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Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS- CRITIC approach

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ABSTRACT

Supply chain risk management research has mainly mistreated the important of sustainability issues. Moreover, there is little knowledge about sustainable management of risk and supply chain and the way they impose losses for firms. Risk management's duty in the supply chain is to identify, analyze, and provide solutions for accountability, control and monitor the risks in the economic and production cycle. This study aims to develop a framework for the sustainable supply chain risk management (SSCRM) evaluation. To this end, an integrated fuzzy multi-criteria decision-making (MCDM) approach is proposed based on the technique in order of preference by similarity to ideal solution (TOPSIS) and criteria importance through inter-criteria correlation (CRITIC) methods. The literature was reviewed and the potential criteria were identified. Through an expert panel the criteria were filtered. Seven main criteria and forty-four sub-criteria were developed for the final evaluation SSCRM framework. The most dominant sub-criteria in each group found to be as; machines & equipment risks, key supplier failures, demand fluctuations, government policy risks, IT security, economic issues, and lack of proper sewage infiltration. Besides, A2 (Nouri complex) found to be the best practitioner. The methodology is successfully implemented in a real case company. The detailed account of implications and limitations are presented as the concluding remarks.

1. Introduction

Todays, organizations have acknowledged the significance of ecological thinking and sustainability in business due to the quality uprising and supply chain (Mangla et al., 2015b; Seuring and Müller, 2008) and it is turn out to be the most important subjects in the modern study of operations management (Lim et al., 2017; Rajeev et al., 2017; Stindt, 2017). Attention to the issues related to risks has been grown because the number of relevant uncertainties has increased. The essence and the type of uncertain developments or the influence of any action have become difficult or even impossible to forecast because modern supply chains' interrelation and communication have been increased (Fahimnia et al., 2015). Additionally, following factors, in general, displayed a loss of readiness for supply chain managers coming to uncertain developments: political issues, technological replacement, demand fluctuations and major disruptions such as flooding, earthquake, global financial crisis, and tsunami.

Company's sustainability highly depends on its purchasing, and supply management function highly depends on implementing sustainable supply (Schneider and Wallenburg, 2012). It has been stated that the adoption and implementation of green supply chain (GSC) not only helps industries to conserve resources, which in turn enhances their ecological and economic performances, but also it corporates the sustainable development of industries (Hu and Hsu, 2010; Mangla et al., 2015b; Rostamzadeh et al., 2015). It can be said that organizations' decisions influence the future condition of the natural environment and societies, and overall business

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achievements are presented by a degree of sustainability (Krysiak, 2009). In addition to the investment costs that are needed to make supply chains more sustainable; sustainability strategies, with this great description, should take the degree of future uncertainty into account and also the risks that decisions may affect the natural and social environments (Giannakis and Papadopoulos, 2016). However, according to (Seuring and Müller, 2008), there is a research gap in examining the connections of supply risks and the sustainable supply chain management. Furthermore, (Ghadge et al., 2012) have pointed that there are two main streams lacking in supply risk research: behavioral perceptions in risk management and sustainability factors (Lintukangas et al., 2014). Many firms are expanding their supply chain to the global level to reduce costs. However, in doing so, such firms encounter new risks because their supply chain could be affected by a natural disaster or an emergency on the other side of the planet (Ellis et al., 2011). Christopher and Lee (2004) proposed that a supply chain with high risk cannot be effective. A company, which only pursues high efficiency and ignores risk management, is doomed to failure in this era (Dong and Cooper, 2016; Fan et al., 2016). In addition, responsiveness, efficiency, and reliability are the important drivers for supply chain profitability (Hendricks and Singhal, 2005). Besides, an important source of cost reduction is supply chain sustainability, and it is also very important for a company's lengthy profitability (Wang and Sarkis, 2013). Managers of supply chains, in order to minimize sustainability-related risks and reduce costs, have the responsibility to decide on asset recovery and relationship management, sustainable sourcing, and local content development. Therefore, the assessment of risk management improvement and sustainability-related influence, and their identification for risk tools and managers of the supply chain are turning to be very important subjects (Giannakis and Papadopoulos, 2016; Hofmann et al., 2014). Supply chains in order to keep their profitability must have the ability to fastly react to external and internal risk incidents, and keep their businesses active and productive. In addition, supply chains must be flexible to unpredicted disastrous matters. To do so, one needs to deeply understand supply chain risks and the way to manage them. There are impreciseness and uncertainty in essence of risk analysis. Any analysis made, which ignore this impreciseness and uncertainty, may cause serious mislead of information and consequently cause large mistakes. According to Waters (2011), supply chain risks happen because of future uncertainty. There is an economic value in uncertainty reduction. Also, the validity of risk management decisions improves by uncertainty reduction. In order to increase supply chain's sustainability, and at the same time to decrease its vulnerability, uncertainty and factors that generate risks must be considered. Furthermore, risks can cause the failure of supply chain and can have a meaningful effect on organization performance. Formal concepts of sustainability that explain uncertainty will be scarce in the literature if uncertainty is unconcerned without conforming to its analysis of the specific problems caused by uncertain results and uncertain favors, and if studies only favor the risk (Krysiak, 2009).

Fuzzy set theory and knowledge management principles can be used to cut off the uncertainty integrated with risk measures. Sustainability risks' conceptualizations, without a deep understanding of this materialization process, will continue to be unclear and development of effective management frameworks cannot be fulfilled. The novel contributions of this research is the application of the methodology. To our knowledge, there is only one prior research (Song et al., 2017) linking sustainability-related issues and supply chain risks using multi-criteria decision-making (MCDM). Considering the results of Song et al. (2017) which will be discussed in the literature review section, our contribution in this paper is two-fold. First, for sustainable supply chain risk management (SSCRM) evaluation, a framework is created. Then, a technique for an order of preference by similarity to ideal solution (TOPSIS), and criteria importance through inter-criteria correlation (CRITIC) method is developed in a fuzzy environment, as we have not come across any application of this technique in SSCRM assessment.

The rest of this paper is as follows: the second section discusses SSCRM related literature. The proposed framework for the evaluation of SSCRM using a TOPSIS-CRITIC method developed in the fuzzy environment is presented in the third section. The suggested framework application for risk evaluation in a real case environment is discussed in the fourth section. Discussions and results are provided in section 5, and finally, the sixth section presents the future work and conclusions.

2. Review of literature

This session discusses the theoretical background of prior studies on the topic and the proposed criteria and measures.

2.1. Sustainable supply chain risk management

Ahi and Searcy (2013) defined sustainable supply chain as "the creation of coordinated supply chains through the voluntary integration of social, environmental, and economic considerations with key inter-organizational business systems designed to effectively and efficiently manage the capital, information, and material flows associated with the production, procurement, and distribution of services and products, or in order to improve the resilience of the organization over the long and short-term and increase the profitability and competitiveness and meet stakeholder requirements". In Christopher et al. (2003) point of view, supply chain risk is as "any risk to product, material, and information flow from original supplier to the delivery of the end product". Sustainability is often characterized as having three pillars which also is referred as the triple bottom line: environmental sustainability, social responsibility, and organizational sustainability. Environmental concerns that are complexly connected to different facets of the supply chain include resources that are nonrenewable, landfill deposits, reducing any kind of energy usage and carbon emission. Resale, rebuild, reuse, and recycle are key concepts in minimization efforts to increase its effectiveness. Social responsibility consists of labor relations, living wage payment, ethical behavior, gender equity, and use of proper labor. The violation in any factors could cause a high risk for the firm (Buddress, 2014). Organizational sustainability requires acting with social responsibility and minimal environmental impact while it maintains financial viability. As a result, profitability will be upheld, customers will be fulfilled, and activities that will damage its perception will refrain by both current and potential customers and suppliers. All of this leads to long-term viability.

Atherton (2011) in his report proposed environmental damages during logistics and transportation, packaging waste, natural disasters, greenhouse gas emissions, accidents, and energy usage are typical sustainability-related risks for many industries. No attention is done by researchers in combining sustainability issues into the existing literature on supply chain risk. (Chopra and Sodhi, 2004; Harwood and Humby, 2008). To understand that how sustainability issues materialize as risks, in fact, current frameworks of supply chain risk management (SCRM) do not provide any means (Hofmann et al., 2014). For example, Cucchiella and Gastaldi (2006) by using a real options approach to reduce firm risks, investigated risk management in supply chain. In order to protect the firm against the risk originating from every source of uncertainty, a useful theoretical framework has been individualized enabling the selection of possible options. Ritchie and Brindley (2007) by examining supply chain risk performance and management, provided a guiding framework for future development. A new framework is presented that helps to provide a categorization of risk drivers and integrate the dimensions of performance and risk in supply chains. For the mitigation and management disruptions of risks in manufacturing supply chains, Giannakis and Louis (2011) provided a framework for the design of a multi-agent based decision support system. The framework focuses on demand-driven supply chains rather than supply chains driven by forecasts since in order to achieve high-throughput but low volume, the latter risk can be mitigated through stockpiling of inventories. An integrated approach to supply chain risk was developed by Cagliano et al. (2012). Supply chain operations reference (SCOR) model was used to analyze the process. The risk analysis and identification tasks are accomplished by applying the risk breakdown matrix (RBM) and the risk breakdown structure (RBS), and key performance indicators are used to evaluate the risk occurrence influences on activities. The framework contributes to increasing companies' communication and awareness about risk. The methodology does not quantify the probabilities of the impacts and occurrence, and it mainly focuses on observing the risks' consequences. It does not analyze whether the risk occurrence has secondary effects on multiple processes. Ghadge et al. (2013) developed a systematic approach for modeling supply chain risks. A research design, which is systematically developed, is used to capture the dynamic behavior of risks. Additionally, a system-based supply chain risk model is conceptualized for risk modeling. The risk model, based on single case study, is tested and confirmed, and the robustness of SCRM framework will be improved by more research in various sectors. Heckmann et al. (2015) based on modeling, measure, and definition, performed an important analyze on supply chain risk. By setting the focus on the definition of supply chain risk and related concepts, existing approaches for quantitative SCRM are analyzed. Venkatesh et al. (2015) proposed a proposal of risk prioritization model by use of interpretive structural modeling (ISM) and a framework to analyze supply chain risks in Indian apparel retail chains. It categorizes factors of risk-based on their dependency and driving power. To help to understand the impact of risks at stages of the retail supply chain, ISM is proved to be a useful tool. Safety and security of resources, labor issues, and globalization turns out to be the strong drivers of other supply chain uncertainties. These risks' domino effect leads to financial crises for the organization. For supply chain risk evaluation, Aqlan and Lam (2015) provided a combined framework. Fuzzy inference system (FIS), Survey, and Bow-Tie analysis are the three main components of the framework. Potential risks are identified based on supply chain structure, historical data, and experts' knowledge. Decision makers, by the aggregated and individual risk scores, can focus on the significant risks that could impact their business performances and either do bottom-up or top-down risk analysis. Kirilmaz and Erol (2015) used a proactive approach to risk management of supply chain among the suppliers to mitigate the supply side risk. In the first stage of the proposed procedure, an initial procurement plan is obtained via a linear programming model, considering the cost criterion as the first priority. In the second stage, as the second priority, this plan is revised by including the risk criterion into the planning. The aim of this procedure, that enables proactive planning, is to reduce the supply-side risks. Finally, the whole SCRM process, including the proposed procedure, is applied to an international automotive company. Giannakis and Papadopoulos (2016) investigated the sustainability of supply chain from the operational viewpoint and saw it as a process of risk management. Common risks of supply chain and developing an analytical process for their management are discovered by supply chain sustainability. The failure mode and effect analysis (FMEA) techniques are utilized for selected risks' relative importance assessment. The studies proved that across different industries, the most important risk is perceived to be the endogenous environmental risks, and the interconnectedness among various risks related to sustainability is very high. Most recently He (2017) examined supply risk sharing in a closed-loop supply chain. This paper analyzes different supply risk sharing contracts including no risk sharing contract, complete supply risk sharing contract, over-supply risk sharing contract, and under-supply risk sharing contract. It is shown that different supply risk sharing contracts may result in both the remanufacturing production quantity decision and the recycling price decision to deviate from those decisions under centralized collection structure. It is observed that approaches of supply risk reduction may result in the alignment between the closed-loop supply chain's (CLSC) environmental and financial goals, while approaches to the demand risk reduction cannot gain such alignment. Based on these, further investigation may be performed to explore contractual designs on risk reduction, especially contracts resulting in voluntary compliances from the perspectives of both the manufacturer and the collector. Fig. 1 shows a framework for management of supply chain risk.

