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A business continuity-based framework for risk management in smart supply chains: a fuzzy multi-criteria decision-making approach

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Abstract: The aim of this study is to develop a novel framework for managing risks in smart supply chains by enhancing business continuity and resilience against potential disruptions. This research addresses the growing uncertainty in supply chain environments, driven by both natural phenomena-such as pandemics and earthquakes—and human-induced events, including wars, political upheavals, and societal transformations. Recognizing that traditional risk management approaches are insufficient in such dynamic contexts, the study proposes an adaptive framework that integrates proactive and remedial measures for effective risk mitigation. A fuzzy risk matrix is employed to assess and analyze uncertainties, facilitating the identification of disruptive events and the selection of appropriate risk treatment plans. Moreover, the framework leverages a fuzzy reasoning system in conjunction with a multi-criteria decision-making method to process ambiguous information, thereby enhancing decision accuracy and reliability. The findings demonstrate that this comprehensive approach not only prioritizes risks effectively but also supports companies in refining their response strategies, ensuring the efficient delivery of services under challenging conditions. Ultimately, the study redefines resilience as a dynamic process of navigating and adapting to chaos rather than merely resisting it.

1 Introduction

Any unfavorable element that prevents companies from achieving their strategic, financial, or operational goals can be described as a risk. In this regard, the risk for profit-driven companies is a potential source of company losses [1,2]. Supply Chains (SCs) are becoming more vulnerable to disruptive events, putting all stakeholders at risk. For the supply chain to be robust, sustainable, and aligned with corporate goals, managing these risks and mitigating their consequences is essential. The uncertainties and risks involved in supply chain operations have increased because of the new reality and configuration of the supply chain [3]. Business Impact Analysis (BIA) and risk assessment are key elements of BCS, both of which look to find and rank the most important organizational resources. I have recently referred to this idea as Business Continuity (BC), i.e., the ability of the organization to support the supply of products and services within reasonable times with predefined capacity during an interruption (Schmid et al., 2021).

Smart technologies and recent advances in technology, as well as the emergence of big data technologies, have led to the emergence of the so-called Smart Supply Chain (SSC [4] . An interconnected network system optimizes the flow of information between physical infrastructure and cyberspace in smart factories and Industry 4.0. With the help of advanced data management and analytics tools, we expect the entire system to function optimally with the help of the smart supply chain [5]. A smart supply chain enhances competitive advantage in speed, flexibility, risk reduction, cost reduction, and storage control. The smart supply chain also plays a role in achieving environmental, social, and economic sustainability, and enhances the long-term performance of companies. A smart supply chain assists solve a lot of productivity and sales problems [6], as well as improved scheduling processes [7] which achieve customer satisfaction [8].

Risk assessment is one of the key stages in risk management, where managers and system developers can respond appropriately to various risks by assessing the potential threats and risks faced by the smart supply chain. Therefore, BC provides many risks treatment programs [9]. Risk assessment entails decisions about the acceptance of risks according to established criteria, while risk analysis involves the systematic use of information available to find risks. Risk assessment refers to the complete procedure of risk analysis and assessment [10]. The logical method of risk assessment is risk evaluation, which considers the potential effects of potential accidents on people, materials, goods, equipment, and the environment [11]. It is difficult for companies to make a final and exact decision about the level of risk and its consequences that sabotage their supply chains, which are considered one of their most essential capabilities. Thus, a wide range of methods is available for addressing fuzzy information through the utilization of fuzzy numbers, and these methods can likewise be extended to the analysis of fuzzy data obtained from experts., many papers have previously used fuzzy logic and the FMCDM approach to assess risk [9]. In the same context, the proposed framework is based on assessing the risks faced by the smart supply chain and proposing proper treatment plans according to the impact and consequences of the risk. It is worth mentioning that BC inspires the risk assessment process and treatment plans. The FBWM algorithm and the Fuzzy Inference System (FIS) are applied to process fuzzy information at the risk analysis stage.

In the first phase of the proposed Smart Supply Chain Risk (SSCR) framework, the researchers conducted a comprehensive survey of the earlier literature and consulted with experts to find the Main risk factors and sub-risk factors. In this way, we found the main SSCRs, which consist of information systems, reliability and integration, infrastructure, operational issues, the environment, and service risks. As for the second stage, the risks are analyzed and consist of two steps. In the first step, weight is decided by each risk according to the opinion of experts. In the second stage, two questionnaires are prepared. The first questionnaire consists of two axes: the vertical axis has risk factors, while the horizontal axis has risk impact, and it does this through the linguistic terms of TFNs. In addition, a list of risk impact factors that have disruptive effects on the company's performance is decided. As for the second questionnaire, it also has two axes, and it aims to show the relationship between risk factors and their consequences. The above stages are considered inputs to the third stage, as in this stage the risks whose impact and consequences on the supply chain have been calculated. At this stage, the fuzzy risk assessment matrix is applied, which consists of three different points of view (soft, standard, and hard) given by [12], based on this, the appropriate program is determined for each category of risks to which the SSC is exposed. BC inspires treatment plans. These plans consist of four programs: the first (accepted), the second (Mitigate), the third (stop), and the last (business continuity). Based on the above stages, a model of the proposed framework is prepared. The following is an outline of the proposed framework's main contributions.

