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Agile supply chain management based on critical success factors and most ideal risk reduction strategy in the era of industry 4.0: application to plastic industry

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Abstract
In the global trade economy, the degree of competition and differentiation among organizations working in the sector of Supply Chain Management (SCM) is expanding gradually. For companies, SCM operations are becoming more important than manufacturing, sales, and marketing activities, and new ways and methods are preferred for efficiency and performance. The agility (or agility phenomenon) is one of the applications that aids effective SCM operations in this context. Agile Supply Chain Management (ASCM) and the emergence of Industry 4.0 practices, in addition to offering a cost advantage and business performance improvement, are crucial in providing flexibility to companies and ensuring their survival in the era of Industry 4.0. Meanwhile, companies aim to deal with uncertainty and implement various risk-reduction strategies as part of effective SCM. In this context, the study lists the critical success factors of ASCM and selects the most appropriate risk reduction strategy for companies that manufacture and market rubber and plastic products with a corporate identity and conduct import and export business in Istanbul. For this purpose, the criteria and alternatives specified in accordance with the literature review and experts' opinions are examined using Bipolar Neutrosophic Stepwise Weight Assessment Ratio Analysis (BN-SWARA) and Bipolar Neutrosophic Technique for Order of Preference by Similarity to Ideal Solution (BN-TOPSIS) methods. The ranking results are then discussed in line with the practical implications to provide managerial insights and decision aids. Finally, the main limitations are expressed in order to delineate useful future research directions.

Keywords Agile supply chain management · Industry 4.0 · Risk reduction · Success factors · Bipolar neutrosophic SWARA · Bipolar neutrosophic TOPSIS

1 Introduction

In today's global marketplace, a company's ability to survive competitive challenges and turn them into a competitive advantage is a critical success component. Since market environments are changing, adaptability is critical to a company's long-term performance and survival (Swafford et al. 2008). The employment of a virtual company with market information to take advantage of profitable possibilities in a volatile market is referred to as "agility". To put it another way, agility refers to a company's way of thinking, logistical procedures, information systems, and organizational structure, as well as a specific degree of business (Christoper et al. 2004). An agile approach is characterized as a production structure that can quickly adapt to customer demands and requests while also fostering productive cooperation (Hormozi 2001).

Agile Supply Chain (ASC) is known as a censorious strategy for corporates to manage their supply chain and provide flexible abilities for meeting fast-changing customer requests (Kim and Chai 2017; Um 2017b). Agile Supply Chain Management (ASCM), on the other hand, refers to the ability to meet market demands and adapt to conclusions (Kamath and Saurav 2016). In another definition, this awareness is expressed as a focus on "finding a quick answer" as one of the underlying elements of Industry 4.0. Traditional supply chains require readiness since they take so long to deliver. ASCs, on the other hand, aim to make deliveries in less time and are demand-driven (Christopher et al. 2004). When demand declines suddenly, an ASC is a system that provides for more flexible supplier connections,

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such as the capacity to change order quantities and goods destinations, as well as cancel orders entirely (Sehgal 2010). For ASCs, it is critical to develop logistics capabilities ahead of time (Tian 2009). Since agility has shifted the focus of supply chains from a company-centric perspective to a customer-centric one (Harrison and Hoek 2008). Supply chain agility is a tool that aids organizations in gaining a competitive advantage (Wu et al. 2017). Consequently, supply chain agility is a critical factor in achieving business excellence (Blome et al. 2013). Similarly, ASCM approach can reduce process and information flow delays at all levels of the supply chain (Başkol 2011).

Manufacturing companies must be able to compete in a global and competitive business world by dealing with shortened product life cycles and increasingly knowledgeable consumers, meeting varying demand, quickly introducing new products to the market, and being forced to use a flexible supply chain in this context (Routroy et al. 2018). Hence, the supply chain's agility and flexibility concurrently raise both cost and operational performance (Wu and Barnes 2018). Critical success factors in ASCM emerge as the fundamental components that have become vital for companies at this point. A high level of connectivity throughout the supply chain, information sharing, process integration, short lead times, optimized safety stock, effective technology and resource management, effective supplier management, and effective material and stock management are all required (Ganguly et al. 2017). Novel business models, as consequence of Industry 4.0 practices and fluctuating market demands, are to deliver better values to customers (Husain et al. 2021). Recently, the outbreak of COVID-19 pandemic has intensified the utility of ASCM based on the digital transformation and technological changes in production and operation management occuring due to Industry 4.0 (Jamwal et al. 2021; Piyathanavong et al. 2022).