2.2. Application of MCDM methods in supply chain risk

In the recent years, by using MCDM techniques, various models have been suggested for supply chain risk management. Wu et al. (2006) used analytic hierarchy process (AHP) to rank risk factors for suppliers and developed a methodology for hierarchical classification of risk factors in inbound supply. Although the above literature does not provide guidance on creating specific plans to mitigate risks, it focuses on different applications of risk assessment methodologies. It does not consider a group decision-making environment. Moeinzadeh and Hajfathaliha (2010) used a combined fuzzy decision-making approach based on analytic network process (ANP) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to supply chain risk assessment. A risk index classification structure is created and SC risks are identified. To find the riskiest partner and rank the SC members, risks weights are calculated and then inserted to the FVIKOR by using FANP. Wang et al. (2012) created a model of risk assessment which enables a structured analysis of aggregative risk of implementing various green initiatives in the fashion industry supply chain. Fuzzy AHP is used to calculate the aggregative risk index (ARI). Ganguly and Guin (2013) provided a methodology for assessing supply risk for a product category. The FAHP has been used for this purpose. The technique is used to determine the supply related risk and its potential impact on the buyer organization. The proposed model is simple and flexible and could be followed by practitioners. But the case example considers a limited number of aspects whereas there may be situations where the number of aspects will be more. Samvedi et al. (2013) used an integrated approach with a FAHP and a fuzzy TOPSIS, as its important elements have been used for this purpose. Fuzzy values help in capturing the subjectivity of the situation with a final conversion to a crisp value which is much more comprehensible. However, various risks and challenges among the case may be imposed on individual organizations depending on their operational objectives and market segmentation. Mangla et al. (2015a) used FAHP to prioritize risks in GSC. Six kinds of risks and twenty-five specific risks, associated with the GSC, were identified and prioritized. The analysis of the results indicates that operational category risks are the most important risks in GSC. To find out cause/effect relationships among the enablers, Rajesh and Ravi (2015) focused on decision-making trial and evaluation laboratory (DEMATEL) approaches and settling the major enablers of supply chain risk mitigation grey theory. The

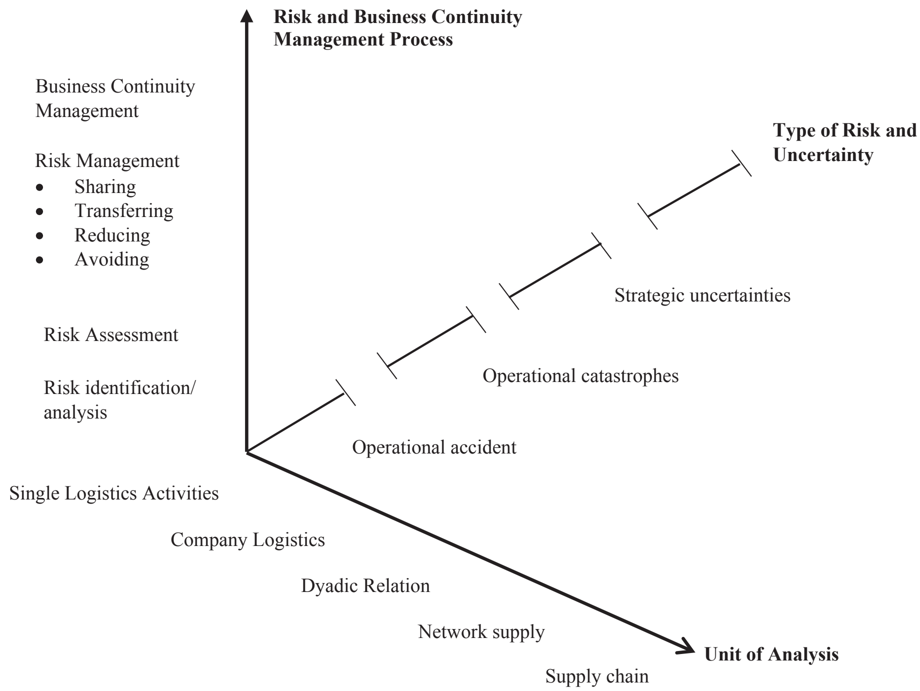

Fig. 1. Framework of SCRM (Norrman and Lindroth, 2004).

results show that supply chain risk mitigation's enablers are intertwined, and active assortment planning is found to be the decisive causal enabler, followed by accurate demand forecasting and flexible supply contracts. To enable the comparison of the intangible and tangible elements that influence supply chain risks, Dong and Cooper (2016) developed an orders-of-magnitude AHP (OM-AHP) based ex-ante supply chain risk assessment model. The proposed supply chain risk assessment framework process consists of three phases: risk analysis and ranking, risk assessment, risk identification. Based on results' consequence severity and probability and tested for robustness via sensitivity analysis, the results are organized in a 2-way risk matrix. Song et al. (2017) investigated the critical risk factors of SSCM based on rough logic and DEMATEL method. The results indicated that the six most important risk factors are: (a) failure to select the right suppliers, (b) volatility of price and cost, (c) inflexibility of supply source, (d) reputation loss or brand damage, (e) poor quality or process yield at supply source and (f) lack of sustainable knowledge/technology. They have also classified these factors into cause groups and effect groups. They have marked the cause factors as being positive in relation and the effect factors as negative in relations. Table 1 shows the summary of the previous researches about the topics and variety of techniques used by different authors.

2.3. Proposed criteria for SSCRM

The process of criteria selection included: (a) a partial literature review to identify all the possible and aforementioned criteria in the literature targeted to the research purpose, (b) a filtering process based on the experts identified in the companies, and (c) a filtering process by an expert panel consisted of the managers, research experts, and practitioners. In the following sections, the criteria are proposed categorically.

2.3.1. Environmental risks (C1)

Generally, one can define environmental risks as any potential or actual threat of adverse effects on the environment or living organisms by resource depletion, wastes, effluents, emissions, etc., arising out of an organization's activities. Environmental analysis refers to the probable or possible effects of causes on an organization's growth, and survival must be evaluated. Environmental risks, including risks that primarily affect human ecology, depending on the situation of the countries, can be a variant. For example, in Iran they can be categorized into three levels: First, climatic hazards which are the source of over 90 percent of the country's natural disasters such as flood, drought, frost, storms, lightning, dust storms, avalanches, frostbite, burning forests, and woodlands. Second, risks of earth construction, such as earthquakes, landslides, and rock debris. Due to its intensity and scope, an earthquake is more important. Finally, human risks that refer to the risk of all processes related to human activities, such as risks associated with the manufacturing technology and operations. In this research, following criteria were used to assess environmental risks: wars (C11), Terrorism (C12), unsteadiness of politics (C13), economic-related concerns (C14), natural incidents (C15), and common work conflicts (C16).

2.3.2. Organizational risks (C2)

Enterprise risk management (ERM) is a continuous process with a comprehensive approach that covers uncertainty of the organization at all levels. This uncertainty can be both negative and positive, influencing the key objectives of the organization. In fact, by creating a structured processes including identification, assessment, and planning, ERM enables the organizations to integrate and manage risks at all levels. Organizational risks can be divided into strategic and operational levels. In strategic risk, the organization tries to achieve its business objectives. In this context, either profitability or unprofitability is potentially possible, which makes the speculative nature of strategic risk. On the other hand, there are operational risks where the managers and employees mostly focus on. It is the potential failure to reach the mission objectives. As the staff and management work begins, operational risks start to emerge. Lack of inherent efficiency and problems during the process can lead to failure of the operations which could adversely

Table 1
Summary of previous research.

Author(s)	Risk variables	Techniques & Modeling used	Research objectives
Chopra and Sodhi (2004)	Delays, disruptions, system risk, forecast risk, Intellectual property risk, procurement risk, receivables risk, inventory risk. capacity risk	Survey	To suggest strategies of risk mitigation and categorize different supply chain risks
Wu et al. (2006)	Internal (controllable, partially controllable, not controllable) and External (controllable, partially controllable, not controllable).	AHP	For hierarchical classification of risk factors in inbound supply, developed a methodology.
Cucchiella and Gastaldi (2006)	production capacity risks and price fluctuation risks	Real option theory	to cut off the company risk, to individualize and finalize a framework, and to manage uncertainty in the supply chain.
Wagner and Bode (2006)	Catastrophic, supply-side, and demand-side	Ordinary least square (OLS) regression	To investigate the relationship between supply chain risk and supply chain vulnerability
Manuj and Mentzer (2008)	Demand, supply, resources, competitive, operational, security, macro, policy	Decision Analysis Approach	To propose a comprehensive mitigation model and risk management for global supply chain.
Olson and Wu (2010)	External (nature, political system, competitor, and market)/internal (available capacity, Internal operation, Information system)	Review	to include classification and identification of types of models, cases, and risks to review published approaches to supply chain risk management,
Moeinzadeh and Hajfathaliha (2010)	Demand risk, environmental risk, control and plan risk, process risk, supply risk	FANP& FVIKOR	SCRM
Giannakis and Louis (2011)	Wrapper agents, disruption manager agent, monitoring agent, communication agent, coordination agent	Multi-agent based	A multi-agent based framework for management of supply chain risk
Diabat et al. (2012)	Service/product, information management risks, management risks, macro level risks, demand management risks, supply management risks,	Interpretative Structural Modeling (ISM)	SCRM and its mitigation in a food industry
Cagliano et al. (2012)	Internal: Strategic, tactical, operational External: Catastrophic, economic, social, political, legal, cultural, industrial, partner	SCOR	combined method to supply chain risk
Wang et al. (2012)	Performance (cost, assurance of supply, delivery, quality, flexibility) and supply chain structure (manufacturing, purchasing, logistics, marketing)	FAHP	Fuzzy-AHP model which is in two stages to evaluate the risk of using green initiatives in the fashion supply chain
Samvedi et al. (2013)	Supply risk, demand risks, process risk, and environmental risk.	FAHP & FTOPSIS	To quantify the risks in a supply chain
Ganguly and Guin (2013)	On-time delivery, order correctness, order completeness, damage, and defect-free and cost	FAHP	Assessing supply risk for a product
Lavastre et al. (2014)	Delivery problem, quality problems, noncompliance, supply disruption, problem in the production process, production line disruption, price, costs, technical problem, forecasting, reliability, uncontrollable external risks, lack of capacity, inventory difference/variation, administrative, contract, customs, human error, information system, overstock, commercial, sales and customer relationship, communication and information exchanges with partners.	Confirmatory analysis & Correlation	To identifying critical success management for SCRM
Aqlan and Lam (2015)	Supplier risks, customer risks, process and control risks, technology risks, product risks, occupational risks, culture risks, transportation risks, commodity risks.	Survey, Bow-Tie analysis, and FIS	A fuzzy-based combined framework to evaluate supply chain risk
Rajesh and Ravi (2015)	flexible supply base, flexible supply contracts, collaborative partner relations, supply chain visibility, supply chain velocity, strategic risk planning, dynamic assortment planning, accurate demand forecasting, information security, technology adaptation, postponement strategies, flexible processes, strategic stocking, responsive pricing strategies, integrated supply chains	Grey–DEMATEL	Supply chain risk mitigation enablers Modeling in electronic supply chains
Venkatesh et al. (2015)	globalization, product quality and raw material standards, lack of resources, supplier uncertainty, lack of alignment/co-ordination, employees' behavior, risks related to infrastructure, delay in schedule/lead time, uncertainty of demand, customer displeasure, financial risk, safety and security.	ISM	Analyzing risks of supply chain in retail chains of Indian apparel
Mangla et al. (2015a)	Operational risk, supply risk, product recovery risk, financial risk, demand risk, governmental and organizational related risk.	FAHP	Risks analysis in green supply chain: Indian poly product-manufacturing
Rogers et al. (2015)	cultural, operational, infrastructure, economic, forecasting and supplier- related risks	Exploratory and confirmatory factor analyses	Management of supply chain risk in India
Giannakis and Papadopoulos (2016)	Environmental, social and financial/economic	Content analysis & FMEA	By considering supply chain sustainability as a process of risk management, developing it from operational viewpoint
(Su et al., 2016)	Sustainable plan, communities for sustainability, sustainable operational process controlling, sustainable certificates and growth	grey-DEMATEL	Improving sustainable supply chain management
Song et al. (2017)	Demand and supply uncertainty, failure to select the right suppliers, lower responsiveness performance, inflexibility of supply source, poor quality or process yield at supply source, coordination complexity/effort, it and information sharing risks, lack of sustainable knowledge/technology, volatility of price and cost, inflation and currency exchange rates, market share reduction, reputation loss or brand damage, natural disasters, inefficient use of resources, environmental pollution, hazardous waste generation, unhealthy/dangerous working environment, violation of human rights, failure to fulfill social commitment, violation of business ethics	DEMATEL	To investigate the effect of strength of each risk factor on the interdependencies of the factors

affect the success of the organization. Criteria for assessing organizational risks are as follows: management policy failures (C21); government policy risks (C22); human error (C23); poor interrelationships between supply chain partners (C24); lack of commitment in the supply chain to go green (C25).

2.3.3. Sustainable supply risks (C3)

Many manufacturing companies are influenced by their own supply and distribution. This happens because the coordination among various units can significantly reduce supply chain costs and can result in more flexibility. Appropriate suppliers selection is the most important decision variable in the success of a supply chain. The question is that how companies without any failure, which can satisfy both environmental issues and organizational objectives, can guarantee their supply needs? From supplier to disturbances, in the production process, there are always risks in the supply chain. The current economic situation is an environment of competition and uncertainty, and all types of uncertainty factors in the supply chain, including risk. In the upstream supply chain companies, suppliers play a major role. Supplier's risk is one of the main sources of risk in the supply chain, it is an important issue and in today's dynamic economic environment. The following criteria were used to evaluate green supply risks: capacity constraints (C31), key supplier failures (C32), supplier quality (C33), supplier uncertainty (C34), material order risks (35), inventory risks (36), limited number of green suppliers to choose from (37) and supplier's financial instability (38).

2.3.4. Sustainable production/manufacturer risks (C4)

Manufacturers need suppliers who provide them with reliability. But for most companies, the instability of commodity prices, credit volume reduction, instability of market and general economy, infrastructural and political problems and many others have created a huge gap in the performance of many producers. Sustainable manufacturing works have been positively linked with competitive results (Rusinko, 2007). The products' value to organizations and to society, the creation of unwanted by-products while keeping or developing, cutting of the strength of energy ejection and usage, and materials used are general concepts of sustainable manufacturing. According to the definition, the combination of all the three signs of environmental, social, and economical, known as the triple bottom line of sustainability, must be addressed by sustainable manufacturing (Amrina and Vilsi, 2015). Therefore, an important universal concern for manufacturing companies has been developing sustainable approaches (Ijomah et al., 2007). The following criteria are used to assess the green production/manufacturer risks: product design risk (41), production capacity risk (42), risk of demand (43), risk of quality (44), poor planning and scheduling (45), forecasting errors (46), labor strike (47), machines & equipment risks (48), long product lead times for green products/materials (49), change in technologies due to green, (410).

2.3.5. Sustainable distribution risks (C5)

For marketing managers and manufacturers, transporting manufactured goods to target markets is known as one of the main challenges. The importance of decisions about distribution channels is that the company has to adhere to this decision for a long time and stay committed to it. The distribution must be done in such a way that facilitates product sales and supply at the time of need. It also must be compatible with other aspects of marketing strategy like the product, promotion, and price. Sustainable distribution includes taking back packaging, carriage to the purchaser or client, the whole distribution process from storehouse, order picking and processing, packaging, increased vehicle loadings, and refers to any means of hauling/transportation of goods among buyer and seller with lowest possible influence on the ecological and social environment (Belz and Peattie, 2012). While combining sustainability issues without damaging any of the conventional goals that distribution has to satisfy, sustainability refers to the macroeconomic management of the objects which are to be distributed (rights, services, goods, information, and fees). Commonly, all the processes that take place among clients, retailers, and producers are referred as distribution. Reverse logistics, labeling, packaging, physical transportation, warehousing, and storage are the distribution functions. Uncertain costs show a high risk in distribution channels, specifically in globe-spanning distribution channels. The overall increase in the cost of fuel and continuous variations can penetrate profit margins and cause a serious damage on pricing. Tariffs can be used due to the destination, source, nature, and place of a product. Based on economic facts and political leanings, the size of tariffs changes, however, they show a confirmed cost of doing business with overseas businesses (Dontigney, 2015). The criteria are as follows: proximity to airports (51), quality of roads (52), demand fluctuations (53), demand forecasting risks (54), market-related risks (55), inability to use green fuel (56), and product perishability risk (57).