2 Literature review

2.1 Smart supply chain

Since there is no widely agreed-upon definition of terms like "digital supply chain," "smart supply chain," "industrial internet," and "supply chain 4.0," all of which are closely related to the idea of industrial advancement through technological innovations, general descriptions are hard to fathom. What distinguishes the traditional supply chain from the smart supply chain is its reliance on the information network as the basis for information transfer [13]. Its purpose is to share information and highly integrate the information flow with each part of the supply chain, thus improving response time and product quality, reducing resource consumption, and increasing the company's ability to make quick and correct decisions [14]. On the other hand, supply chains are now more vulnerable to shocks and disruptions because of their increasing globalization and interdependence. No company is immune as supply chains grow more intertwined. Supply chains must become smarter to effectively manage risks and achieve company goals [15].

SSC is gradually becoming a key strategy to promote sustainable development [16], due to its feasibility in achieving economic, environmental, and social benefits [17], as well as to be able to face challenges [13]. By exchanging data in real-time, the underlying technologies help with faster selections and transactions. These enable cross-functional technologies such as the Internet of things, cloud computing, big data analytics, artificial intelligence, and blockchain. [18], as well as cloud computing and RFID systems [19]. A pivotal role in the shift towards the smart supply chain. A digital platform that connects all components in the supply chain enables flexibility, traceability, and visibility in a smart supply chain. We have found that SSC offers new insights and characteristics compared to traditional supply chains [17].

A smart supply chain has many financial, environmental, regulatory, and social challenges [20] The most prominent of which is the high cost of smart devices, particularly RFID, as the design and pricing of software and smart operation systems for the process are the main obstacles to the smart supply chain [19]. On the other hand, a smart supply chain needs regular attention and significant financial investment. In addition, the team will need to move towards more advanced technology applications, and this may require redefining the team [21]. Improved collaboration among supply chain participants has been shown to reduce overall costs and improve delivery service. Furthermore, [22,23] discovered that the intelligent supply chain supports collaboration between consumers and the entire organization, from the distribution of completed items to the production and acquisition of raw materials to interact with suppliers of goods and services. Studies have also shown that enhanced supply chain collaboration has resulted from increased digital transformation [4]. By carefully regulating the flow of suppliers, the idea of a smart supply chain performs the entire logistical chain from supplier to customer, no matter where they are located [24], On the other hand, a smart supply chain brings great benefits to the manufacturer [25]. It assists them implement smart manufacturing [5].

2.2 Smart supply chain risk and business continuity

Smart Supply Chain Risk (SSCR) refers to the process of creating a strategy and working to find, assess, and mitigate risks in the entire supply chain. Supply chain risk management is the second-biggest concern of any company's executives [15], For this reason, there are various methodologies adopted in the assessment and analysis of risks, such as the Failure Mode and Effects Analysis (FMEA) methodology [11], and ARAMIS methodology, which is used to meet the requirements of SEVESO II [26]. It should be noted that BC is part of the Risk Treatment Plans (RTPs) that companies adopt to face operational risks (i.e., risks that have a minimal impact but have high consequences for the critical activities of the organization). Someone proactively provides these plans to recover and resume disrupted activities post-disruption [9]. On this basis, BC is described as a strategic and comprehensive management process that relies on risk management techniques, identifies the risks to which the organization is exposed, which result from natural or man-made disasters, and provides alternative responses to the impact of such disasters that can enable organizations to deal effectively with a crisis with minimal disruption to their basic operations [27].

In the past ten years, organizations have become more aware that not being prepared to deal with disruptive situations can have disastrous results. Business Continuity Management (BCM) is a new strategy to mitigate these disruptive risks [28]. BC refers to the advanced planning and preparation made to guarantee that a company's critical business functions can function normally in an emergency [29]. Emergencies include things like pandemics, corporate crises, natural catastrophes, workplace crimes, and other incidents that stop regular company operations [30,31]. In this paper, the risks of the smart supply chain are found and analyzed to select treatment plans according to the impact of the risks and their consequences (Figure 1). It conducted this through a framework inspired by BC.

Organizations all around the world are increasingly aware of how important it is to create BC strategies [32]. Regardless of the business model, firms are working in a more complicated, dangerous, and global environment [33]. Events relating to the economy, society, politics, technology, and the environment may interfere with fundamental operations [34]. Growth and performance can be significantly affected by natural disasters, illnesses, terrorist attacks, strikes, financial crises, unreliable systems, logistical breakdowns, supply chain failures, and unanticipated shortages of key manufacturing inputs [35]. A goal should be the creation of established plans that consider the risk assessment of business interruption, the definition of strategic and tactical plans, initiative-taking management, and response readiness [36].