ASCM is clearly one of the most important success elements in ensuring all of these capabilities. The ability of a company to develop strong long-term relationships with suppliers and other strategic partners is crucial in this respect. Any failure in the supply chain flow related to these priorities which set companies apart from the competition risks may raise the risk levels in Supply Chain Management (SCM). Prior to deciding on functional solutions to reduce the risks, they may encounter in SCM, managers must comprehend the main risk categories, their contents, and the facts that affect and drive them (Korucuk and Memiş 2018). Risk, on the other hand, cannot be totally minimized or avoided. It is critical for businesses to maintain the required initiative in all processes and to reduce or limit risk. Risk management strategies, it is expressed in this way, help to reduce the likelihood of disruptions by limiting the magnitude of financial losses that the risk will cause (Shah 2009).

At this point, supply chain risk reduction measures are beneficial to businesses. Since supply chain risk reduction strategies include business operations targeted at lowering the probability of risks and their consequences (Chang et al. 2015). Businesses must first assess the threats to their operations, and then implement effective risk-reduction strategies that are adapted to their specific needs (Chopra and Sodhi 2004). The type of risk and the budget set aside by the corporate influence the selection of an effective risk reduction strategy (Fan and Stevenson 2018). Since risks are interconnected, a supply chain risk reduction strategy might affect many risk types and risk reduction strategies at the same time. Some risk mitigation measures have also been found to enhance some forms of risk (Rajesh et al. 2015). While this emphasizes the importance of selecting appropriate strategies, it also makes selecting the best strategies extremely challenging (Çıkmak et al. 2020).

Many factors motivate the authors to examine the research problem in this regard. It is an important concept in terms of making SCM agile, increasing competitiveness, creating customer satisfaction and loyalty, optimizing security stock, sharing information, and ensuring process optimization and efficiency with the least risk, and it is contingent on the experiencem expertise, and knowledge of decision-makers. The increased rate of change in business and trade environments, as well as companies' willingness to take advantage of global opportunities, effective technology application, risk factors, ASCM application, and adoption of success factors, have revealed a new relationship and enabled new models applicable in the era of Industry 4.0. Moreover, this reserach is regarded as a significant component in terms of providing an effective and appropriate answer to the decision-making problem including the choice of ASCM success factors and risk reduction strategies in a essential field; e.g., manufacturing sector.

Working on ASCM success criteria and developing a methodology that allows companies to self-assess risk management is beneficial. This work serves as a roadmap for achieving ASCM success criteria and sustainable procedures in the manufacturing sector, also looks at the similarities and differences in ASCM success criteria across organizations along with the extent to which they can be addressed. Consequently, this work develops a practical roadmap for the manufacturing sector's selection of ASCM success criteria and risk reduction plan strategy. Coming up with an efficient, robust, and practical decision-making model is another theoretical and practical target of the study which is able to treat the real-world uncertainty.

This study is valuable for providing evidence related to the effect of ASCs' critical success applications on the reduction of risk and uncertainty. Furthermore, it is novel and original in terms of developing and confirming the solution of risky and uncertainty-based structures, and enhancing corporate performance via ASC applications. This work also has important implications regarding the increase of the agility inherent in supply chain value streams in businesses in the sector and how to help them successfully minimize and manage risk and uncertainty. Then, it calls on businesses that seek success to reflect on the depth of their success criteria and the risk reduction strategies of their ASCM to become resilient to unexpected disruptions. For instance, the ongoing pandemic presents many risks and uncertainties. The phenomenon of agility and its applications play an essential role in coping with these risks and uncertainties, hence the level of risk reduction can be considered another motivational contribution.

Additionally, from the manager's perspective, this study also illustrates why ASC success factors should be carefully considered when deciding whether to deploy a particular risk reduction strategy along with development. Success in this area also assures the organization of sustainable competitive advantages. Similarly, the successful application of ASCM and the selection of the right risk reduction strategy will increase internal and external cooperation and assure the organization of resources and competencies that competitors may find difficult or impossible to imitate. Managers and stakeholders can use the framework presented in this research to evaluate the effectiveness of their risk reduction and uncertainty handling efforts throughout the supply chain and take corrective action where necessary. It is then expected to provide an efficient and robust model to cover theoretical gaps in the literature by employing the advantages of the research methodologies along with contributing to the long-term solution of decision-making problems in the manufacturing sector. As a result, it will help solve problems in various sectors. It is also anticipated that the current research will make a remarkable contribution to the literature and business world, particularly in terms of sustainable SCM and sustainable production. Accordingly, the obtained results related to the manufacturing sector are comparable with other sectors.