2.3.6. Sustainable recycling risks (C6)

Processing of used materials into new products and materials is referred to as recycling in order to prevent waste of potentially useful (storage), reducing the raw materials consumption, and use of energy, reducing air pollution by burning of waste material, reducing water pollution by wastes burial which resulted by producing less waste in the territory and finally reducing greenhouse gas emissions compared with net production. Recycling prevents of wasting useful resources and national assets and it reduces the consumption of raw materials and energy. This will also reduce greenhouse gas emissions. Recycling is an important concept in waste management. The criteria used are as follows: lack of proper sewage infiltration (61), inability in use of other company's wastes (62), discharging of wastes risks (63) and groundwater pollution risks (64).

2.3.7. Information technology-related risks (C7)

SC and Global distribution channels rely more and more on real-time information updates over networks and IT. The Internet for businesses that deal in digital-only products and information, becomes a distribution channel. Reliance on the Internet builds a host of digital security issues. These issues range from securing trade secrets to securing customer information. A security damage possibly reveals confidential information that damages revenue streams and strategic position and businesses meet the continual risk of this. A security failure also opens you up to possible legal action from the clients or government, or other members of the distribution channel (Dontigney, 2015). Documentation measurement includes, input/output controls, verification, authorize processing, systems software maintenance, physical and environmental protection, and hardware are IT security metrics. Risk management measurement is the particular interest here. Financial as well as regulatory factors cause the need to measure risk management performance in particular and IT security performance in general. A number of occurring regulations, rules, and laws refer to IT security performance measurements as a need (Kouns and Minoli, 2011; Young, 2016). The criteria used to evaluate IT-related risks are as follows: IT security (71), bullwhip effect (72), fail to access information (73) and IT system failure (74).

3. Research framework and the case study

The environment of the company, the company itself, and the risk status changes are not static. The recognized risk factors can be monitored to identify the potential increasing trends in their consequences or probability. In addition, there may be new significant risk factors. In order to identify these factors, it is necessary to update the risk assessment, to monitor customer needs, partner strategies, technology, competitors, and the changes in the network, (Hallikas et al., 2004). Because of the uncertainty increased in the supply chain, organizations need to reduce vulnerability and enhance their sustainability of their supply chain. To do so, they have to spend resources to forecast demand, suppliers and internal organizations uncertainties. Management of Supply chain risk is necessary to identify and deal with this uncertainty and reduce the vulnerability of the supply chain (Olson and Wu, 2010).

The oil industry is one of the most effective and largest industries in the world, especially in Iran. Based on the data of the organization of the petroleum exporting countries (OPEC) Iran is one of the world's top four countries with regard to proven oil and gas reserves. It plays an important role in the determination of national power and in the validity of different international countries. An important section of oil products includes petrochemical industry like chemical fertilizers, urea, ammonia, and sulfur. These products in comparison to the tens of thousands of oil and natural gas derivatives of petrochemicals, which are obtained through advanced technology, are so small. Offering environmentally friendly products and services on one hand, and the development of oil/gas and expansion of high risky actions and environmental and technologic changes, on the other hand, lead all large international companies, also Iranian national oil company, to pay enough attention to evaluate their units regarding sustainability and risk issues, because they play a determinant role in promoting the efficiency, productivity, and economy of the country.

Given the importance of the petrochemical industry in Iran, Pars Special Economic Energy Zone which includes different complexes like Pardis, Nouri, Pars, Arya Sasol, Mobin, Mehr, Jam, Zagros, and Morvarid Petrochemical Complex were chosen to investigate the proposed method in practice. However, in this study, the complexes with highest production capacity were selected which include; Arya Sasol (A1), Nouri (A2), Mobin (A3) and Zagros (A4). The general information of the companies is found on the websites. Based on the partial literature review, 7 main criteria and forty-four sub-criteria were developed to evaluate alternatives to choose the best practitioner. The filtering process to choose the final criteria is presented in section 2.3. Fig. 2 illustrates the hierarchal structure of the problem and the finalized criteria and sub-criteria.

4. Methodology

This section describes the methodology was applied in this research. The proposed model is based on fuzzy sets theory and TOPSIS-CRITIC method which will be discussed in continue. Fig. 3 shows the proposed research framework.

4.1. Fuzzy sets

To map linguistic variables to numerical variables within decision-making processes, Fuzzy set theory first was introduced by Zadeh (1965). to resolve the ratings of alternatives against evaluation criteria and the lack of precision in assigning importance weights of criteria, later it was manipulated to develop fuzzy multi-criteria decision making (FMCDM) methodology by (Bellman and Zadeh, 1970). Because human minds work with different logics and make decisions based on them, therefore; new logical and multi-valued methods are needed to build and invent. Fuzzy logic is one of them. Some of the basic definitions of fuzzy sets (Kaufmann and Gupta, 1991; Zadeh, 1965; Zimmermann, 1993, 1987) presented as Appendix 1.

4.2. Fuzzy CRITIC

In the decision-making problems, criteria can be viewed as a source of information. The importance weight of criteria could reflect the amount of information contained in each of them. This weight is referred to as "objective weight". The CRITIC is a method for determining the objective weights of criteria in the MCDM problems (Diakoulaki et al., 1995). The weights derived by this method incorporate both contrast intensity of each criterion and conflict between criteria. Contrast intensity of criteria is considered by the standard deviation and conflict between them is measured by the correlation coefficient. In this section, we extend this method in a fuzzy environment. Suppose that $\tilde{x}_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4})$ represents the fuzzy performance value of ith alternative according to jth criterion $(i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m)$, $\tilde{w}_j^o = (w_{j1}^o, \square w_{j2}^o, w_{j3}^o, w_{j4}^o)$ denotes the fuzzy objective weight of jth criterion,N is the set of non-beneficial criteria and B is the set of beneficial criteria. The following summarizes the process of determining fuzzy objective weights of criteria based on this method:

Step 1: Calculate the transformations of performance values and obtain criteria vectors as follows:

$$x_{ijk}^T = \begin{cases} \dfrac{x_{ijk} - x_{jk}^-}{x_{jk}^* - x_{jk}^-} & if \quad j \in B \\[2ex] \dfrac{x_{jk}^- - x_{ijk}}{x_{jk}^- - x_{jk}^*} & if \quad j \in N \end{cases} \tag{13}$$

$$\mathbf{x}_{jk} = \left(x_{1jk}^T \cdot x_{2jk}^T \cdot \ldots \cdot x_{njk}^T \right)$$

where x_{ijk}^T is the transformed value of kth element of $\tilde{x}_{ij}$ $(k = 1, 2, 3, 3)$, $\mathbf{x}_{jk}$ denotes the kth vector of jth criterion, x_{jk}^* and x_{jk}^- are the ideal and anti-ideal values with respect to jth criterion and kth element of $\tilde{x}_{ij}$. If $j \in B$, $x_{jk}^* = \max_i x_{ijk}$ and $x_{jk}^- = \min_i x_{ijk}$, and if $j \in N$, $x_{jk}^* = \min_i x_{ijk}$ and $x_{jk}^- = \max_i x_{ijk}$.

Step 2: Calculate the standard deviation (σ_{jk}) of each vector $(\mathbf{x}_{jk})$.
Step 3: Construct four symmetric matrices, with dimension $m \times m$ and generic elements $r_{jj'}^k$ $(j'=1,2, \ldots, m$ and $k = 1,2,3,4)$. The elements of this matrix are the linear correlation coefficient between the vectors $\mathbf{x}_{jk}$ and $\mathbf{x}_{j'k}$.

It should be noted that if all elements of $\mathbf{x}_{jk}$ or $\mathbf{x}_{j'k}$ vectors are identical, we can suppose that there is no correlation $(r_{jj'}^k = 0)$.

Step 4: Calculate the information measures of each criterion as follows:

$$\mathrm{H}_{jk} = \sigma_{jk} \sum_{j'=1}^{m} \left(1 - r_{jj'}^k \right) \tag{14}$$

Step 5: Determine the unsorted objective weights as follows:

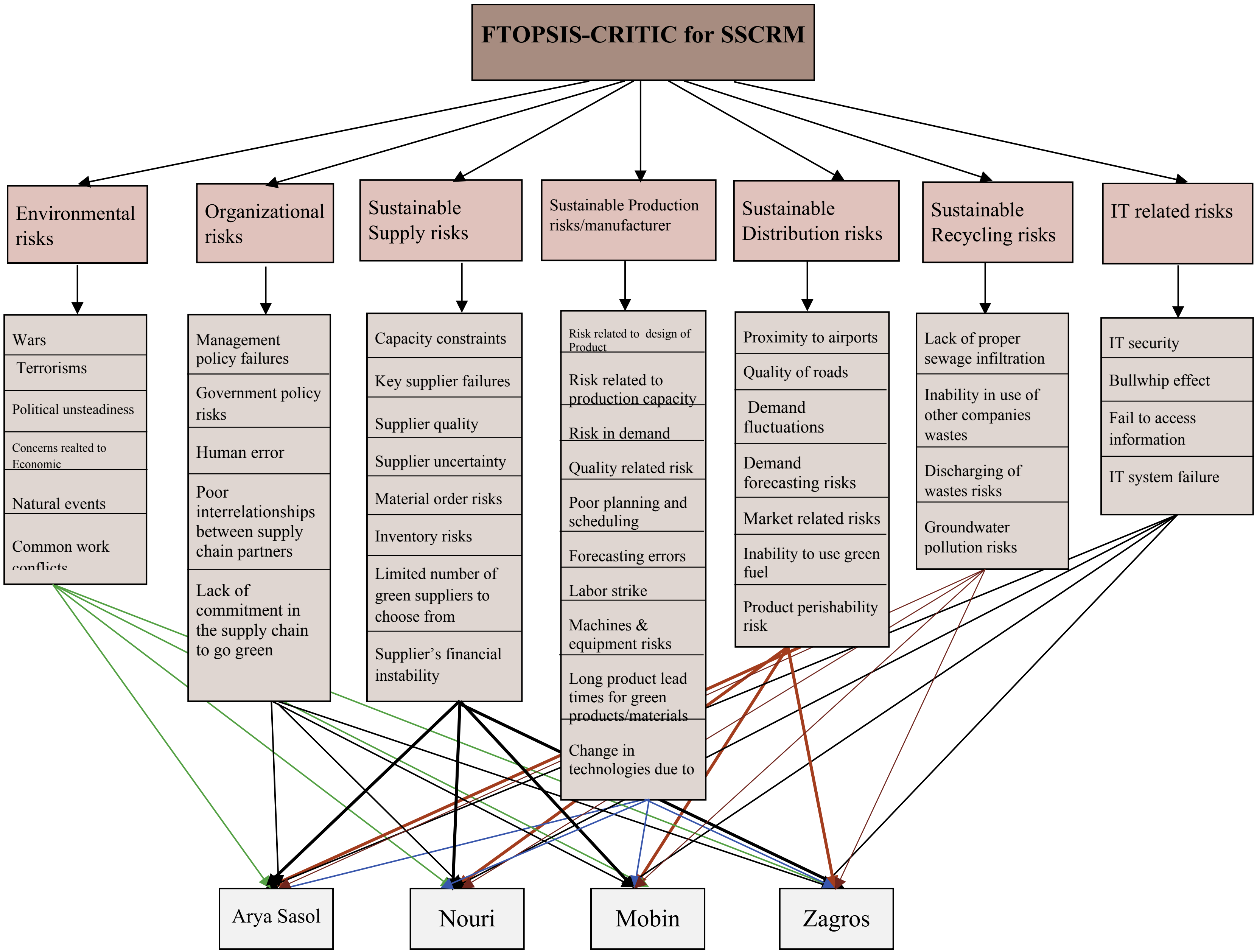

Fig. 2. Hierarchy of the problem.

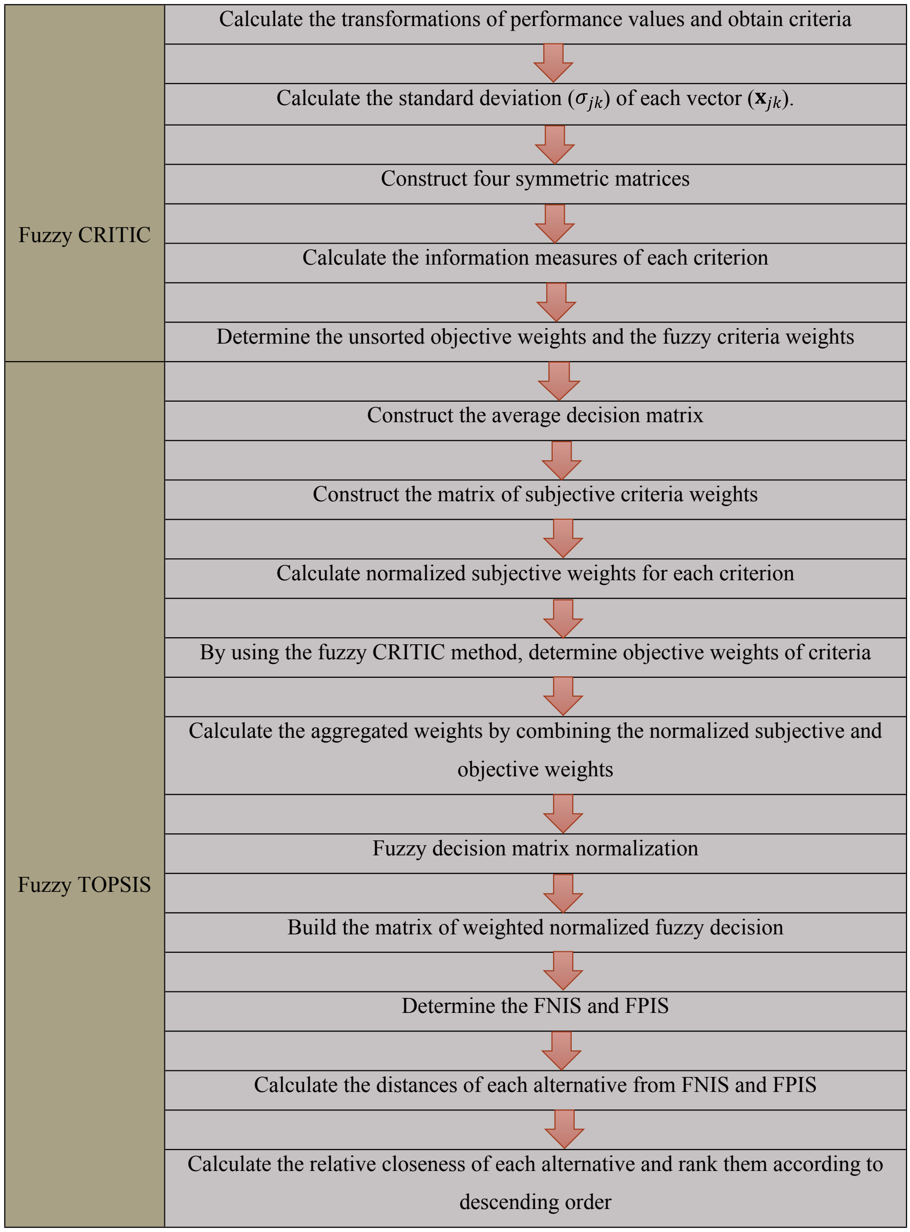

Fig. 3. Proposed research framework.

