40)
		DR4	(0.69, 0.80, 0.90)	(6.50, 7.70, 8.80)
		DR5	(0.66, 0.77, 0.88)	(5.40, 6.80, 8.20)
		DR6	(0.54, 0.68, 0.82)	(4.60, 6.20, 7.80)
		DR7	(0.58, 0.71, 0.84)	(4.60, 6.20, 7.80)

Table 10
Natural Linguistic terms and fuzzy numbers for risk level.

Linguistic variable	Fuzzy Number	Euclidean distance
Very High (VH)	(7.0, 8.5, 10)	D (FRI, VH) = 2.76
High (H)	(5.5, 7, 8.5)	D (FRI, H) = 0.27
Moderate (M)	(3.5, 5, 6.5)	D (FRI, M) = 3.32
Low (L)	(1.5, 3, 4.5)	D (FRI, L) = 6.78
Very Low (VL)	(0, 1.5, 3)	D (FRI, VL) = 9.38

$FPII_{ER1} = (1.39, 0.99, 0.50)$

Accordingly, FPII for all forty-two SCR attributes are calculated, are shown in Appendix-C. In the literature, several methods are available to rank the FPIIs. In the past researches, centroid method is widely used for ranking, hence the same method is used in this research. The computation of ranking score of each risk-attribute is done with the help of centroid method for membership function (a, b, c) as given in Eq. 6.9, where a, b and c are the lower, middle and upper values of triangular fuzzy number [61]. For example, a = 1.39, b = 0.99, c = 0.50 for $FPII_{ER1}$.

$$\text{Ranking Score} = \frac{a + 4b + c}{6} \tag{9}$$

Using above equation, calculation of Ranking Score of SCR attribute '*Change in Government regulation*' (ER1) is as follows;.

$$\text{Ranking Score} = \frac{1.39 + 4 \times 0.99 + 0.50}{6} = 0.98$$

Similarly, Fuzzy Performance Importance Index (FPII) and Ranking Score of each risk-attribute is calculated and shown in Table 11.

4. Results and discussions

From Table 11, Ranking Score of each risk-attribute are compared with the threshold value. A threshold value is required to identify the obstacles of SCRM. With the help of experts, the threshold value is determined to 1.40 for this case organisation. SCR attributes having ranking score less than determined threshold value are identified as main obstacles to SCRM. A Scatter plot of the FPII of all SCR-attributes is plotted and shown in Fig. 4. Based on threshold value and ranking score of SCR attribute, 20 SCR attributes are identified as main obstacles of SCRM. Table 12 shows the ranking score of these SCR attributes. The supply chain manager should primarily focus on these risk attributes to make supply chain more robust.

The findings of this study indicate that it has been almost 2.5 years since the beginning of the pandemic the fear of Covid-19 still persist in SMEs but at the same time other types of risks are now taking precedence in the post-Covid era. The SMEs were seriously threatened by Covid-19, and many of them were completely destroyed by the pandemic. A thorough examination of the risk factors is extremely helpful in the post-Covid-19 environment, when SMEs are working extremely hard to make a comeback. These findings can be used as a reference for managers to pinpoint and rank the key risk factors for their company. A better understanding of the various risk variables, as well as their prioritisation, assists the company in better preparing for the future. A higher risk variable needs more of the attention and resources available.

The findings of this study also provide useful guidance to managers in their decision-making processes. This enables them to make informed resource allocation decisions, focusing on the risks that pose the greatest threat to their business. SMEs can optimise their risk management efforts and improve their overall preparedness by allocating attention and resources based on the level of risk associated with each factor. In conclusion, this study sheds light on the ongoing impact of Covid-19, the shifting risk landscape in the post-pandemic era, and the critical need for SMEs to proactively manage and prioritise risk factors. SMEs can minimise potential disruptions, and position themselves for long-term success in a dynamic and uncertain business environment by understanding and addressing these risks.

5. Conclusion and future scope

The modern supply chain operates in a dynamic business environment and is exposed to a number of supply chain network-related risks. These supply chain risks cannot be eliminated entirely, but their impact can be mitigated by proactively evaluating the supply chain's risk level and developing a risk management plan to mitigate their effect. Risk level would provide information about the supply chain's exposure to risk and the major SCR variables and their attributes, allowing SC managers to select a more effective risk management strategy. Consequently, in the post-Covid era, the evaluation of supply chain risk has become essential for organisations to thrive in a dynamic, competitive environment.