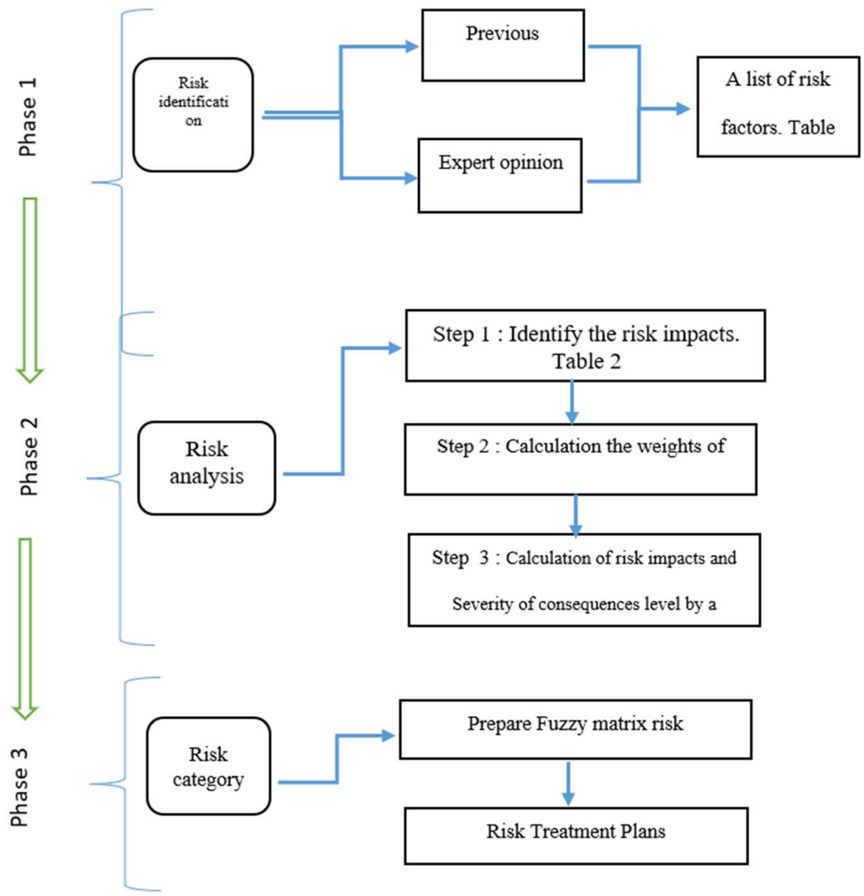

Figure 1 The response to (SSCR) inspired BC

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3 The proposed framework: preparing the fuzzy risk matrix

3.1 Risk identification

The smart supply chain faces various risks, so the first phase will be to show those risks (see Table 1), to include them in the proposed framework. We relied on earlier research papers to identify these risks, as well as the opinions of experts obtained through conducting many field interviews. The output will be a list of Main risk factors and sub-risks.

3.2 Risk analysis

After finding the risks facing the smart supply chain shown in Table 1 in the first stage, we analyze them in the second stage. This process requires three steps:

Identify the risk's impact: The impact of risks is determined by reviewing the relevant literature and expert opinions (see Table 2). It is worth noting that these factors may vary according to the organization's policies and capabilities, which are used to estimate the overall impact of risks [9].

Calculation of the weights of risk impact factors: In this step, the impact weights are calculated for each of the risks included in the list (see Table 4). In this regard, the method of [37], is applied, as is the consistency ratio calculated for each risk profile using the Fuzzy Best-Worst Method (FBWM) [38].

Calculation of risk impacts and severity of consequences: A questionnaire was prepared to collect expert opinions on the impact of each risk and the Severity of consequences. Therefore, the linguistic terms (TFNs) were prepared in Table 3. Due to the lack of correct quantitative data, this paper uses terminology to deal with uncertainties due to the lack of knowledge that experts have about providing correct parameters [39].

Table 1 Main and sub-risk factors

Main risk	Symbol	Sub-risk (SR)	References
Information Technology Risks	SR1	Security and system integrity	[20] [14]
	SR2	Complexity and collaborative risk across the chain	[20] [14]
	SR3	Unavailability of blockchain tools	[20]
	SR4	Database	[9]
	SR5	The risk of security breaches	
Reliability and integration	SR6	Cooperation	
	SR7	Control	[14]
	SR8	Transparency	New
	SR9	Sustainability	New
Infrastructure	SR10	Business Smart Support is weak	[14] [20]
	SR11	Network infrastructure failures or errors	
	SR12	Technology limitations	[20]
Operational issues	SR13	Lack of training for staff System documentation	[40]
	SR14	Not systematically managed	
	SR15	Inventory levels are unstable	New
	SR16	Operating costs	New
	SR17	Low predictability of supply and demand	(Omar F. Hassan Al-obaidy, 2023)
Environmental	SR18	Increased weste	[46]
	SR19	Water damage at the server	
	SR20	Lightning attacks Earthquake	
Service risks	SR21	Customer satisfaction	[14]
	SR22	Delay in providing the service	New