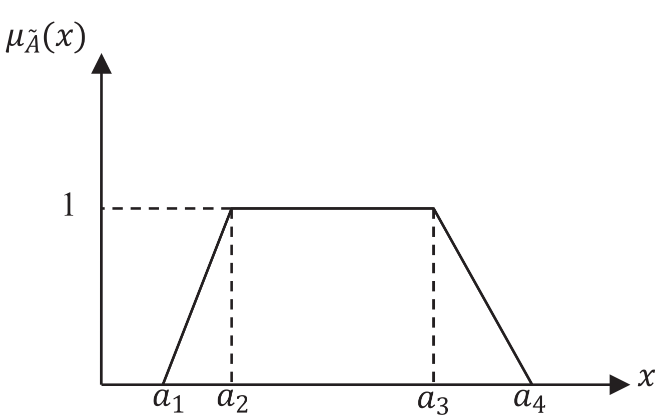

Fig. 4. A trapezoidal fuzzy number.

$$w'_{jk} = \frac{\mathrm{H}_{jk}}{\sum_{j'=1}^{m} \mathrm{H}_{jj'}} \tag{15}$$

Step 6: Determine the fuzzy criteria weights using the following formulas:

$w^o_{jk} = w'_{jk'}$ where k and $k' \in \{1.2.3.\ 4\}$ and,

$$\begin{aligned} w^o_{j4} &= \max_k w'_{jk} \\ w^o_{j1} &= \min_k w'_{jk} \end{aligned} \tag{16}$$

4.3. An integrated fuzzy TOPSIS-CRITIC approach

The TOPSIS method is a very popular method among numerous MCDM methods to deal with real-life decision problems in diverse application areas. This method was proposed by (Hwang and Yoon, 1981) originally and has received much interest from researchers and practitioners. In this section, we presented an integrated fuzzy MCDM approach based on the TOPSIS and CRITIC methods. Suppose that we have a set of n alternatives $(A = \{A_1, A_2, \ldots, A_n\})$, a set of m criteria $(C = \{c_1, c_2, \ldots, c_m\})$ and k decision-makers $(D = \{D_1 \cdot D_2 \ldots . D_k\})$. The following steps present the extended fuzzy method:

Step 1: As it is presented, construct the average decision matrix (X):

$$X = [\tilde{x}_{ij}]_{n\times m} \tag{17}$$

where,

$$\tilde{x}_{ij} = \frac{1}{k} \overset{k}{\underset{p=1}{\oplus}} \tilde{x}_{ij}^{p} \tag{18}$$

with regard to criterion c_j $(1 \le j \le m)$ assigned by the pth decision-maker $(1 \le p \le k)$, the performance value of alternative A_i $(1 \le i \le n)$ is donated by $\tilde{x}_{ij}^{p}$.

Step 2: As shown in the following step, construct the subjective criteria weights' matrix:

$$W = \left[\tilde{w}_j^s\right]_{1\times m} \tag{19}$$

where,

$$\tilde{w}_j^s = \frac{1}{k} \overset{k}{\underset{p=1}{\oplus}} \tilde{w}_{jp}^{s} \tag{20}$$

The subjective weight of criterion c_j $(1 \le j \le m)$ which is assigned by the pth decision-maker $(1 \le p \le k)$ is donated by $\tilde{w}_{jp}^{s}$:

Step 3: Calculate normalized subjective weights for each criterion:

$$\tilde{w}_j^{sn} = \tilde{w}_j^s \Big/ \kappa \left(\overset{m}{\underset{j=1}{\oplus}} \tilde{w}_j^s \right) \tag{21}$$

Step 4: By using the fuzzy CRITIC method described in the previous section, determine objective weights of criteria.

Step 5: Calculate the aggregated weights by combining the normalized subjective weights and the objective weights, shown as follows:

$$\tilde{w}_j = \rho \cdot \tilde{w}_j^{sn} \oplus (1-\rho) \cdot \tilde{w}_j^{o} \tag{22}$$

Step 6: Normalize the fuzzy decision matrix:

$$R = [\tilde{r}_{ij}]_{n\times m}$$
$$\tilde{r}_{ij} = \left(\frac{x_{ij1}}{u_j}, \frac{x_{ij2}}{u_j}, \frac{x_{ij3}}{u_j}, \frac{x_{ij4}}{u_j}\right)$$
$$\tilde{r}_{ij} = \left(\frac{l_j}{x_{ij4}}, \frac{l_j}{x_{ij3}}, \frac{l_j}{x_{ij2}}, \frac{l_j}{x_{ij1}}\right) \tag{23}$$

where

$$l_j = \min_i x_{ij1}$$
$$u_j = \max_i x_{ij4} \tag{24}$$

Step 7: Build the matrix of weighted normalized fuzzy decision As shown in this step:

$$Z = [\tilde{z}_{ij}]_{n\times m}$$
$$\tilde{z}_{ij} = \tilde{w}_j \otimes \tilde{r}_{ij} \tag{25}$$

Step 8: As shown in the following, determine the fuzzy negative ideal solution (FNIS) and fuzzy positive ideal solution (FPIS):

$$A^+ = \left(v_1^+,\ v_2^+, \ldots, v_m^+\right)$$
$$A^- = \left(v_1^- \cdot\ v_2^- \ldots . v_m^-\right) \tag{26}$$

where

$$v_j^+ = \begin{cases} \max_i z_{ij4} & if \quad j \in B \\ \min_i z_{ij1} & if \quad j \in N \end{cases}$$
$$v_j^- = \begin{cases} \min_i z_{ij1} & if \quad j \in B \\ \max_i z_{ij4} & if \quad j \in N \end{cases} \tag{27}$$

Step 9: Calculate the distances of each alternative from FNIS and FPIS:

$$d_i^+ = \sum_{j=1}^{m} d\left(\tilde{z}_{ij} \cdot v_j^+\right)$$
$$d_i^- = \sum_{j=1}^{m} d\left(\tilde{z}_{ij} \cdot v_j^-\right) \tag{28}$$

Step 10: Calculate the relative closeness of each alternative and rank them according to descending order of these values:

$$C_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{29}$$

5. Results

The steps of FTOPSIS- CRITIC method implemented in this research as follows:

Step 1. As depicted in Fig. 2, the scope of the problem and the objectives in the decision-making process were structured.

Step 2. The decision-making group arranged and relevant attributes were described. The metrics in the study were selected with a thorough literature review represented in Table 1.

Step 3. Linguistic scales for importance and rating of the alternatives were determined for the evaluation purpose as shown in Table 2. Then, ratings of the alternatives and importance weight of the criteria with regard to the main criteria assessed by decision makers as illustrated in Tables 3 and 4 respectively and converted to Table 5 in order to construct average decision matrix.

Table 2
Linguistic scales for importance and rating.

Linguistic scale for importance	Triangular fuzzy scale	Linguistic scale for rating
Very Low (VL)	(0, 0, 0.1, 0.2)	Very Poor (VP)
Low (L)	(0.1, 0.2, 0.2, 0.3)	Poor (P)
Medium Low (ML)	(0.2, 0.3, 0.4, 0.5)	Medium Poor (MP)
Medium (M)	(0.4, 0.5, 0.5, 0.6)	Medium (M)
Medium High (MH)	(0.5, 0.6, 0.7, 0.8)	Medium Good (MG)
High (H)	(0.7, 0.8, 0.8, 0.9)	Good (G)
Very High (VH)	(0.8, 0.9, 1, 1)	Very Good (VG)

Table 3
Importance weight of the criteria assessed by decision makers (linguistic values).

	D1	D2	D3
C11	VL	VL	VL
C12	VL	L	VL
C13	MH	H	H
C14	VH	H	VH
C15	MH	MH	M
C16	ML	L	ML
C21	VH	H	H
C22	VH	VH	H
C23	M	ML	ML
C24	M	M	M
C25	MH	MH	H
C31	ML	L	L
C32	VH	VH	VH
C33	MH	MH	H
C34	H	H	MH
C35	MH	M	M
C36	M	MH	MH
C37	H	H	H
C38	H	MH	H
C41	VL	L	L
C42	M	ML	ML
C43	M	MH	M
C44	VH	VH	H
C45	H	VH	H
C46	MH	M	MH
C47	ML	L	L
C48	VH	VH	VH
C49	MH	MH	H
C410	H	MH	H
C51	L	L	L
C52	VL	L	L
C53	VH	H	H
C54	MH	MH	H
C55	H	MH	H
C56	MH	M	M
C57	ML	L	L
C61	VH	H	H
C62	ML	L	L
C63	MH	H	MH
C64	H	H	H
C71	H	VH	VH
C72	M	MH	M
C73	H	VH	H
C74	H	H	H

Table 4
With regard to the main criteria assessed by decision makers, ratings of the alternatives are as follow.

	D1				D2				D3			
	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4
C11	VP	VP	P	P	MP	P	P	P	VP	VP	P	P
C12	VP	MP	P	P	VP	P	P	P	MP	VP	P	P
C13	G	G	G	MG	MG	MG	MG	G	G	G	MG	G
C14	G	VG	G	VG	G	G	G	VG	MG	VG	G	VG
C15	MG	G	G	G	VG	G	MG	MG	G	G	MG	G
C16	MP	P	P	MP	M	M	M	M	MP	M	MP	M
C21	G	VG	G	MG	G	VG	G	G	MG	G	G	G
C22	VG	G	G	G	G	G	G	VG	MG	G	MG	G
C23	M	MG	M	MP	MP	M	MG	M	M	M	MP	M
C24	M	M	MG	MG	M	MG	G	G	MG	M	MP	M
C25	MG	MG	M	M	M	MG	MG	MG	G	VG	G	G
C31	MG	G	M	M	M	MG	M	M	M	MP	M	M
C32	VG	VG	G	VG	G	VG	G	G	G	VG	G	VG
C33	MP	M	M	MP	P	M	MP	M	P	MP	P	P
C34	M	M	MP	P	M	M	MP	MP	M	MG	M	M
C35	MG	G	G	G	G	M	M	MG	G	VG	G	G
C36	MP	MG	M	M	MP	MG	M	M	MP	M	P	P
C37	G	G	MG	M	M	MG	G	MG	M	M	M	M
C38	MG	G	MP	MP	P	MP	P	M	M	MP	M	P
C41	M	MG	MG	MG	M	MP	P	MP	M	MG	M	M
C42	P	MP	MP	P	M	M	M	M	MG	MG	M	M
C43	MG	G	G	G	MG	MG	MG	M	M	M	M	MP
C44	G	G	MG	MG	VG	VG	MG	G	G	G	G	VG
C45	MG	MG	M	M	M	MP	MG	G	G	G	MG	M
C46	MP	P	M	MP	M	MG	M	MG	MG	MG	M	M
C47	VP	P	P	P	P	MP	MP	P	P	P	P	VP
C48	G	G	G	G	VG	VG	G	VG	G	VG	MG	G
C49	G	MG	G	M	MG	G	G	G	MG	VG	G	M
C10	M	MG	M	M	M	M	MG	MP	M	M	M	MG
C51	G	VG	G	G	MG	G	MG	MG	MG	M	M	M
C52	M	M	M	G	MG	MG	M	M	M	MG	M	M
C53	M	MP	MP	P	M	MP	M	M	MP	MP	M	P
C54	G	G	G	MG	M	G	MG	MG	G	G	M	G
C55	MP	P	P	P	M	MP	P	M	M	MP	MP	P
C56	G	VG	G	MG	G	MG	MG	G	MG	M	M	M
C57	MP	M	M	M	MP	P	P	P	M	M	M	M
C61	VG	G	G	G	MG	MG	G	M	MG	G	MG	M
C62	MP	M	MP	P	M	M	M	M	MP	MG	M	MP
C63	P	MP	MP	P	P	MP	P	M	MP	M	MP	P
C64	M	MG	M	M	G	G	MG	MG	M	M	MP	MP
C71	G	VG	G	G	MG	G	G	G	MG	G	G	M
C72	MG	G	G	M	MG	M	MP	M	M	MG	M	MP
C73	MG	M	M	M	M	MG	G	MG	G	G	MG	G
C74	M	MG	M	M	MP	M	P	MP	M	M	MP	MP

Step 4. Subjective weights, normalized subjective weights, objective and aggregated weights calculated as Table 6. Then, as shown in Table 7, decision matrix was normalized and converted to a matrix of the weighted normalized decision as shown in Table 8.

Step 5. FNIS and FPIS, and distances of each alternative were calculated as Table 9. Finally, the relative closeness of each alternative and their rank presented in Table 10 in descending order as A2>A1>A3>A4.

Sustainable production/manufacturer risks (C4) was known as the most important main criteria with 0.228. In the next following orders were obtained as *Sustainable supply risks (C3)* 0.201; *Sustainable distribution risks (C5)* 0.130; *Organizational risks (C2)* 0.125; *Information technology-related risks (C7)* 0.115; *Environmental risks (C1)* 0.103; *Sustainable recycling risks (C6)* 0.097 respectively. Table 11 presents the summary of the results of criteria.