A supply chain risk assessment framework is developed in this study using a Fuzzy-logic approach. Following development, this framework is used to assess the risk level for identified SCR variables and SCR attributes that have a significant impact on the case-organisation's supply chain. Each SCR attribute's and variable's Risk Index (RI) is identified. The fuzzy risk index (FRI) is calculated using these risk indices to represent the risk level of the case organisation's supply chain. The FRI is matched to the linguistic level, and the risk-level of the case organisation's supply chain is determined to be "High." SC managers must understand the main SCRM obstacles in order to improve risk management and reduce supply chain risk. FPII is calculated for each SCR attribute to determine the main supply chain obstacles. To identify the main barriers to SCRM, SCR attributes with ranking scores are compared to a threshold value. The threshold value of 1.40 was determined by expert opinion. Twenty SCR attributes are identified as major SCRM obstacles based on their threshold value and ranking score. To reduce the risk level from 'High' to 'Low' or 'Very low,' the supply chain manager should prioritise these twenty SCR attributes. This model assists supply chain managers in assessing risk levels and

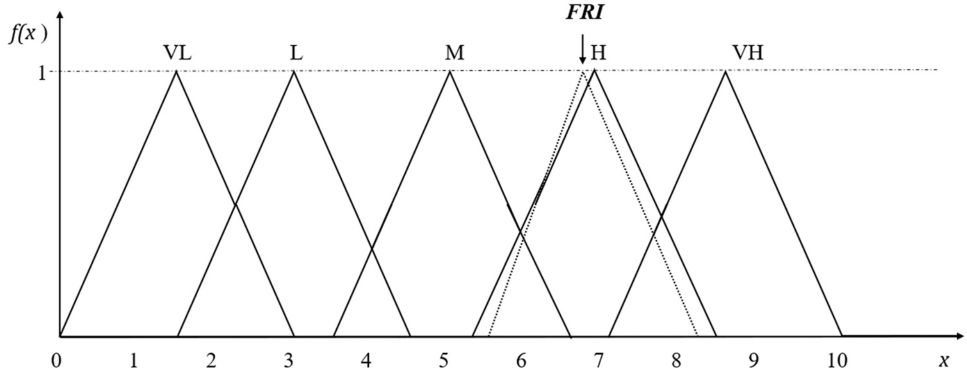

Fig. 3. Matching the Fuzzy Risk Index (*FRI*) with the standard linguistic level.

Table 11
Fuzzy Performance Importance Index (FPII) and Ranking Score of SCR Attributes.

SCR Attributes	FPII	Ranking score
ER1- Change in government regulation	(1.39, 0.99, 0.50)	0.98
ER2- Natural disaster	(1.22, 0.78, 0.34)	0.78
ER3- Seasonal production	(2.05, 1.77, 1.15)	1.71
ER4- Political instability and Man-made disaster	(1.84, 1.56, 0.98)	1.51
ER5- Economic imbalances	(2.67, 2.54, 1.87)	2.45
ER6- Effect of pandemic such as Covid-19	(2.36, 2.46, 1.92)	2.36
IR1- IT system failure	(1.39, 0.99, 0.50)	0.98
IR2- Distortions in information sharing	(1.28, 0.81, 0.34)	0.81
IR3- Hacking, Virus and Cyber-attacks, etc.	(1.93, 1.89, 1.37)	1.81
IR4- Physical damage in computer network	(1.93, 1.89, 1.37)	1.81
SR1- Supplier fulfilment errors	(1.73, 1.16, 0.55)	1.15
SR2- Financial failure of supplier	(1.45, 0.88, 0.36)	0.89
SR3- Mismanagement in supplier selection	(1.60, 1.53, 1.06)	1.47
SR4- Inflexible supply source	(1.37, 0.85, 0.35)	0.85
SR5- Sluggish attitude in delivery performance	(1.60, 0.95, 0.38)	0.96
SR6- Supply shortage due to Covid-19 restrictions	(2.10, 2.07, 1.52)	1.98
PR1- Internal labour strikes or shortages due to Covid-19 restrictions	(1.90, 1.96, 1.48)	1.87
PR2- Lack of production planning and quality failures	(1.60, 0.95, 0.38)	0.96
PR3- Lack of skilled employees	(1.39, 0.99, 0.50)	0.98
PR4- Poor inventory management	(1.39, 0.99, 0.50)	0.98
PR5- High production cost	(1.30, 0.66, 0.18)	0.69
PR6- Inflexible manufacturing process	(1.89, 1.56, 0.98)	1.52
PR7- Frequent changes in product/process designs	(1.62, 1.21, 0.67)	1.19
TR1- Higher freight charges	(1.39, 0.99, 0.50)	0.98
TR2- Limited Port capacity	(1.93, 1.80, 1.25)	1.73
TR3- Transporters issues/strikes	(1.79, 1.79, 1.33)	1.71
TR4- Exorbitant paperwork and poor scheduling	(1.30, 0.81, 0.34)	0.82
TR5- Selection of wrong transportation mode	(2.05, 1.77, 1.15)	1.71
DE1- Delay due poor information/material flow	(2.10, 2.07, 1.52)	1.98
DE2- Excessive handling due to border crossings	(2.11, 2.33, 1.87)	2.22
DE3- Delay due to system failure	(1.80, 1.42, 0.84)	1.39
DE4- Limited Port capacity	(2.05, 2.13, 1.63)	2.03
DE5- Insensitiveness suppliers during Covid-19	(2.92, 2.58, 1.80)	2.51
DE6- Lengthy Custom clearance process	(1.43, 1.36, 0.91)	1.29
DE7- Mismanagement in production processes	(2.11, 1.77, 1.15)	1.72
DR1- Information distortion due to Bullwhip effect	(1.22, 0.78, 0.34)	0.78
DR2- Unpredictability of Demand	(1.30, 0.81, 0.34)	0.82
DR3- Inaccuracy in demand forecasting	(1.37, 0.69, 0.19)	0.72
DR4- Shorter product life cycle	(2.02, 1.54, 0.88)	1.51
DR5- Expansion in product range	(1.84, 1.56, 0.98)	1.51
DR6- Exaggeration in Demand during Covid- 19	(2.12, 1.98, 1.40)	1.91
DR7- Information distortion due to Sales promotion	(1.93, 1.80, 1.25)	1.73