The current research was performed in companies operating in İstanbul, that manufacture and market cleaning and cleaning products with a global corporate identity, with the goal of ranking the success criteria of ASCM and determining the optimum risk reduction strategy. The elements from the literature review were examined using Bipolar Neutrosophic Stepwise Weight Assessment Ratio Analysis (BN-SWARA) and Bipolar Neutrosophic Technique for Order of Preference by Similarity to Ideal Solution (BN-TOPSIS) techniques. There are several reasons why BN-SWARA and BN-TOPSIS were chosen to treat the suggested decision-making problem. These reasons can be deduced from the methodology's fundamental characteristics. The propensity of the human mind to argue and make decisions based on positive and negative influences is called *bipolarity*. In such a manner, positive information expresses what is possible, decent, permissible, desirable, or deemed acceptable. On the contrary, negative statements explain what is impossible, rejected, or prohibited. Positive preferences match with wishes, as they identify which objects or values are more ideal than others without declining those that do not fulfill the wishes. Furthermore, negative preferences match with constraints, as they identify which objects or values must be rejected, whereas negative preferences associated with constraints, as they determine which values or objects must be declined (Bosc and Pivert 2013; Deli et al. 2015). As a result, numerous authors have suggested bipolar fuzzy sets and models. Deli et al (2015) offered Bipolar Neutrosophic sets (BNSs) as one of these options. The membership degrees of Neutrosophic Sets (NSs) for Truth (T), Indeterminacy (I), and Falsity (F), as well as the negative equivalents of these memberships, are bipolar in BNSs. This ensures that the decision-making problem incorporates both positive and negative evaluations holistically.

This study employs the BN-TOPSIS and BN-SWARA methods in addition to the Bipolar Neutrosophic (BN) structure mentioned above. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) evaluates the alternatives using ideal and anti-ideal values to tackle the decision-making problem. It is organized in a way that is both useful and clear to comprehend. Moreover, SWARA allows weights to be determined efficiently based on expert assessments in cases when finding the weight values of the criterion subjectively is challenging. It also provides a comprehensible and easily applied structure for decision-makers who are new to decision-analysis methods.

A survey on the literature of ASCM success criteria and risk reduction strategies, explanations of the BN-SWARA and BN-TOPSIS methods, application of the methodology in the context of companies operating in Istanbul, especially the plastic industry, and the findings are discussed in the following sections of the study. Finally, the work ends with a conclusion, limitations, and future research recommendations.

2 Survey on the literature

Agility-based organizations have begun to replace mass manufacturing in global trade, requiring a series of interconnected marketing, production, and organizational structure changes (Storey et al. 2005). Companies with ASCs can rapidly fulfill customer orders, launch new products on a regular basis, and develop strategic relationships with their partners (Um 2017a). True supply chain agility can only be realized when all companies and their capabilities, involving logistical capabilities, are linked at the supply chain level (Gligor et al. 2013).

On the other hand, businesses that want to compete in today's global market must prioritize risk criteria in all areas. Logistics practices emerge and change on a daily basis all over the world, including in Turkey, and as a result, risk factors emerge (Korucuk and Erdal 2018). At the same time, rather than passively reacting to uncertainties, businesses may choose to control unexpected events caused by various risks (Jüttner et al. 2003).

Table 1 presents a literature review on ASCM critical success factors and risk reduction strategies in this context.

The comprehensive literature search included studies on businesses that manufacture and sell cleaning products for the real-life ASCM critical success factors and risk reduction strategies selection problem discussed in this study. In as much as being flexible and meeting demand variables is critical in business, as is developing a sustainable SCM approach and investigating risk reduction elements to address Industry 4.0 requirements. Besides, no other study in this area has been discovered that takes into account the dimensions of responding quickly to market variables, ensuring customer satisfaction, cost minimization, risk management, increasing competitiveness, and process management in enterprises. Moreover, no quantitative research within the scope of ASCM critical success factors and risk reduction strategies problem for the province of Istanbul has been identified in the literature. The model developed in this work is helpful because it demonstrates the study's importance by providing solutions to critical success factors and risk reduction strategies of ASCM at various levels of importance, which will be determined by decision-makers for each criterion and alternative.