5.1. Discussion and managerial implications

To evaluate sustainable supply chain risk management, this

Table 5
Step 1: Average decision matrix.

	A1	A2	A3	A4
C11	(0.067,0.1,0.2,0.3)	(0.033,0.067,0.133,0.233)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)
C12	(0.067,0.1,0.2,0.3)	(0.1,0.167,0.233,0.333)	(0.1,0.2,0.2,0.3)	(0.1,0.2,0.2,0.3)
C13	(0.633,0.733,0.767,0.867)	(0.633,0.733,0.767,0.867)	(0.567,0.667,0.733,0.833)	(0.633,0.733,0.767,0.867)
C14	(0.633,0.733,0.767,0.867)	(0.767,0.867,0.933,0.967)	(0.7,0.8,0.8,0.9)	(0.8,0.9,1,1)
C15	(0.667,0.767,0.833,0.9)	(0.7,0.8,0.8,0.9)	(0.567,0.667,0.733,0.833)	(0.633,0.733,0.767,0.867)
C16	(0.267,0.367,0.433,0.533)	(0.3,0.4,0.4,0.5)	(0.233,0.333,0.367,0.467)	(0.333,0.433,0.467,0.567)
C21	(0.633,0.733,0.767,0.867)	(0.767,0.867,0.933,0.967)	(0.7,0.8,0.8,0.9)	(0.633,0.733,0.767,0.867)
C22	(0.667,0.767,0.833,0.9)	(0.7,0.8,0.8,0.9)	(0.633,0.733,0.767,0.867)	(0.733,0.833,0.867,0.933)
C23	(0.333,0.433,0.467,0.567)	(0.433,0.533,0.567,0.667)	(0.367,0.467,0.533,0.633)	(0.333,0.433,0.467,0.567)
C24	(0.433,0.533,0.567,0.667)	(0.433,0.533,0.567,0.667)	(0.467,0.567,0.633,0.733)	(0.533,0.633,0.667,0.767)
C25	(0.533,0.633,0.667,0.767)	(0.6,0.7,0.8,0.867)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)
C31	(0.433,0.533,0.567,0.667)	(0.467,0.567,0.633,0.733)	(0.4,0.5,0.5,0.6)	(0.4,0.5,0.5,0.6)
C32	(0.733,0.833,0.867,0.933)	(0.8,0.9,1,1)	(0.7,0.8,0.8,0.9)	(0.767,0.867,0.933,0.967)
C33	(0.133,0.233,0.267,0.367)	(0.333,0.433,0.467,0.567)	(0.233,0.333,0.367,0.467)	(0.233,0.333,0.367,0.467)
C34	(0.4,0.5,0.5,0.6)	(0.433,0.533,0.567,0.667)	(0.267,0.367,0.433,0.533)	(0.233,0.333,0.367,0.467)
C35	(0.633,0.733,0.767,0.867)	(0.633,0.733,0.767,0.833)	(0.6,0.7,0.7,0.8)	(0.633,0.733,0.767,0.867)
C36	(0.2,0.3,0.4,0.5)	(0.467,0.567,0.633,0.733)	(0.3,0.4,0.4,0.5)	(0.3,0.4,0.4,0.5)
C37	(0.5,0.6,0.6,0.7)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)	(0.433,0.533,0.567,0.667)
C38	(0.333,0.433,0.467,0.567)	(0.367,0.467,0.533,0.633)	(0.233,0.333,0.367,0.467)	(0.233,0.333,0.367,0.467)
C41	(0.4,0.5,0.5,0.6)	(0.4,0.5,0.6,0.7)	(0.333,0.433,0.467,0.567)	(0.367,0.467,0.533,0.633)
C42	(0.333,0.433,0.467,0.567)	(0.367,0.467,0.533,0.633)	(0.333,0.433,0.467,0.567)	(0.3,0.4,0.4,0.5)
C43	(0.467,0.567,0.633,0.733)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)	(0.433,0.533,0.567,0.667)
C44	(0.733,0.833,0.867,0.933)	(0.733,0.833,0.867,0.933)	(0.567,0.667,0.733,0.833)	(0.667,0.767,0.833,0.9)
C45	(0.533,0.633,0.667,0.767)	(0.467,0.567,0.633,0.733)	(0.467,0.567,0.633,0.733)	(0.5,0.6,0.6,0.7)
C46	(0.367,0.467,0.533,0.633)	(0.367,0.467,0.533,0.633)	(0.4,0.5,0.5,0.6)	(0.367,0.467,0.533,0.633)
C47	(0.067,0.133,0.167,0.267)	(0.133,0.233,0.267,0.367)	(0.133,0.233,0.267,0.367)	(0.067,0.133,0.167,0.267)
C48	(0.733,0.833,0.867,0.933)	(0.767,0.867,0.933,0.967)	(0.633,0.733,0.767,0.867)	(0.733,0.833,0.867,0.933)
C49	(0.567,0.667,0.733,0.833)	(0.667,0.767,0.833,0.9)	(0.7,0.8,0.8,0.9)	(0.5,0.6,0.6,0.7)
C410	(0.4,0.5,0.5,0.6)	(0.433,0.533,0.567,0.667)	(0.433,0.533,0.567,0.667)	(0.367,0.467,0.533,0.633)
C51	(0.567,0.667,0.733,0.833)	(0.633,0.733,0.767,0.833)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)
C52	(0.433,0.533,0.567,0.667)	(0.467,0.567,0.633,0.733)	(0.4,0.5,0.5,0.6)	(0.5,0.6,0.6,0.7)
C53	(0.333,0.433,0.467,0.567)	(0.2,0.3,0.4,0.5)	(0.333,0.433,0.467,0.567)	(0.2,0.3,0.3,0.4)
C54	(0.6,0.7,0.7,0.8)	(0.7,0.8,0.8,0.9)	(0.533,0.633,0.667,0.767)	(0.567,0.667,0.733,0.833)
C55	(0.333,0.433,0.467,0.567)	(0.167,0.267,0.333,0.433)	(0.133,0.233,0.267,0.367)	(0.2,0.3,0.3,0.4)
C56	(0.633,0.733,0.767,0.867)	(0.567,0.667,0.733,0.8)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)
C57	(0.267,0.367,0.433,0.533)	(0.3,0.4,0.4,0.5)	(0.3,0.4,0.4,0.5)	(0.3,0.4,0.4,0.5)
C61	(0.6,0.7,0.8,0.867)	(0.633,0.733,0.767,0.867)	(0.633,0.733,0.767,0.867)	(0.5,0.6,0.6,0.7)
C62	(0.267,0.367,0.433,0.533)	(0.433,0.533,0.567,0.667)	(0.333,0.433,0.467,0.567)	(0.233,0.333,0.367,0.467)
C63	(0.133,0.233,0.267,0.367)	(0.267,0.367,0.433,0.533)	(0.167,0.267,0.333,0.433)	(0.2,0.3,0.3,0.4)
C64	(0.5,0.6,0.6,0.7)	(0.533,0.633,0.667,0.767)	(0.367,0.467,0.533,0.633)	(0.367,0.467,0.533,0.633)
C71	(0.567,0.667,0.733,0.833)	(0.733,0.833,0.867,0.933)	(0.7,0.8,0.8,0.9)	(0.6,0.7,0.7,0.8)
C72	(0.467,0.567,0.633,0.733)	(0.533,0.633,0.667,0.767)	(0.433,0.533,0.567,0.667)	(0.333,0.433,0.467,0.567)
C73	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)	(0.533,0.633,0.667,0.767)
C74	(0.333,0.433,0.467,0.567)	(0.433,0.533,0.567,0.667)	(0.233,0.333,0.367,0.467)	(0.267,0.367,0.433,0.533)

paper, based on TOPSIS- CRITIC framework, developed a fuzzy multi-criteria decision making. Seven main criteria and forty-four sub-criteria are proposed. The most important criteria are known to be sustainable production/manufacturer risks (C4), and sustainable recycling risk (C7) found to be the least important one. Seven most dominant sub-criteria in each group found to be as follows: machines & equipment risks, key supplier failures, demand fluctuations, government policy risks, IT security, economic issues and lack of proper sewage infiltration. Also the practitioners rank found to be as follow; Nouri complex is known to be the best unit. Arya Sasol placed in the second order, Mobin and Zagros placed in the third and fourth respectively.

As shown in Table 6, based on normalized weight obtained by decision makers, the main criteria of the research ranked as follow: sustainable production/manufacturer risks (C4) with 0.228 placed in the first priority. Sustainable supply risks (C3) with 0.201 placed in the second, sustainable distribution risks (C5) with 0.13 in the third, organizational risks (C2) with 0.125 in the fourth, information technology-related risks (C7) with 0.115 in the fifth, environmental risks (C1) with 0.103 in the sixth and sustainable recycling risks (C6) with 0.097 in the seventh place.

In environmental risks (C1) group, economic issues (C14) with 0.033 placed in the first rank and wars (C11) with 0.002 obtained the last rank. In organizational risks (C2) group, government policy risks (C22) with 0.033 placed in the first and human error (C23) with 0.015 placed in the last. In sustainable supply risks (C3) group, key supplier failures (C32) with 0.035 placed in the first and capacity constraints (C31) with 0.01 received the last priority. In sustainable production/manufacturer risks (C4) group, machines & equipment risks (48) with 0.035 obtained the first rank and product design risk (41) with 0.006 received the lowest rank. In sustainable distribution risks (C5) group, demand fluctuations (53) with 0.032 obtained the first and quality of roads (52) with 0.002 placed in the last. In sustainable recycling risks (C6) group, lack of proper sewage infiltration (61) with 0.032 obtained the first and inability in use of other company's wastes (62) with 0.01 received the last score. In information technology-related risks (C7) group, IT security (71) with 0.033 placed in the first and bullwhip effect (72) with 0.021 received the last.

It looks that methods of traditional risk management fail to effectively tackle and address sustainability issues in supply chains. As the body of literature is revealed, regarding the research topic there are few types of research conducted (Hofmann et al., 2014; Mangla et al., 2015a; Song et al., 2017) which cannot satisfy the needs of organizations in connecting their SCM activities and risk management in a sustainable way. There isn't either a suitable

Table 6
Steps 2 to 5: Subjective weights, normalized subjective weights, objective and aggregated weights.