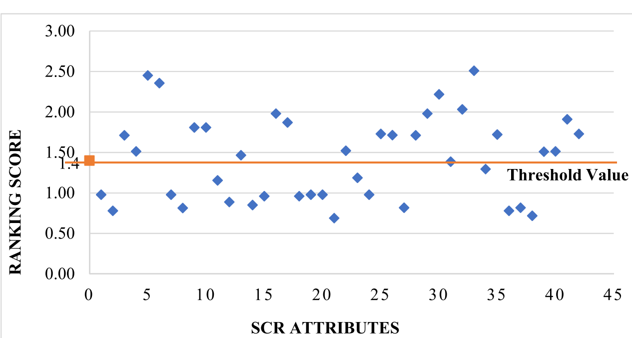

Fig. 4. Scatter chart of the FPII of all SCR-attributes.

prioritising risks while implementing supply chain risk management.

The findings of this case study are based on an assessment of Indian manufacturing small and medium-sized enterprises (SMEs). While the study's focus was limited to this specific group, the findings are thought to accurately depict the current situation in Indian manufacturing SMEs post-COVID-19. These findings shed light on the challenges, practises, and dynamics confronting these SMEs at the time. Future research should include multiple case studies conducted across various enterprises and sectors to further enhance and refine the supply chain risk assessment model developed in this study. By broadening the scope of the investigation, a more comprehensive understanding of supply chain risks and assessment methods can be gained, thereby contributing to the model's ongoing improvement and applicability in a variety of business contexts.

Table 12
Main obstacles of SCRM.

SCR Attributes	Ranking score
ER1- Change in government regulation	0.98
ER2- Natural disaster	0.78
IR1- IT system failure	0.98
IR2- Distortions in information sharing	0.81
SR1- Supplier fulfilment errors	1.15
SR2- Financial failure of supplier	0.89
SR4- Inflexible supply source	0.85
SR5- Sluggish attitude in delivery performance	0.96
PR2- Lack of production planning and quality failures	0.96
PR3- Lack of skilled employees	0.98
PR4- Poor inventory management	0.98
PR5- High production cost	0.69
PR7- Frequent changes in product/process designs	1.19
TR1- Higher freight charges	0.98
TR4- Exorbitant paperwork and poor scheduling	0.82
DE3- Delay due to system failure	1.39
DE6- Lengthy Custom clearance process	1.29
DR1- Information distortion due to Bullwhip effect	0.78
DR2- Unpredictability of Demand	0.82
DR3- Inaccuracy in demand forecasting	0.72

Declaration of Competing Interest

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.

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