3 Methodology

The BN-TOPSIS method will be used to evaluate alternatives in the study. The criteria will be weighted using BN-SWARA. In this context, firstly, the explanations of BNS are elaborated as follows.

3.1 Bipolar neutrosophic sets

Smarandache (1998) was the first to propose the NS. NS provides the solution to a problem with varying degrees of T, I, and F. NS differs from intuitionistic fuzzy sets in that it can handle uncertainty independently of T and I, it has a more flexible structure, and it can process more information. NSs are the generalization of classical fuzzy sets, Intuitionistic Fuzzy Sets (IFSs), q-Rung Orthopair Fuzzy Sets (q-ROFSs), and Pythagorean Fuzzy Sets (PFSs) (Smarandache 2019). On the other hand, BNSs were defined by Deli et al. (2015) and applied to MCDM problems. Some explanations for BNSs are listed below.

Consider X as a universe of discourse. Then, a BNS A in X is denoted as $\widetilde{A} = \left\{\langle x, T^{+}(x), I^{+}(x), F^{+}(x), T^{-}(x), I^{-}(x), F^{-}(x)\rangle : x \in X\right\}$, where $T^{-}, I^{-}, F^{-} : X \to [-1,0]$ and $T^{+}, I^{+}, F^{+} : X \to [1,0]$. Among the positive membership degrees of an element $x \in X$ related to a BNS A , $T^{+}(x)$ denotes the T membership degree, $F^{+}(x)$ shows the F membership degree and $I^{+}(x)$ stands for the I membership degree. The T, F, and I memberships of an element $x \in X$ to some implicit counter property corresponding to BNS A are denoted by $T^{-}(x), F^{-}(x)$ and $I^{-}(x)$, which are also called negative membership degrees (Deli et al. 2015; Abdel-Baset et al. 2020).

Let $\widetilde{A}_1$ and $\widetilde{A}_2$ be two BNSs. In this context, the union and intersection of $\widetilde{A}_1$ and $\widetilde{A}_2$ are presented in Eqs. (1)-(2). Furthermore, the complement of $\widetilde{A}_1$ is given in Eq. (3). The conditions defined in Eqs. (1)-(3) are satisfied, where $\widetilde{A}_1^C(x)$ is the complement of $\widetilde{A}_1(x)$ for all $x \in X$ (Deli et al. 2015; Irvanizam et al. 2021):

$$\left(\widetilde{A}_1 \cup \widetilde{A}_2\right)(x) = \left\langle \begin{array}{l} max\left(T_1^{+}(x), T_2^{+}(x)\right), \frac{I_1^{+}(x)+I_2^{+}(x)}{2}, min\left(F_1^{+}(x), F_2^{+}(x)\right) \\ min\left(T_1^{-}(x), T_2^{-}(x)\right), \frac{I_1^{-}(x)+I_2^{-}(x)}{2}, max\left(F_1^{-}(x), F_2^{-}(x)\right) \end{array} \right\rangle, \tag{1}$$

$$\left(\widetilde{A}_1 \cap \widetilde{A}_2\right)(x) = \left\langle \begin{array}{l} \min\left(T_1^{+}(x), T_2^{+}(x)\right), \frac{I_1^{+}(x)+I_2^{+}(x)}{2}, \max\left(F_1^{+}(x), F_2^{+}(x)\right) \\ \max\left(T_1^{-}(x), T_2^{-}(x)\right), \frac{I_1^{-}(x)+I_2^{-}(x)}{2}, \min\left(F_1^{-}(x), F_2^{-}(x)\right) \end{array} \right\rangle, \tag{2}$$

$$\widetilde{A}_1^C(x) = \left\langle \begin{array}{c} 1 - T_1^{+}(x), 1 - I_1^{+}(x), 1 - F_1^{+}(x) \\ -1 - T_1^{-}(x), -1 - I_1^{-}(x), -1 - F_1^{-}(x) \end{array} \right\rangle. \tag{3}$$