	Subjective weights		Normalized subjective weights		Objective weights		Aggregated weights	
	fuzzy	defuzzy	fuzzy	defuzzy	fuzzy	defuzzy	fuzzy	defuzzy
C11	(0,0,0.1,0.2)	**0.078**	(0,0,0.004,0.008)	**0.003**	(0.043,0.044,0.05,0.052)	**0.047**	(0.021,0.022,0.027,0.03)	**0.025**
C12	(0.033,0.067,0.133,0.233)	**0.119**	(0.001,0.003,0.005,0.009)	**0.005**	(0.018,0.018,0.029,0.031)	**0.024**	(0.01,0.01,0.017,0.02)	**0.014**
C13	(0.633,0.733,0.767,0.867)	**0.750**	(0.024,0.028,0.029,0.033)	**0.029**	(0.025,0.025,0.025,0.025)	**0.025**	(0.024,0.026,0.027,0.029)	**0.027**
C14	(0.767,0.867,0.933,0.967)	**0.881**	(0.029,0.033,0.035,0.036)	**0.033**	(0.024,0.024,0.029,0.031)	**0.027**	(0.027,0.029,0.032,0.034)	**0.031**
C15	(0.467,0.567,0.633,0.733)	**0.600**	(0.018,0.021,0.024,0.028)	**0.023**	(0.017,0.017,0.02,0.021)	**0.019**	(0.017,0.019,0.022,0.024)	**0.021**
C16	(0.167,0.267,0.333,0.433)	**0.300**	(0.006,0.01,0.013,0.016)	**0.011**	(0.024,0.024,0.031,0.032)	**0.028**	(0.015,0.017,0.022,0.024)	**0.020**
C1	*[2.067,2.501,2.899,3.433]*	***2.730***	*[0.078,0.095,0.11,0.13]*	***0.103***	*[0.151,0.152,0.184,0.192]*	***0.170***	*[0.114,0.123,0.147,0.161]*	***0.136***
C21	(0.733,0.833,0.867,0.933)	**0.839**	(0.028,0.031,0.033,0.035)	**0.032**	(0.018,0.019,0.019,0.019)	**0.019**	(0.023,0.025,0.026,0.027)	**0.025**
C22	(0.767,0.867,0.933,0.967)	**0.881**	(0.029,0.033,0.035,0.036)	**0.033**	(0.024,0.024,0.027,0.032)	**0.027**	(0.026,0.028,0.031,0.034)	**0.030**
C23	(0.267,0.367,0.433,0.533)	**0.400**	(0.01,0.014,0.016,0.02)	**0.015**	(0.017,0.017,0.024,0.024)	**0.021**	(0.014,0.016,0.02,0.022)	**0.018**
C24	(0.4,0.5,0.5,0.6)	**0.500**	(0.015,0.019,0.019,0.023)	**0.019**	(0.037,0.037,0.048,0.05)	**0.043**	(0.026,0.028,0.033,0.036)	**0.031**
C25	(0.567,0.667,0.733,0.833)	**0.700**	(0.021,0.025,0.028,0.031)	**0.026**	(0.017,0.017,0.018,0.018)	**0.018**	(0.019,0.021,0.023,0.025)	**0.022**
C2	*[2.734,3.234,3.466,3.866]*	***3.320***	*[0.103,0.122,0.131,0.145]*	***0.125***	*[0.113,0.114,0.136,0.143]*	***0.127***	*[0.108,0.118,0.133,0.144]*	***0.126***
C31	(0.133,0.233,0.267,0.367)	**0.250**	(0.005,0.009,0.01,0.014)	**0.010**	(0.016,0.016,0.017,0.017)	**0.017**	(0.01,0.012,0.014,0.016)	**0.013**
C32	(0.8,0.9,1,1)	**0.922**	(0.03,0.034,0.038,0.038)	**0.035**	(0.017,0.017,0.018,0.018)	**0.018**	(0.024,0.026,0.028,0.028)	**0.026**
C33	(0.567,0.667,0.733,0.833)	**0.700**	(0.021,0.025,0.028,0.031)	**0.026**	(0.017,0.017,0.02,0.021)	**0.019**	(0.019,0.021,0.024,0.026)	**0.023**
C34	(0.633,0.733,0.767,0.867)	**0.750**	(0.024,0.028,0.029,0.033)	**0.029**	(0.015,0.016,0.02,0.02)	**0.018**	(0.02,0.022,0.024,0.026)	**0.023**
C35	(0.433,0.533,0.567,0.667)	**0.550**	(0.016,0.02,0.021,0.025)	**0.021**	(0.025,0.025,0.025,0.032)	**0.027**	(0.021,0.023,0.023,0.028)	**0.024**
C36	(0.467,0.567,0.633,0.733)	**0.600**	(0.018,0.021,0.024,0.028)	**0.023**	(0.016,0.016,0.018,0.018)	**0.017**	(0.017,0.019,0.021,0.023)	**0.020**
C37	(0.7,0.8,0.8,0.9)	**0.800**	(0.026,0.03,0.03,0.034)	**0.030**	(0.023,0.023,0.026,0.027)	**0.025**	(0.025,0.027,0.028,0.031)	**0.028**
C38	(0.633,0.733,0.767,0.867)	**0.750**	(0.024,0.028,0.029,0.033)	**0.029**	(0.017,0.017,0.02,0.02)	**0.019**	(0.02,0.022,0.024,0.026)	**0.023**
C3	*[4.366,5.166,5.534,6.234]*	***5.319***	*[0.164,0.195,0.209,0.236]*	***0.201***	*[0.146,0.147,0.164,0.173]*	***0.158***	*[0.156,0.172,0.186,0.204]*	***0.180***
C41	(0.067,0.133,0.167,0.267)	**0.161**	(0.003,0.005,0.006,0.01)	**0.006**	(0.017,0.017,0.021,0.021)	**0.019**	(0.01,0.011,0.014,0.016)	**0.013**
C42	(0.267,0.367,0.433,0.533)	**0.400**	(0.01,0.014,0.016,0.02)	**0.015**	(0.016,0.016,0.016,0.016)	**0.016**	(0.013,0.015,0.016,0.018)	**0.016**
C43	(0.433,0.533,0.567,0.667)	**0.550**	(0.016,0.02,0.021,0.025)	**0.021**	(0.024,0.024,0.024,0.025)	**0.024**	(0.02,0.022,0.023,0.025)	**0.023**
C44	(0.767,0.867,0.933,0.967)	**0.881**	(0.029,0.033,0.035,0.036)	**0.033**	(0.02,0.021,0.021,0.021)	**0.021**	(0.025,0.027,0.028,0.029)	**0.027**
C45	(0.733,0.833,0.867,0.933)	**0.839**	(0.028,0.031,0.033,0.035)	**0.032**	(0.023,0.024,0.035,0.035)	**0.029**	(0.025,0.028,0.034,0.035)	**0.030**
C46	(0.467,0.567,0.633,0.733)	**0.600**	(0.018,0.021,0.024,0.028)	**0.023**	(0.025,0.025,0.037,0.037)	**0.031**	(0.021,0.023,0.03,0.032)	**0.027**
C47	(0.133,0.233,0.267,0.367)	**0.250**	(0.005,0.009,0.01,0.014)	**0.010**	(0.028,0.028,0.032,0.033)	**0.030**	(0.016,0.018,0.021,0.023)	**0.020**
C48	(0.8,0.9,1,1)	**0.922**	(0.03,0.034,0.038,0.038)	**0.035**	(0.016,0.017,0.019,0.019)	**0.018**	(0.023,0.026,0.028,0.028)	**0.026**
C49	(0.567,0.667,0.733,0.833)	**0.700**	(0.021,0.025,0.028,0.031)	**0.026**	(0.021,0.024,0.024,0.024)	**0.023**	(0.021,0.024,0.026,0.028)	**0.025**
C410	(0.633,0.733,0.767,0.867)	**0.750**	(0.024,0.028,0.029,0.033)	**0.029**	(0.023,0.023,0.029,0.03)	**0.026**	(0.023,0.025,0.029,0.031)	**0.027**
C4	*[4.867,5.833,6.367,7.167]*	***6.050***	*[0.184,0.22,0.24,0.27]*	***0.228***	*[0.213,0.219,0.258,0.261]*	***0.238***	*[0.197,0.219,0.249,0.265]*	***0.232***
C51	(0.1,0.2,0.2,0.3)	**0.200**	(0.004,0.008,0.008,0.011)	**0.008**	(0.016,0.016,0.017,0.022)	**0.018**	(0.01,0.012,0.012,0.017)	**0.013**
C52	(0.067,0.133,0.167,0.267)	**0.161**	(0.003,0.005,0.006,0.01)	**0.006**	(0.019,0.019,0.024,0.024)	**0.022**	(0.011,0.012,0.015,0.017)	**0.014**
C53	(0.733,0.833,0.867,0.933)	**0.839**	(0.028,0.031,0.033,0.035)	**0.032**	(0.03,0.031,0.044,0.045)	**0.038**	(0.029,0.031,0.038,0.04)	**0.035**
C54	(0.567,0.667,0.733,0.833)	**0.700**	(0.021,0.025,0.028,0.031)	**0.026**	(0.015,0.015,0.017,0.017)	**0.016**	(0.018,0.02,0.022,0.024)	**0.021**
C55	(0.633,0.733,0.767,0.867)	**0.750**	(0.024,0.028,0.029,0.033)	**0.029**	(0.025,0.025,0.029,0.029)	**0.027**	(0.024,0.026,0.029,0.031)	**0.028**
C56	(0.433,0.533,0.567,0.667)	**0.550**	(0.016,0.02,0.021,0.025)	**0.021**	(0.023,0.026,0.027,0.027)	**0.026**	(0.019,0.023,0.024,0.026)	**0.023**
C57	(0.133,0.233,0.267,0.367)	**0.250**	(0.005,0.009,0.01,0.014)	**0.010**	(0.028,0.029,0.033,0.034)	**0.031**	(0.017,0.019,0.021,0.024)	**0.020**
C5	*[2.666,3.332,3.568,4.234]*	***3.450***	*[0.101,0.126,0.135,0.159]*	***0.130***	*[0.156,0.161,0.191,0.198]*	***0.177***	*[0.128,0.143,0.161,0.179]*	***0.153***
C61	(0.733,0.833,0.867,0.933)	**0.839**	(0.028,0.031,0.033,0.035)	**0.032**	(0.023,0.023,0.024,0.026)	**0.024**	(0.025,0.027,0.028,0.03)	**0.028**
C62	(0.133,0.233,0.267,0.367)	**0.250**	(0.005,0.009,0.01,0.014)	**0.010**	(0.016,0.017,0.017,0.017)	**0.017**	(0.011,0.013,0.013,0.015)	**0.013**
C63	(0.567,0.667,0.733,0.833)	**0.700**	(0.021,0.025,0.028,0.031)	**0.026**	(0.017,0.017,0.018,0.019)	**0.018**	(0.019,0.021,0.023,0.025)	**0.022**
C64	(0.7,0.8,0.8,0.9)	**0.800**	(0.026,0.03,0.03,0.034)	**0.030**	(0.016,0.016,0.021,0.021)	**0.019**	(0.021,0.023,0.025,0.027)	**0.024**
C6	*[2.133,2.533,2.667,3.033]*	***2.589***	*[0.08,0.095,0.101,0.114]*	***0.097***	*[0.072,0.073,0.08,0.083]*	***0.077***	*[0.076,0.084,0.089,0.097]*	***0.087***
C71	(0.767,0.867,0.933,0.967)	**0.881**	(0.029,0.033,0.035,0.036)	**0.033**	(0.019,0.021,0.022,0.022)	**0.021**	(0.024,0.027,0.028,0.029)	**0.027**
C72	(0.433,0.533,0.567,0.667)	**0.550**	(0.016,0.02,0.021,0.025)	**0.021**	(0.017,0.017,0.017,0.018)	**0.017**	(0.017,0.018,0.019,0.021)	**0.019**
C73	(0.733,0.833,0.867,0.933)	**0.839**	(0.028,0.031,0.033,0.035)	**0.032**	(0,0,0,0)	**0**	(0.014,0.016,0.016,0.018)	**0.016**
C74	(0.7,0.8,0.8,0.9)	**0.800**	(0.026,0.03,0.03,0.034)	**0.030**	(0.014,0.015,0.016,0.016)	**0.015**	(0.02,0.022,0.023,0.025)	**0.023**
C7	*[2.633,3.033,3.167,3.467]*	***3.069***	*[0.099,0.114,0.119,0.13]*	***0.115***	*[0.05,0.053,0.055,0.056]*	***0.053***	*[0.075,0.083,0.086,0.093]*	***0.084***

The Bold items shows the defuzzy value and Italic ones show the Main criteria (in this way it separated from sub-criteria).

prescription for sustainability risks specific management, or a well-grounded conceptualization for them (Hofmann et al., 2014). Because risk assessment is “needed to be able to choose suitable management actions for the identified risk factors”, then it is a basic stage in the process of supply chain risk management (Hallikas et al., 2004). Without performing a thorough risk assessment to rank the risks, the proactive planning and mitigation strategies are built on a shaky foundation. Despite the clear need to assess supply chain risks, there is still limited research about how to specifically develop a risk assessment model for the broad application (Dong and Cooper, 2016; Ellis et al., 2011). Hofmann et al. (2014) argued that involvement of stakeholders is an only possible option for managing of sustainability risks in supply chains to be successful. Specifically, stakeholders assume that firms can control or supervise their suppliers' behavior by many means which affect governance mechanisms and strategies that keep firms responsible for the misbehavior of the supplier. Using mitigation strategies to control and recognize risks that source from outside of an organization is more difficult. Sinha et al. (2004) argued that there is no clear benefit for an organization to try to consider external risks before reducing internal ones because internal risks cannot be controlled by the enterprise. In spite of having difficulty to control these kinds of risks, by efficient contingency planning they can be managed (Giannakis and Papadopoulos, 2016; Wu and Blackhurst, 2009). Risks arisen from internal policies and actions are often largely declined, but external supply chain risks are under great attention. Sustainability efforts also increase force supply chain managers to improve internal sustainability practices and to ask the

Table 7
Step 6: Matrix of the normalized decision.

	A1	A2	A3	A4
C11	(0.222,0.333,0.667,1)	(0.111,0.222,0.444,0.778)	(0.333,0.667,0.667,1)	(0.333,0.667,0.667,1)
C12	(0.2,0.3,0.6,0.9)	(0.3,0.5,0.7,1)	(0.3,0.6,0.6,0.9)	(0.3,0.6,0.6,0.9)
C13	(0.731,0.846,0.885,1)	(0.731,0.846,0.885,1)	(0.654,0.769,0.846,0.962)	(0.731,0.846,0.885,1)
C14	(0.633,0.733,0.767,0.867)	(0.767,0.867,0.933,0.967)	(0.7,0.8,0.8,0.9)	(0.8,0.9,1,1)
C15	(0.741,0.852,0.926,1)	(0.778,0.889,0.889,1)	(0.63,0.741,0.815,0.926)	(0.704,0.815,0.852,0.963)
C16	(0.471,0.647,0.765,0.941)	(0.529,0.706,0.706,0.882)	(0.412,0.588,0.647,0.824)	(0.588,0.765,0.824,1)
C21	(0.655,0.759,0.793,0.897)	(0.793,0.897,0.966,1)	(0.724,0.828,0.828,0.931)	(0.655,0.759,0.793,0.897)
C22	(0.714,0.821,0.893,0.964)	(0.75,0.857,0.857,0.964)	(0.679,0.786,0.821,0.929)	(0.786,0.893,0.929,1)
C23	(0.5,0.65,0.7,0.85)	(0.65,0.8,0.85,1)	(0.55,0.7,0.8,0.95)	(0.5,0.65,0.7,0.85)
C24	(0.565,0.696,0.739,0.87)	(0.565,0.696,0.739,0.87)	(0.609,0.739,0.826,0.957)	(0.696,0.826,0.87,1)
C25	(0.615,0.731,0.769,0.885)	(0.692,0.808,0.923,1)	(0.615,0.731,0.769,0.885)	(0.615,0.731,0.769,0.885)
C31	(0.591,0.727,0.773,0.909)	(0.636,0.773,0.864,1)	(0.545,0.682,0.682,0.818)	(0.545,0.682,0.682,0.818)
C32	(0.733,0.833,0.867,0.933)	(0.8,0.9,1,1)	(0.7,0.8,0.8,0.9)	(0.767,0.867,0.933,0.967)
C33	(0.235,0.412,0.471,0.647)	(0.588,0.765,0.824,1)	(0.412,0.588,0.647,0.824)	(0.412,0.588,0.647,0.824)
C34	(0.6,0.75,0.75,0.9)	(0.65,0.8,0.85,1)	(0.4,0.55,0.65,0.8)	(0.35,0.5,0.55,0.7)
C35	(0.731,0.846,0.885,1)	(0.731,0.846,0.885,0.962)	(0.692,0.808,0.808,0.923)	(0.731,0.846,0.885,1)
C36	(0.273,0.409,0.545,0.682)	(0.636,0.773,0.864,1)	(0.409,0.545,0.545,0.682)	(0.409,0.545,0.545,0.682)
C37	(0.652,0.783,0.783,0.913)	(0.696,0.826,0.87,1)	(0.696,0.826,0.87,1)	(0.565,0.696,0.739,0.87)
C38	(0.526,0.684,0.737,0.895)	(0.579,0.737,0.842,1)	(0.368,0.526,0.579,0.737)	(0.368,0.526,0.579,0.737)
C41	(0.571,0.714,0.714,0.857)	(0.571,0.714,0.857,1)	(0.476,0.619,0.667,0.81)	(0.524,0.667,0.762,0.905)
C42	(0.526,0.684,0.737,0.895)	(0.579,0.737,0.842,1)	(0.526,0.684,0.737,0.895)	(0.474,0.632,0.632,0.789)
C43	(0.609,0.739,0.826,0.957)	(0.696,0.826,0.87,1)	(0.696,0.826,0.87,1)	(0.565,0.696,0.739,0.87)
C44	(0.786,0.893,0.929,1)	(0.786,0.893,0.929,1)	(0.607,0.714,0.786,0.893)	(0.714,0.821,0.893,0.964)
C45	(0.696,0.826,0.87,1)	(0.609,0.739,0.826,0.957)	(0.609,0.739,0.826,0.957)	(0.652,0.783,0.783,0.913)
C46	(0.579,0.737,0.842,1)	(0.579,0.737,0.842,1)	(0.632,0.789,0.789,0.947)	(0.579,0.737,0.842,1)
C47	(0.182,0.364,0.455,0.727)	(0.364,0.636,0.727,1)	(0.364,0.636,0.727,1)	(0.182,0.364,0.455,0.727)
C48	(0.759,0.862,0.897,0.966)	(0.793,0.897,0.966,1)	(0.655,0.759,0.793,0.897)	(0.759,0.862,0.897,0.966)
C49	(0.63,0.741,0.815,0.926)	(0.741,0.852,0.926,1)	(0.778,0.889,0.889,1)	(0.556,0.667,0.667,0.778)
C410	(0.6,0.75,0.75,0.9)	(0.65,0.8,0.85,1)	(0.65,0.8,0.85,1)	(0.55,0.7,0.8,0.95)
C51	(0.68,0.8,0.88,1)	(0.76,0.88,0.92,1)	(0.64,0.76,0.8,0.92)	(0.64,0.76,0.8,0.92)
C52	(0.591,0.727,0.773,0.909)	(0.636,0.773,0.864,1)	(0.545,0.682,0.682,0.818)	(0.682,0.818,0.818,0.955)
C53	(0.588,0.765,0.824,1)	(0.353,0.529,0.706,0.882)	(0.588,0.765,0.824,1)	(0.353,0.529,0.529,0.706)
C54	(0.667,0.778,0.778,0.889)	(0.778,0.889,0.889,1)	(0.593,0.704,0.741,0.852)	(0.63,0.741,0.815,0.926)
C55	(0.588,0.765,0.824,1)	(0.294,0.471,0.588,0.765)	(0.235,0.412,0.471,0.647)	(0.353,0.529,0.529,0.706)
C56	(0.731,0.846,0.885,1)	(0.654,0.769,0.846,0.923)	(0.615,0.731,0.769,0.885)	(0.615,0.731,0.769,0.885)
C57	(0.5,0.688,0.813,1)	(0.563,0.75,0.75,0.938)	(0.563,0.75,0.75,0.938)	(0.563,0.75,0.75,0.938)
C61	(0.692,0.808,0.923,1)	(0.731,0.846,0.885,1)	(0.731,0.846,0.885,1)	(0.577,0.692,0.692,0.808)
C62	(0.4,0.55,0.65,0.8)	(0.65,0.8,0.85,1)	(0.5,0.65,0.7,0.85)	(0.35,0.5,0.55,0.7)
C63	(0.25,0.437,0.5,0.688)	(0.5,0.688,0.813,1)	(0.313,0.5,0.625,0.813)	(0.375,0.562,0.562,0.75)
C64	(0.652,0.783,0.783,0.913)	(0.696,0.826,0.87,1)	(0.478,0.609,0.696,0.826)	(0.478,0.609,0.696,0.826)
C71	(0.607,0.714,0.786,0.893)	(0.786,0.893,0.929,1)	(0.75,0.857,0.857,0.964)	(0.643,0.75,0.75,0.857)
C72	(0.609,0.739,0.826,0.957)	(0.696,0.826,0.87,1)	(0.565,0.696,0.739,0.87)	(0.435,0.565,0.609,0.739)
C73	(0.696,0.826,0.87,1)	(0.696,0.826,0.87,1)	(0.696,0.826,0.87,1)	(0.696,0.826,0.87,1)
C74	(0.5,0.65,0.7,0.85)	(0.65,0.8,0.85,1)	(0.35,0.5,0.55,0.7)	(0.4,0.55,0.65,0.8)