Table 2 Risk impact typer factors

Risk impact (RI)	References
Fragility of the supply chain. RI1	[41]
Difficulties in increasing production capacity. RI2	[41]
Difficulty maintaining a smooth flow of raw materials. RI3	(Omar F. Hassan Al-Obaidy, 2023)
Flexibility losses. RI4	[9]
Financial losses. RI5	[9]
Reputation losses. RI6	[9]
loss of cooperation. RI7	Experts
Weak competitiveness. RI8	[14]
Loss of time and control. RI9	Experts
Unexpected risks appear. RI10	Experts

Table 3 Triangular fuzzy numbers (TFN) Linguistic terms of FR and SC and RC

Risk impact		Severity consequences SC		Risk category RC	
Very high (VL)	(1,1,2)	Negligible (N)	(0,0,1)	Acceptable (A)	(0,0,0.5)
High (H)	(1,2,3)	Low (L)	(0,1,2)	Tolerable–acceptable (TA)	(0,0.4,0.7)
Moderate (M)	(2,3,4)	Moderate (M)	(1,2,3)	Tolerable–unacceptable (TU)	(0.5,0.7,0.9)
Low (L)	(3,4,5)	High (H)	(2,3,4)	Unacceptable (UN)	(0.85,1,1.3)
Very low (VL)	(4,5,6)	Catastrophic (C)	(3,4,5)		
Unlikely (U)	(5,6,7)				
Remote (R)	(6,7,7)				

The main and sub-risks constitute the cornerstone of this paper, so classifying these risks into main and sub-risks is due to the nature of the risk itself, as few research papers give a comprehensive classification of the risks of the smart supply chain, some of which focus on a specific company or a specific sector, such as [14] or the paper [20] that addressed barriers to implementing Blockchain in reverse logistics. In this sense, many of the classifications in Table 1 refer to the opinions of experts in showing some sub-risks. The current study focuses on identifying those risks that affect the organization’s activities and critical activities. To understand the consequences of risks if they are not considered, this study identifies several types of factors for the impact of these risks on the organization. Hence, Table 2 has prepared for this purpose.

The impact of the risks referred to in Table 2 is not final. There may be other impact factors that were not included in the current study. The inclusion of these factors was based mainly on previous literature that dealt with these effects in its content. To achieve the main aim of this paper, the factors most affecting the critical activities of the organization were relied upon, which could have catastrophic results if neglected or ignored. Therefore, the focus was on these factors as more comprehensive factors.

Two questionnaires were designed; each of these forms has two main parts. The first form consists of two axes; it is the vertical axis that includes the risks that were collected based on earlier literature and expert opinions, i.e., using the collective decision-making model, these risks are divided into main risks and sub-risks. These risks differ from one organization to another and from one country to another, according to their ability, viability, and competitive position. However, there may be other risks that are not included in the list, and this is due to the nature of the database available on the research papers available on the Internet. The second axis that the questionnaire has is the horizontal axis, which includes the impact of risks. The second form also consists of two axes: the vertical axis has risk factors, while the horizontal axis includes Severity consequences for each of the risks included in the vertical axis. The factors that are criteria for measuring severity consequences were collected through earlier literature and after presentation to experts and filtering. To calculate the weight of each risk, reliance was placed on [37].

Table 4 Risk impact weights

Risk impct (RI)	**RI_1**	**RI_2**	**RI_3**	**RI_4**	**RI_5**	**RI_6**	**RI_7**	**RI_8**	**RI_9**	**RI_{10}**
Weights	0.0952	0.1111	0.0873	0.1190	0.1587	0.1507	0.0476	0.0714	0.1031	0.0555

4 Risk category: implementing a fuzzy risk matrix

After the process of finding the risks, their impact, and the consequences of those risks, their category in terms of impact and the consequences of this impact are determined. In this step, the Fuzzy Matrix Risk (FMR) is relied upon to classify risks: acceptable (A), tolerable-acceptable (TA), tolerable-unacceptable (TU), and unacceptable (UN). Where this classification was adopted as rules for determining the category of each of these risks and their consequences. Figure (2) shows a description of all four categories and the characteristics of each category. The FRM Fuzzy Risk Matrix (FRM) is a risk assessment tool that uses fuzzy logic to assess risk impact and severity consequences. This phase is considered one of the basic steps of the BC model, so the risk assessment process depends mainly on the risk identification process as its input. Figure 3 shows the risk matrices that will be adopted in determining the relationship between the impact of risks and their consequences and the category of each of these risks. The easy matrix is the one that has a low cost, but its layers of protection are less to provide safety against risks. On the other hand, there is the Hard matrix, which has a prohibitive cost but is more secure. As for the Standard matrix, it mediates between the two and is the most used.