Two BN Numbers (BNNs) can be defined by $\widetilde{a}_1 = \langle T_1^{+}, I_1^{+}, F_1^{+}, T_1^{-}, I_1^{-}, F_1^{-}\rangle$ and $\widetilde{a}_2 = \langle T_2^{+}, I_2^{+}, F_2^{+}, T_2^{-}, I_2^{-}, F_2^{-}\rangle$ for the sake of simplicity. The operators for BNSs are defined in Eqs. (4)-(7), where $\lambda > 0$ (Deli et al. 2015):

$$\begin{aligned} \widetilde{a}_1 + \widetilde{a}_2 =& \langle T_1^{+} + T_2^{+} - T_1^{+}T_2^{+}, I_1^{+}I_2^{+}, F_1^{+}F_2^{+}, -T_1^{-}T_2^{-}, \\ & -(-I_1^{-} - I_2^{-} - I_1^{-}I_2^{-}), -(-F_1^{-} - F_2^{-} - F_1^{-}F_2^{-})\rangle, \end{aligned} \tag{4}$$

$$\begin{aligned} \widetilde{a}_1\widetilde{a}_2 =& \langle T_1^{+}T_2^{+}, I_1^{+} + I_2^{+} - I_1^{+}I_2^{+}, F_1^{+} + F_2^{+} - F_1^{+}F_2^{+}, \\ & -(-T_1^{-} - T_2^{-} - T_1^{-}T_2^{-}), -I_1^{-}I_2^{-}, -F_1^{-}F_2^{-}\rangle, \end{aligned} \tag{5}$$

$$\begin{aligned} \lambda\widetilde{a}_1 =& \langle 1 - \left(1 - T_1^{+}\right)^{\lambda}, \left(I_1^{+}\right)^{\lambda}, \left(F_1^{+}\right)^{\lambda}, -\left(-T_1^{-}\right)^{\lambda}, \\ & -\left(-I_1^{-}\right)^{\lambda}, -\left(1 - (1 - (-F_1^{-}))^{\lambda}\right)\rangle, \end{aligned} \tag{6}$$

$$\begin{aligned} \widetilde{a}_1^{\lambda} =& \langle \left(T_1^{+}\right)^{\lambda}, 1 - \left(1 - I_1^{+}\right)^{\lambda}, 1 - \left(1 - F_1^{+}\right)^{\lambda}, \\ & -(1 - (1 - (-T_1^{-}))^{\lambda}), -\left(-I_1^{-}\right)^{\lambda}, -\left(-F_1^{-}\right)^{\lambda}\rangle. \end{aligned} \tag{7}$$

The score function $\varsigma\left(\widetilde{a}_1\right)$, certainty function $c\left(\widetilde{a}_1\right)$, and accuracy function $a\left(\widetilde{a}_1\right)$ are defined in Eqs. (8)-(10) for BNN $\widetilde{a}_1$ (Deli et al. 2015):