same from their suppliers. The uncertainty sources are linked to the incorrect definition of the relationships between the actors placed in the network or the internal organization on the lack of knowledge of the correct design of the supply chain. This can settle a low ability to adopt new technologies or determine a low teamwork between the actors inside the network (Cucchiella and Gastaldi, 2006). Besides, inter-organizational knowledge transfer and information sharing cause a great deal of risk and uncertainty. The development of knowledge and information systems is a potential means to manage risks and is, therefore, a great challenge (Hallikas et al., 2004).

For disruptions management, SCRM focuses on developing new approaches. From the idea of ERM, the field of SCRM has been originated which is the paradigm for managing the portfolio of risks that threaten organizations (Ghadge et al., 2013; Gordon et al., 2009). The first step of ERM system is to identify the quantitative and qualitative possibilities. Certainly, risk management and assessment cannot be disconnected from the social norms and customs judgments. For this reason, risk perception, as a component of risk management, should be considered along with scientific assessments. Generally, risk analysis is based on the theory of probability. Also, practical methods identify the causal connections between different types of hazardous activities and their results. Further, understanding the causes of risk characteristics and the way to calculate them are important factors. To label the environmental risks linked with oversea renewable energy devices, the ERM is utilized. However, ERMs can also be used to help stakeholders, decision-makers and regulators, including the offshore renewable energy industry, to compare the benefits and costs of various installation options, set priorities for research activities, and evaluate their tolerance for risk. Explaining the uncertainty of the resulting consequences, the uncertainty linked with the happening of a chronic, an intermittent, or an episodic event is a key characteristic of understanding risk (Copping and Hanna, 2011). Furthermore, an international organization for standardization (ISO) in November 2009 for the first time issued an international standard for risk management under ISO 31000 so that the principles and general guidelines in the field of risk management provided for organizations. The standard aims to provide a clear framework for a risk management system that is applicable to any type of organization and industry. In fact, some benefits will be obtained by implementing organizational risk management system as follows:

Table 8
Step 7: Matrix of the Weighted normalized decision.

	A1	A2	A3	A4
C11	(0.005,0.007,0.018,0.03)	(0.002,0.005,0.012,0.023)	(0.007,0.015,0.018,0.03)	(0.007,0.015,0.018,0.03)
C12	(0.002,0.003,0.01,0.018)	(0.003,0.005,0.012,0.02)	(0.003,0.006,0.01,0.018)	(0.003,0.006,0.01,0.018)
C13	(0.018,0.022,0.024,0.029)	(0.018,0.022,0.024,0.029)	(0.016,0.02,0.023,0.028)	(0.018,0.022,0.024,0.029)
C14	(0.017,0.021,0.025,0.029)	(0.02,0.025,0.03,0.032)	(0.019,0.023,0.026,0.03)	(0.021,0.026,0.032,0.034)
C15	(0.013,0.016,0.02,0.024)	(0.014,0.017,0.019,0.024)	(0.011,0.014,0.018,0.022)	(0.012,0.016,0.019,0.023)
C16	(0.007,0.011,0.017,0.023)	(0.008,0.012,0.015,0.021)	(0.006,0.01,0.014,0.02)	(0.009,0.013,0.018,0.024)
C21	(0.015,0.019,0.02,0.024)	(0.018,0.023,0.025,0.027)	(0.017,0.021,0.021,0.025)	(0.015,0.019,0.02,0.024)
C22	(0.019,0.023,0.028,0.033)	(0.02,0.024,0.027,0.033)	(0.018,0.022,0.026,0.032)	(0.021,0.025,0.029,0.034)
C23	(0.007,0.01,0.014,0.019)	(0.009,0.013,0.017,0.022)	(0.008,0.011,0.016,0.021)	(0.007,0.01,0.014,0.019)
C24	(0.015,0.019,0.025,0.031)	(0.015,0.019,0.025,0.031)	(0.016,0.021,0.028,0.035)	(0.018,0.023,0.029,0.036)
C25	(0.012,0.015,0.018,0.022)	(0.013,0.017,0.021,0.025)	(0.012,0.015,0.018,0.022)	(0.012,0.015,0.018,0.022)
C31	(0.006,0.009,0.011,0.014)	(0.007,0.01,0.012,0.016)	(0.006,0.008,0.009,0.013)	(0.006,0.008,0.009,0.013)
C32	(0.017,0.021,0.024,0.026)	(0.019,0.023,0.028,0.028)	(0.017,0.021,0.022,0.025)	(0.018,0.022,0.026,0.027)
C33	(0.005,0.009,0.011,0.017)	(0.011,0.016,0.02,0.026)	(0.008,0.012,0.015,0.021)	(0.008,0.012,0.015,0.021)
C34	(0.012,0.016,0.018,0.024)	(0.013,0.017,0.021,0.026)	(0.008,0.012,0.016,0.021)	(0.007,0.011,0.013,0.018)
C35	(0.015,0.019,0.021,0.028)	(0.015,0.019,0.021,0.027)	(0.014,0.018,0.019,0.026)	(0.015,0.019,0.021,0.028)
C36	(0.005,0.008,0.011,0.016)	(0.011,0.015,0.018,0.023)	(0.007,0.01,0.011,0.016)	(0.007,0.01,0.011,0.016)
C37	(0.016,0.021,0.022,0.028)	(0.017,0.022,0.025,0.031)	(0.017,0.022,0.025,0.031)	(0.014,0.019,0.021,0.027)
C38	(0.011,0.015,0.018,0.024)	(0.012,0.016,0.021,0.026)	(0.007,0.012,0.014,0.019)	(0.007,0.012,0.014,0.019)
C41	(0.006,0.008,0.01,0.013)	(0.006,0.008,0.012,0.016)	(0.005,0.007,0.009,0.013)	(0.005,0.007,0.01,0.014)
C42	(0.007,0.01,0.012,0.016)	(0.007,0.011,0.014,0.018)	(0.007,0.01,0.012,0.016)	(0.006,0.009,0.01,0.014)
C43	(0.012,0.016,0.019,0.024)	(0.014,0.018,0.02,0.025)	(0.014,0.018,0.02,0.025)	(0.011,0.015,0.017,0.022)
C44	(0.019,0.024,0.026,0.029)	(0.019,0.024,0.026,0.029)	(0.015,0.019,0.022,0.026)	(0.018,0.022,0.025,0.028)
C45	(0.018,0.023,0.029,0.035)	(0.015,0.02,0.028,0.034)	(0.015,0.02,0.028,0.034)	(0.017,0.022,0.026,0.032)
C46	(0.012,0.017,0.026,0.032)	(0.012,0.017,0.026,0.032)	(0.013,0.018,0.024,0.031)	(0.012,0.017,0.026,0.032)
C47	(0.003,0.007,0.01,0.017)	(0.006,0.012,0.015,0.023)	(0.006,0.012,0.015,0.023)	(0.003,0.007,0.01,0.017)
C48	(0.018,0.022,0.025,0.027)	(0.018,0.023,0.027,0.028)	(0.015,0.019,0.023,0.025)	(0.018,0.022,0.025,0.027)
C49	(0.013,0.018,0.021,0.026)	(0.016,0.021,0.024,0.028)	(0.017,0.022,0.023,0.028)	(0.012,0.016,0.017,0.022)
C410	(0.014,0.019,0.022,0.028)	(0.015,0.02,0.025,0.031)	(0.015,0.02,0.025,0.031)	(0.013,0.018,0.023,0.03)
C51	(0.007,0.01,0.011,0.017)	(0.008,0.011,0.011,0.017)	(0.006,0.009,0.01,0.015)	(0.006,0.009,0.01,0.015)
C52	(0.006,0.009,0.012,0.015)	(0.007,0.009,0.013,0.017)	(0.006,0.008,0.01,0.014)	(0.007,0.01,0.012,0.016)
C53	(0.017,0.024,0.032,0.04)	(0.01,0.017,0.027,0.035)	(0.017,0.024,0.032,0.04)	(0.01,0.017,0.02,0.028)
C54	(0.012,0.016,0.017,0.021)	(0.014,0.018,0.02,0.024)	(0.011,0.014,0.016,0.021)	(0.011,0.015,0.018,0.022)
C55	(0.014,0.02,0.024,0.031)	(0.007,0.012,0.017,0.024)	(0.006,0.011,0.014,0.02)	(0.009,0.014,0.015,0.022)
C56	(0.014,0.019,0.021,0.026)	(0.013,0.018,0.021,0.024)	(0.012,0.017,0.019,0.023)	(0.012,0.017,0.019,0.023)
C57	(0.008,0.013,0.017,0.024)	(0.009,0.014,0.016,0.022)	(0.009,0.014,0.016,0.022)	(0.009,0.014,0.016,0.022)
C61	(0.018,0.022,0.026,0.03)	(0.019,0.023,0.025,0.03)	(0.019,0.023,0.025,0.03)	(0.015,0.019,0.02,0.025)
C62	(0.004,0.007,0.009,0.012)	(0.007,0.01,0.011,0.015)	(0.005,0.008,0.009,0.013)	(0.004,0.006,0.007,0.011)
C63	(0.005,0.009,0.012,0.017)	(0.01,0.014,0.019,0.025)	(0.006,0.011,0.014,0.02)	(0.007,0.012,0.013,0.019)
C64	(0.014,0.018,0.02,0.025)	(0.015,0.019,0.022,0.027)	(0.01,0.014,0.018,0.023)	(0.01,0.014,0.018,0.023)
C71	(0.015,0.019,0.022,0.026)	(0.019,0.024,0.026,0.029)	(0.018,0.023,0.024,0.028)	(0.016,0.02,0.021,0.025)
C72	(0.01,0.014,0.016,0.02)	(0.011,0.015,0.017,0.021)	(0.009,0.013,0.014,0.019)	(0.007,0.01,0.012,0.016)
C73	(0.01,0.013,0.014,0.018)	(0.01,0.013,0.014,0.018)	(0.01,0.013,0.014,0.018)	(0.01,0.013,0.014,0.018)
C74	(0.01,0.015,0.016,0.021)	(0.013,0.018,0.019,0.025)	(0.007,0.011,0.013,0.017)	(0.008,0.012,0.015,0.02)

- To manage and control the effect of negative or positive events that influence organization's objectives (Manuj and Mentzer, 2008).
- The ability to make decisions regarding managing the potentially negative effects of risk and taking advantage of opportunities (Chopra and Sodhi, 2004; Manuj and Mentzer, 2008).
- The focus on business activities and improve business using planning processes and performance management (Cucchiella and Gastaldi, 2006).
- Organization's ability to direct resources on more important and effective risk.
- With a vivid picture of the position of the organization and industry one can avoid unplanned works in the processes and events and consequently increase organizational efficiency (Olson and Wu, 2010).
- Combining other managerial processes with risk management processes in the organization (Manuj and Mentzer, 2008).
- Notifying risk management benefits to stakeholders (Cucchiella and Gastaldi, 2006).
- Creating an organizational culture in which all employees are aware of their role in achieving the organization's goals.
- To determine organizational policy and risk management approach (Chopra and Sodhi, 2004; Olson and Wu, 2010; Cucchiella and Gastaldi, 2006).
- To determine the scope and application of risk management in the organization. (Olson and Wu, 2010).
- To define the roles and responsibilities in the organizational risks management (Giannakis and Louis, 2011).
- Development of a continuous process of risk management in the organization according to relevant standards (Aqlan and Lam, 2015).
- Formulating of risks reporting process (Aqlan and Lam, 2015; Cucchiella and Gastaldi, 2006).