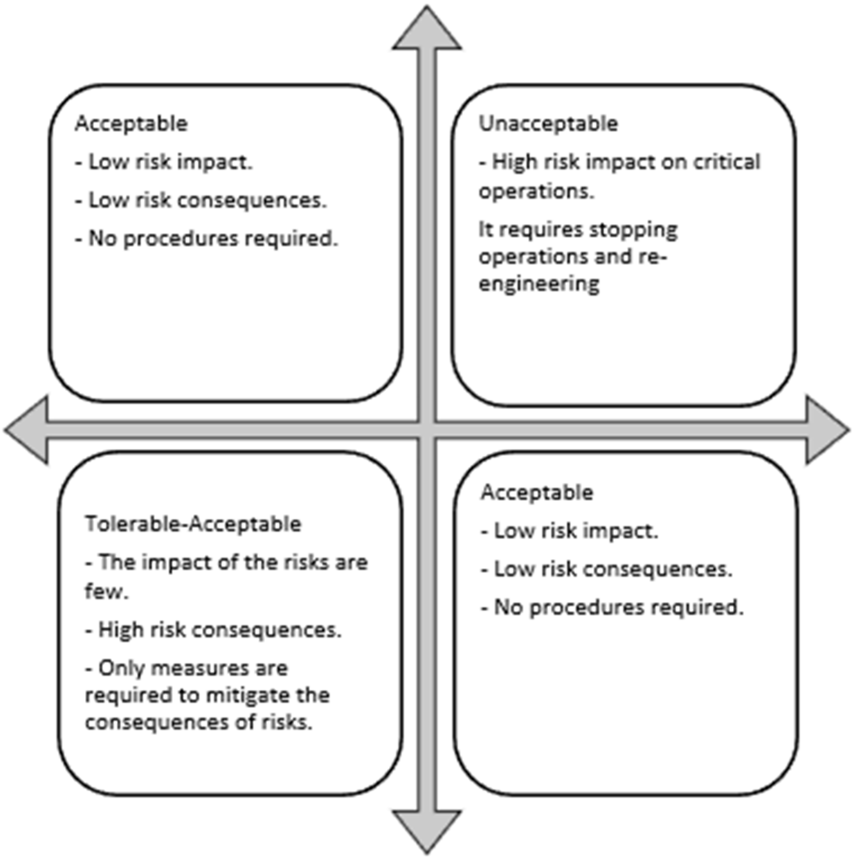

Figure 2 Characteristics of risk categories

The matrix is prepared for the purpose of determining the relationship between the impact of risks and the consequences of those risks on the critical operations of the organization. As we mentioned earlier, the risk categories are rules for defining the relationship between the impact of risk and its consequences to determine that relationship according to the rules that control that relationship. Four categories are taken into consideration for the risk scale [12]. Thus, by combining various levels of influence and consequences of influence (5 * 7 * 4), a total of 140 rules are extracted. However, only 35 of the 140 rules are accepted by experts and adopted in this paper [9].

The process of dealing with risks requires different procedures according to the category of each risk and its position in the matrix. Therefore, the main purpose of the matrices is to divide the risks into categories, determine the proper methods of dealing with each category, and identify those that require special tools, such as those provided by business continuity. [9] introduced an algorithm called Risk Treatment Plans (RTPs). This algorithm consists of four risk treatment programs according to each category:

- Acceptable: the risk impact and their consequences are low, do not require any procedures to deal with them, and are present in most organizations.
- Mitigate: Tolerable-Acceptable, meaning that risks have a low impact but high consequences. Therefore,

the organization requires measures to mitigate risks and a mixture of BC plans.

- Stop: Tolerable-Unacceptable, meaning that the impact of risks and their consequences is high, and therefore the organization needs to mitigate the risk and its consequences. If there is no treatment, the process can be stopped and re-engineered.
- Continuity plan: if the risks fall into the Unacceptable category, and thus the critical tasks of the organization are disrupted, the most proper solution is to use continuity plans to overcome such risks.

The algorithm provides the proper flexible decisions for each of the risk categories above by providing different treatments for each risk according to the matrices (easy, standard, and hard). These three matrices are used in this study according to the specified rules. These rules depend mainly on the approved inputs, which contribute to decoding the defuzzifier. To decipher this defuzzifier, the method of [42], was used. Figure 3 shows the inputs and outputs of the fuzzy data and processing it. On the other hand, the FRM is the most likely approach that is based on the total value of risk. To make the appropriate decision regarding the appropriate measures, confidence scores are calculated to determine the low, medium, and high-risk categories, while the confidence ratio is used to determine the acceptability of risks at a certain level to determine the appropriate treatments based on them [9].