6. Conclusion

Although vast research have produced useful understandings and analyzed the supply chain risks' nature, little study has been done to increase risk considerations that consist the idea of sustainability across the supply chain. Unfortunately, understanding what SSCRM means, and which information should be controlled is difficult, and by considering these risks, how risk reduction and

Table 9
Step 8 and 9: FNIS and FPIS, and distances of each alternative from them.

	FNIS	FPIS	d_i^-				d_i^+			
			A1	A2	A3	A4	A1	A2	A3	A4
C11	0.0024	0.0297	0.013	0.008	0.015	0.015	0.015	0.019	0.012	0.012
C12	0.0019	0.0200	0.006	0.008	0.007	0.007	0.012	0.01	0.011	0.011
C13	0.0160	0.0290	0.007	0.007	0.006	0.007	0.006	0.006	0.007	0.006
C14	0.0168	0.0336	0.006	0.01	0.008	0.011	0.011	0.007	0.009	0.005
C15	0.0110	0.0241	0.007	0.008	0.005	0.006	0.006	0.006	0.008	0.007
C16	0.0062	0.0243	0.008	0.008	0.006	0.01	0.01	0.01	0.012	0.008
C21	0.0150	0.0271	0.005	0.008	0.006	0.005	0.007	0.004	0.006	0.007
C22	0.0179	0.0343	0.008	0.008	0.007	0.009	0.009	0.008	0.01	0.007
C23	0.0069	0.0222	0.006	0.008	0.007	0.006	0.01	0.007	0.008	0.01
C24	0.0146	0.0362	0.008	0.008	0.01	0.012	0.014	0.014	0.012	0.01
C25	0.0119	0.0247	0.005	0.007	0.005	0.005	0.008	0.006	0.008	0.008
C31	0.0057	0.0155	0.004	0.005	0.003	0.003	0.006	0.005	0.006	0.006
C32	0.0166	0.0281	0.006	0.008	0.005	0.007	0.006	0.004	0.007	0.005
C33	0.0045	0.0260	0.006	0.014	0.01	0.01	0.016	0.008	0.012	0.012
C34	0.0069	0.0262	0.011	0.012	0.007	0.005	0.009	0.007	0.012	0.014
C35	0.0144	0.0284	0.006	0.006	0.005	0.006	0.008	0.008	0.009	0.008
C36	0.0046	0.0228	0.005	0.012	0.006	0.006	0.013	0.006	0.012	0.012
C37	0.0140	0.0305	0.008	0.01	0.01	0.006	0.009	0.007	0.007	0.011
C38	0.0075	0.0264	0.009	0.011	0.006	0.006	0.01	0.008	0.013	0.013
C41	0.0046	0.0156	0.005	0.006	0.004	0.005	0.006	0.005	0.007	0.006
C42	0.0061	0.0179	0.005	0.006	0.005	0.004	0.007	0.005	0.007	0.008
C43	0.0114	0.0249	0.006	0.008	0.008	0.005	0.007	0.006	0.006	0.009
C44	0.0150	0.0289	0.01	0.01	0.006	0.008	0.004	0.004	0.008	0.006
C45	0.0154	0.0352	0.011	0.009	0.009	0.009	0.009	0.011	0.011	0.011
C46	0.0124	0.0324	0.01	0.01	0.009	0.01	0.011	0.011	0.011	0.011
C47	0.0030	0.0233	0.006	0.011	0.011	0.006	0.014	0.009	0.009	0.014
C48	0.0152	0.0284	0.008	0.009	0.005	0.008	0.005	0.004	0.008	0.005
C49	0.0119	0.0278	0.008	0.01	0.01	0.005	0.008	0.006	0.006	0.011
C410	0.0129	0.0315	0.008	0.01	0.01	0.008	0.011	0.009	0.009	0.01
C51	0.0064	0.0167	0.005	0.005	0.004	0.004	0.006	0.005	0.007	0.007
C52	0.0058	0.0170	0.005	0.006	0.004	0.006	0.007	0.006	0.008	0.006
C53	0.0102	0.0399	0.018	0.012	0.018	0.009	0.012	0.018	0.012	0.021
C54	0.0108	0.0241	0.006	0.008	0.005	0.006	0.007	0.005	0.009	0.007
C55	0.0057	0.0310	0.017	0.009	0.007	0.009	0.009	0.016	0.018	0.016
C56	0.0120	0.0262	0.008	0.007	0.006	0.006	0.006	0.007	0.009	0.009
C57	0.0084	0.0238	0.007	0.007	0.007	0.007	0.008	0.008	0.008	0.008
C61	0.0147	0.0304	0.009	0.01	0.01	0.005	0.006	0.006	0.006	0.011
C62	0.0037	0.0154	0.004	0.007	0.005	0.003	0.007	0.004	0.006	0.008
C63	0.0048	0.0251	0.006	0.012	0.008	0.008	0.014	0.008	0.012	0.012
C64	0.0101	0.0274	0.009	0.011	0.006	0.006	0.008	0.007	0.011	0.011
C71	0.0147	0.0291	0.006	0.01	0.009	0.006	0.009	0.004	0.006	0.009
C72	0.0072	0.0214	0.008	0.009	0.007	0.004	0.006	0.005	0.008	0.01
C73	0.0096	0.0176	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
C74	0.0071	0.0249	0.008	0.012	0.005	0.007	0.009	0.006	0.013	0.011

Table 10
Step 10: The relative closeness of each alternative and rank them.

Alternative	C_i	Rank
A1 (Aryasasol)	0.4637	2
A2 (Nouri)	0.5404	1
A3(Mobin)	0.4414	3
A4 (Zagros)	0.4207	4

management can be designed. The developing framework to identify and analyze SSCRM is grounded. By thinking of sustainability of supply chain as a process of risk management, the study contributes to the SSCRM literature. In today supply chain management, the two most important issues which are frequently intertwined, are the supply chain risk and sustainability and they are often viewed in separation. Since catastrophic events occur suddenly and leaving little time for adaptation; therefore, supply chains becoming more resilient is essential. In whole, supply chain risks involve external risks, such as logistical difficulties, supplier problems, and those sourcing from governmental actions, and internal risks (operations and primarily policies). Organizational sustainability, social responsibility, and the environmental sustainability are typically defined as three categories of sustainability. Actions in one area frequently influence the actions in the other area. For these reasons, meeting sustainability and supply chain risk cooperatively is sensible. This work tried to bridge sustainability and supply chain risk management, however, future works could focus on developing a conceptual framework for the evaluation of SSCRM. As it is still in the beginning and needs to be delved more on the topic. Various limitations can be counted in each phase of the research. First, although the researchers have tried to propose a comprehensive model for the sustainable risk evaluation process, but future research could focus on the different contexts to specify needs of various sections of industries. The distinction between upward and downward decisions affecting the supply chain sustainability could be of importance in the risk assessment process that due to the methodological limitation this study couldn't address. Some cross-sectional case studies can enhance our understanding of the various decisions made in the supply chain. The inclusion of managerial mindsets in the evaluation process using qualitative research methods could improve the understandability

Table 11
Prioritizing of main criteria and sub-criteria.

Main criteria	Rank	Sub-criteria	Rank
Sustainable production/manufacturer risks (C4)	1	Machines & equipment risks (48)	1
		Quality risk (44)	2
		Poor planning and scheduling (45)	3
		Change in technologies due to green, (410)	4
		Long product lead times for green products/materials (49)	5
		Forecasting errors (46)	6
		Demand risk (43)	7
		Production capacity risk (42)	8
		Labor strike (47)	9
		Product design risk (41)	10
Sustainable supply risks (C3)	2	Key supplier failures (C32)	1
		Limited number of green suppliers to choose from (37)	2
		Supplier's financial instability (38)	3
		Supplier uncertainty (C34)	4
		Supplier quality (C33)	5
		Inventory risks (36)	6
		Material order risks (35)	7
		Capacity constraints (C31)	8
Sustainable distribution risks (C5)	3	Demand fluctuations (53)	1
		Market related risks (55)	2
		Demand forecasting risks (54)	3
		Inability to use green fuel (56)	4
		Product perishability risk (57)	5
		Proximity to airports (51)	6
		Quality of roads (52)	7
Organizational risks (C2)	4	Government policy risks (C22)	1
		Management policy failures (C21)	2
		Lack of commitment in the supply chain to go green (C25)	3
		Poor interrelationships between supply chain partners (C24)	4
		Human error (C23)	5
Information technology-related risks (C7)	5	IT security (71)	1
		Fail to access information (73)	2
		IT system failure (74)	3
		Bullwhip effect (72)	4
Environmental risks (C1)	6	Economic issues (C14)	1
		Political instability (C13)	2
		Natural disasters (C15)	3
		Epidemics labor dispute (C16)	4
		Terrorisms (C12)	5
		Wars (C11)	6
Sustainable recycling risks (C6)	7	Lack of proper sewage infiltration (61)	1
		Groundwater pollution risks (64)	2
		Discharging of wastes risks (63)	3
		Inability in use of other company's wastes (62)	4

of the methods proposed and could increase the rate of acceptance within the industries.

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Appendix 1

Definition 1. function $\mu_{\tilde{A}}(x)$ as the membership of a fuzzy subset $\tilde{A}$ of a universal set X can define it as (Zimmermann, 2010):

$$\tilde{A} = \left\{ \left(x \cdot \mu_{\tilde{A}}(x) \right) | x \in X \right\} \quad (1)$$

The elements belonging to the universal set are presented by $x \in X$, and. $\mu_{\tilde{A}\square}(x) : X \to [0.\ 1]$.

Definition 2. A special case of a convex is as a fuzzy number, fuzzy subset which is normalized as $(\sup \mu_{\tilde{A}\square}(x) = 1)$ of the real line $\mathbb{R}$ ($\mu_{\tilde{A}\square}(x) : \mathbb{R} \to [0.\ 1]$) (Wang and Lee, 2007).

Definition 3. A fuzzy number $\tilde{A}$membership function is as follow if it is a trapezoidal fuzzy number (Ölçer and Odabaşi, 2005):

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{(x - a_1)}{(a_2 - a_1)} & a_1 \le x \le a_2 \\ 1 & a_2 \le x \le a_3 \\ \dfrac{(a_4 - x)}{(a_4 - a_3)} & a_3 \le x \le a_4 \\ 0 & otherwise \end{cases} \quad (2)$$

A quadruplet$\tilde{A} = (a_1, a_2, a_3, a_4)$can also define this fuzzy number. Fig. 4 presents an example of this type of fuzzy numbers.

Definition 4. Suppose that$k$ is a crisp number, and $\tilde{A} = (a_1, a_2, a_3, a_4)$ and $\tilde{B} = (b_1, b_2, b_3, b_4)$ be two positive trapezoidal fuzzy numbers ($a_1 \ge 0$ and $b_1 \ge 0$). The following defines arithmetic operations with these fuzzy numbers (Chen and Hwang, 1992):

- Addition:

$$\tilde{A} \oplus \tilde{B} = (a_1 + b_1 \cdot a_2 + b_2 \cdot a_3 + b_3 \cdot a_4 + b_4) \quad (3)$$

$$\tilde{A} + k = (a_1 + k \cdot a_2 + k \cdot a_3 + k \cdot a_4 + k) \quad (4)$$

- Subtraction:

$$\tilde{A} \ominus \tilde{B} = (a_1 - b_4 \cdot a_2 - b_3 \cdot a_3 - b_2 \cdot a_4 - b_1) \quad (5)$$

$$\tilde{A} - k = (a_1 - k \cdot a_2 - k \cdot a_3 - k \cdot a_4 - k) \quad (6)$$

- Multiplication:

$$\tilde{A} \otimes \tilde{B} = (a_1 \times b_1 \cdot a_2 \times b_2 \cdot a_3 \times b_3 \cdot a_4 \times b_4) \quad (7)$$

$$\tilde{A} \times k = \begin{cases} (a_1 \times k \cdot a_2 \times k \cdot a_3 \times k \cdot a_4 \times k) & if \quad k \geq 0 \\ (a_4 \times k \cdot a_3 \times k \cdot a_2 \times k \cdot a_1 \times k) & if \quad k < 0 \end{cases} \quad (8)$$

- Division:

$$\tilde{A} \oslash \tilde{B} = \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right) \quad (9)$$

$$\tilde{A} \Big/ k = \begin{cases} \left(\frac{a_1}{k}, \frac{a_2}{k}, \frac{a_3}{k}, \frac{a_4}{k}\right) & if \quad k > 0 \\ \left(\frac{a_4}{k}, \frac{a_3}{k}, \frac{a_2}{k}, \frac{a_1}{k}\right) & if \quad k < 0 \end{cases} \quad (10)$$

Definition 5. By supposing $\tilde{A} = (a_1, a_2, a_3, a_4)$ as a trapezoidal fuzzy number, the following defines this fuzzy number's defuzzified (crisp) value (Wang et al., 2006):

$$\kappa\left(\tilde{A}\right) = \frac{1}{3}\left(a_1 + a_2 + a_3 + a_4 - \frac{a_3 a_4 - a_1 a_2}{(a_3 + a_4) - (a_1 + a_2)}\right) \quad (11)$$

Definition 7. The Hamming distance between two trapezoidal fuzzy numbers is defined as follows (Li, 2007):

$$d\left(\tilde{A} \cdot \tilde{B}\right) = \frac{|a_1 - b_1| + |a_2 - b_2| + |a_3 - b_3| + |a_4 - b_4|}{4} \quad (12)$$

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