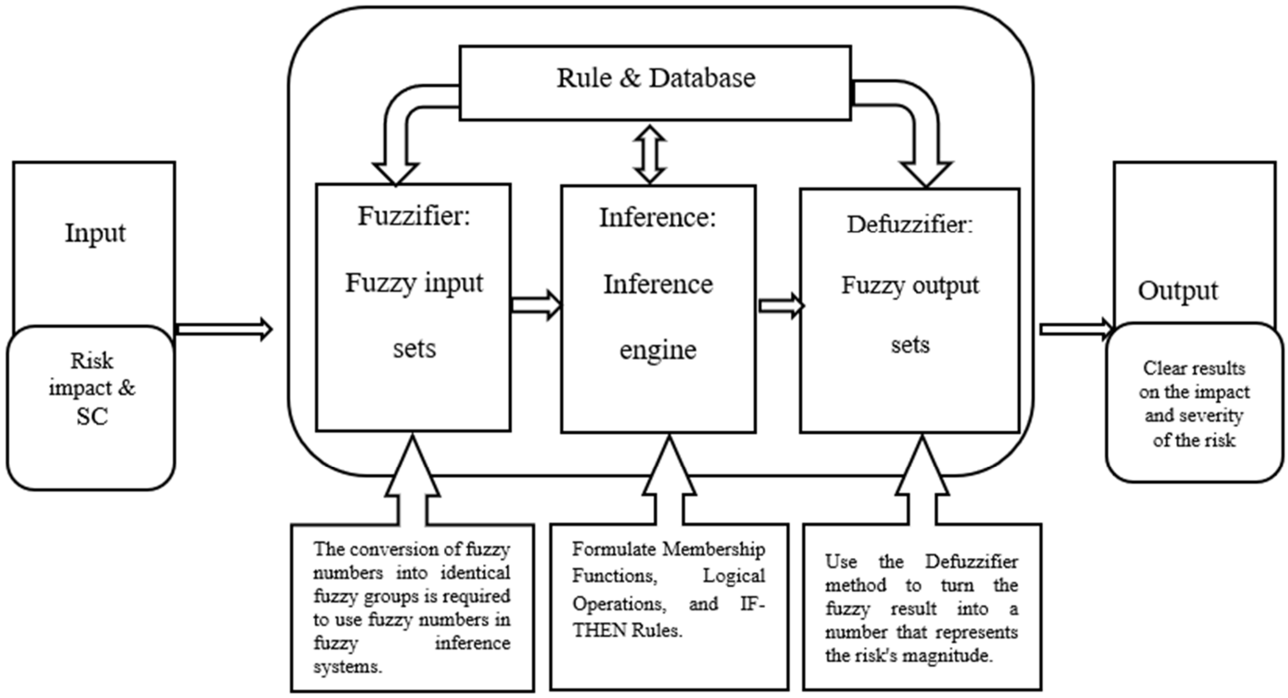

Figure 3 FIS used for constructing the SSC risk matrix

5 Results and discussion

In this section, a risk weight is calculated for each type of risk factor that was identified in the first phase. Therefore, the MCDM-enabled [38] algorithm was used for this purpose. So, acceptable, or unacceptable risks are determined according to the impact of the risks and their consequences, to determine the appropriate program and the extent to which each of these risks needs a mitigation, stop, or continuity plan. A risk weight is calculated for each type of risk factor identified in the first stage. Therefore, an algorithm that supports MCDM was used for this purpose. Thus, acceptable or unacceptable risks are determined according to the impact of the risk and its consequences. Consequently, the appropriate program is then determined and the extent to which each of these risks needs mitigation, cessation, or a continuity plan.

To measure the impact of risks and their consequences, the equations shown in Appendix 1 were used, as the impact of risks and their consequences are based on the questionnaire prepared for this purpose. It is worth noting that the impact of risk and its consequences, as well as the overall risk level, are measured using the equation used by [9], which is used to measure risk at the level of the three matrices (easy, standard, and hard). A threshold value is considered the main criterion in determining the type of program required for each risk category. Risks whose threshold value is low are considered acceptable. As for risks whose threshold value is critical, the Stop program must be approved, i.e., the risks impact and their consequences are high. On the other hand, when the impact of risks is significant on critical tasks, a program of continuity plans must be proposed. It is worth noting that some risks require merging more than one program, and this is what the threshold value determines for the impact of the risk and its consequences. The threshold value that we referred to is the difference between the impact of the risk and its consequences. In this study, a threshold value was determined for the merge, which is 18%–4%, and this means that if the difference ranges between 18%–4% according to the threshold value, then the Mitigate program can be adopted, but if the threshold value is 18%–26). Here, BC plans must be approved, and if this value is exceeded, the process requires stopping and acting. Also, the consistency ratio appeared within acceptable levels, amounting to 0.079. Whenever the consistency ratio is close to zero, it shows that there is consistency in the responses received from the experts [43]. On the other hand, Table 5 shows the necessary statistical tests, the aim of which is to ensure the reliability of the proposed framework, where the Reliability coefficient of α was measured, as well as the measurement of alpha, corrected, and correlation for each of the risk factors.

Table 5 Reliability analysis

Main risks	Sub-risk (SR)	Corrected and correlation	Alpha	Reliability coefficient of α
Information Technology Risks	SR1	0.6241	0.9014	0.8247
	SR2	0.5831	0.9102	
	SR3	0.4872	0.8724	
	SR4	0.2542	0.8724	
	SR5	0.3648	0.918	
Reliability and integration	SR6	0.5201	0.8814	0.7625
	SR7	0.6635	0.9153	
	SR8	0.4692	0.8614	
	SR9	0.6103	0.8714	
Infrastructure	SR10	0.6541	0.8913	0.7991
	SR11	0.3648	0.89471	
	SR12	0.5935	0.9075	
Operational issues	SR13	0.5671	0.9054	0.8402
	SR14	0.5534	0.8725	
	SR15	0.6203	0.8941	
	SR16	0.6154	0.9087	
	SR17	0.5107	0.8646	
Environmental	SR18	0.6482	0.8936	0.8354
	SR19	0.4725	0.8874	
	SR20	0.5032	0.9254	
Service risks	SR21	0.5165	0.9158	0.7862
	SR22	0.5948	0.8725	

To obtain weight for the impact of risks, a standard questionnaire was prepared for this purpose. The weights shown in Table 4 show the impact of each risk. It is worth noting that these weights are the opinions of the 34 experts, where experts in different companies accounted for 62%, while experts in the academic field amounted to approximately 38%. The goal of diversifying experts is to achieve a balance between practical and academic realities. As shown in Table 4, there is a discrepancy in the impact of risks on the basic functions of the company, where financial losses and reputational losses are the highest weight; in contrast, the loss of cooperation constitutes the least impact. As we mentioned before, to calculate the overall impact of risks and their consequences for the three matrices (easy, standard, and hard), Table 6 was prepared for this purpose.

Table 6 The overall risk scale

Sub-risk	Severity consequences	Impact of risk	Overall risk	Sub-risk	Severity consequences	Impact of risk	Overall risk
SR1	0.084018	0.183788	0.210467	SR12	0.262239	0.573641	0.656912
SR2	0.177808	0.38895	0.445411	SR13	0.090244	0.197405	0.226061
SR3	0.22489	0.491941	0.563352	SR14	0.271181	0.5932	0.67931
SR4	0.23192	0.507319	0.580962	SR15	0.242302	0.53003	0.60697
SR5	0.114338	0.250112	0.286419	SR16	0.198972	0.435246	0.498427
SR6	0.264799	0.579242	0.663325	SR17	0.153724	0.336267	0.38508
SR7	0.216942	0.474555	0.543442	SR18	0.119152	0.260642	0.298477
SR8	0.076856	0.16812	0.192524	SR19	0.028148	0.061572	0.07051
SR9	0.196064	0.428885	0.491143	SR20	0.027511	0.060179	0.068915
SR10	0.230256	0.503678	0.576793	SR21	0.27858	0.609386	0.697845
SR11	0.188678	0.412728	0.47264	SR22	0.24574	0.53755	0.615582

Risks that have a high impact require more time, effort, and costs, so that executives can face the consequences of these risks. The results presented in Table 6 indicate the total risks according to the easy, standard, and difficult matrix. Where the easy matrix requires less effort, time, and cost, given that it does not take the size risks proactively with important levels of preparation and therefore does not require resources at elevated levels. The hard matrix is the opposite of the easy matrix, as it requires more resources to prepare for expected risks proactively, and this is what makes it a costly matrix. On the other hand, the standard matrix is considered the most balanced, as it requires resources at medium levels, and this is what makes it the most used by companies. Deciding the type of mitigation plan depends on threshold values, and these represent the difference between the impact of the risk and its consequences. Referring to the threshold values, it becomes clear that most of the risks require a mixed plan, see Table 7. It is worth mentioning that many risks need to be re-engineered, that is, a stopping program must be adopted, given that the specified risk limits are exceeded. Some risks can be accepted, see Figure 4, and they do not need any measures, due to their minimal impact and consequences. On the other hand, there are risks whose consequences are high and their impact is low or vice versa. Therefore, such risks need mitigation measures inspired by BC plans, that is, a combination of mitigation plans and business continuity.

Table 7 Threshold values between the impact risk and severity consequences

Sub-Risk	**SR1**	**SR2**	**SR3**	**SR4**	**SR5**	**SR6**	**SR7**	**SR8**	**SR9**	**SR10**	**SR11**
Threshold Values	0.099	0.2111	0.2670	0.2753	0.1357	0.3144	0.2576	0.0912	0.2328	0.2734	0.224
Sub-Risk	**SR12**	**SR13**	**SR14**	**SR15**	**SR16**	**SR17**	**SR18**	**SR19**	**SR20**	**SR21**	**SR22**
Threshold Values	0.3114	0.1071	0.3220	0.2877	0.2362	0.1825	0.141	0.0334	0.0326	0.3308	0.291

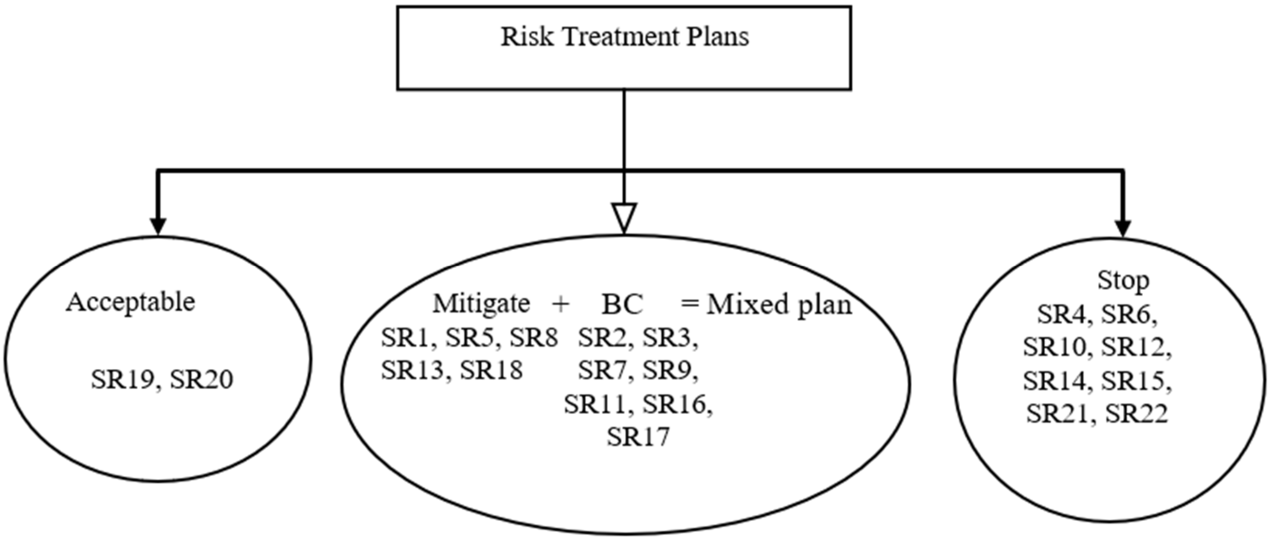

Figure 4 Classification of risks according to the risk treatment plans

6 Managerial implications

The supply chain of any company is like a lifeline. Therefore, the risks that affect it are like a deadly epidemic. On this basis, this study provides a framework to mitigate the effects of this epidemic by presenting programs that mitigate risks inspired by BC faced by the smart supply chain. Therefore, there are several administrative implications for the proposed framework, whose application could improve the performance of the supply chain. The proposed framework helps line managers visualize risks that have devastating effects on the supply chain and thus develop proper actions proactively.

The proposed framework helps companies expect the impacts (Table 3) that could affect them in case of the expected risks (Table 1). The proposed framework offers many advantages, most notably the classification of risks in terms of impact and consequences and, thus, the ability to understand the application of the ISO 22301:2019 standard. On the other hand, companies can receive help from measuring risks in a quantitative manner and through three different points of view (easy, standard, and difficult), which makes the risk assessment and analysis process more comprehensive and correct. The proposed framework was based on three basic stages. In the first stage, risks, and the effects of risks on SSC were found. In the second stage, the risks that were found in the first stage were analyzed using several appropriate techniques. In the third stage, risks were classified. According to threshold values, proper mitigation plans are decided for each risk category.

In addition, the proposed framework offers practical guidance for companies, as some risks related to information technology can be avoided through organizing training courses and improving infrastructure, while others require the presence of skilled human resources. It is worth noting that some risks require building resilience as well as using risk transfer mechanisms such as insurance and diversifying suppliers.

7 Conclusion remarks

In the last ten years, the expansion of the virtual world and technology, as well as the integration of artificial intelligence, have heightened organizations' awareness of the importance of addressing disruptive incidents. The lack of preparation to manage these disruptions can lead to catastrophic consequences, as evidenced by the COVID-19 pandemic. BC is an approach capable of mitigating such disruptive risks. This study proposes a practical framework inspired by BC to identify and manage risks in the smart supply chain. The proposed framework utilizes the BC approach to demonstrate, analyze, and classify risks, encompassing three fundamental stages. In the first stage, risks and their impacts are identified through a review of existing literature and expert opinions, using the Fuzzy Multi-Criteria Decision-Making (FMCDM) approach. The second stage involves analyzing the risks via a meticulously prepared questionnaire. In the third stage, risks are classified, and risk measures are calculated using the Fuzzy Inference Approach (FIA). A FRM is employed to determine risk levels from three perspectives: easy, standard, and hard.

The impacts of risks and their consequences are derived from expert opinions, making the selection and methodology of experts crucial for obtaining accurate data that contributes to the framework's implementation. Using linguistic terms such as fuzzy numbers provide a strategic method for addressing risks that are difficult to analyze or predict. The proposed framework is versatile and can be applied across various industrial and service sectors. Future research should focus on enhancing this model to cater to organizations with extremely high risks due to the nature of their business. Additionally, incorporating other techniques, such as simulation, would be beneficial for further studies.

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