Table 1 Literature review on critical factors related to ASCM

Author(s)	Year	Objective	Method(s)
Power et al.	2001	Examining the critical success factors for manufacturing companies' ASCM	Statistical analysis
Tsourveloudis and Valavanis	2002	Overcoming the uncertainty of agility assessments	Fuzzy logic
Bruce et al.	2004	Examining lean or agile approaches	Depth interview
Lin et al.	2006	Studying the supply chain agility model	Fuzzy logic
Goh et al.	2007	Examining the multi-stage global supply chain network	Multi-Stage Stochastic Modelling
Bergvall-Forsberg and Towers	2007	Examining agile retailing in the European apparel and textile sector	Case study
Schoenherr et al.	2008	Assessing the importance of a group of risk factors in SCM and choosing the best alternative	Analytical Hierarchy Process (AHP)
Jain et al.	2008	Investigation of agility evaluation and decision-making flexibility	Fuzzy logic
Ganguly et al.	2009	Proposal of three technical and associated metrics to determine enterprise agility	Case study
Tuncel and Alpan	2010	Investigation of disruption factors of supply chain networks	Failure Modes and Effects Analysis (FMEA)
Pearson et al.	2010	Developing a model to assist decision-making in the ASC	Quantitative Analysis
Tang and Musa	2011	Investigation of major risk points in SCM	Literature review
Giannakis and Louis	2011	Examining risk management in manufacturing supply chains	Multi-agent based decision support system
Sukati et al.	2012	Analysis of the relationship between organizational practices and supply chain agility	Statistical analysis
Blome et al.	2013	Examining ASC studies	Literature review
Čiarnienė and Vienažindienė	2014	Investigation of agility problems in ready-to-wear clothing companies	Qualitative analysis
Mehralian et al.	2015	Evaluation of criteria in the ASC	TOPSIS
Çalışkan et al.	2016	Investigating the effect of sub-dimensions of agile and flexible SCM on company performance	Statistical analysis
Sartal et al.	2017	Examining how to balance overseas sourcing and agility in ready-made clothing supply chains	Case study
Rajagopal et al.	2017	Comprehensive review of 126 articles in the context of supply chain risk reduction	Literature review
Ciccullo et al.	2018	An integrated examination of environmental and social sustainability fundamentals with lean and ASCM paradigms	Literature review
Wu and Barnes	2018	Designing ASCs in transportation companies via dynamic programming modeling	Dynamic Programming
Korucuk and Memiş	2018	Examining Risk Factors in SCM	AHP
Kittisak et al.	2019	Examining the role of ASCM in enhancing the external supply chain	Partial Least Squares Structural-Equation Modeling (PLS-SEM)
Alkahtani et al.	2019	Conducting ASC Assessment	Empirical study
Kumar et al.	2019	Examining the agile supplier selection criteria via Multi-Criteria Decision-Making (MCDM) approaches	Fuzzy DEMATEL
Centobelli et al.	2020	Examining digital transformation and ASCM	Qualitative analysis
Çıkmak et al.	2020	Investigating supply chain risk reduction strategies in a defense industry enterprise	Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL)
Piya et al.	2020	Identifying critical factors and their interrelationships to design ASCs in oil and gas industries	Brainstorming digraph
McMaster et al.	2020	Studying risk management in the fashion supply chain during the COVID-19 pandemic	Qualitative analysis

Table 1 (continued)

Author(s)	Year	Objective	Method(s)
Nouri et al.	2021	Analyzing the impact of lean and ASC strategies on responsiveness and firm efficiency via the mediating role of delaying the order and strategic partnership of suppliers in the automative industry	Structural Equation Modeling (SEM)
Yıldız Çankaya and Can	2021	Examining the effect of supply chain integration on operational agility and customization capability	Least square technique
Shahed et al.	2021	Studying supply chain risk reduction in the COVID-19 period	Genetic Algorithm (GA)
Raji et al.	2021	Examining Industry 4.0 technologies as enablers of lean and ASC strategies	Exploratory case study
Dağsuyu et al.	2021	Studying integrated risk prioritization and action selection for the cold chain	AHP
Oliveira-Dias et al.	2022	Studying the relationships between information technology and lean and ASC strategies	Literature review
Hamdani et al.	2022	Proposed a framework for Big Data Analytics (BDA) organizational implementation in operational SCM and tested this framework by the approaches of agile project management, data mining model processing and case study	CRoss Industry Standard Process for Data Mining (CRISP-DM)
Waqas et al.	2022	Analysis of sustainable firm performance through lean, green and ASC practices	Structural Equation Modeling (SEM)
Seker	2022	Evaluating the most important agility factors in a fuel oil supply company via MCDM methods	Interval-Valued Pythagorean Fuzzy (IVPF) and AHP
Najar	2022	Evaluating lean SCM innovation performance	Statistical analysis

$$\varsigma(\widetilde{a}_1) = \frac{T_1^+ + 1 - I_1^+ + 1 - F_1^+ + 1 + T_1^- - I_1^- - F_1^-}{6}, \quad (8)$$

$$c(\widetilde{a}_1) = T_1^+ - F_1^-, \quad (9)$$

$$a(\widetilde{a}_1) = T_1^+ - F_1^+ + T_1^- - F_1^-. \quad (10)$$

Let $\left\{\widetilde{a}_{ij}^1, \dots, \widetilde{a}_{ij}^t\right\}$ be t BNNs and $\left\{w_1, \dots, w_t\right\}$ be the corresponding weight coefficients, where $w_k \geq 0$ and $\sum_{k=1}^{t} w_k = 1$. Bipolar Neutrosophic Weighted Aggregation Operator (BNWAO) is defined using Eq. (11) (Pramanik et al. 2018):

$$a_{ij} = BNWAO_w\left(\widetilde{a}_{ij}^1, \dots, \widetilde{a}_{ij}^t\right) = w_1\widetilde{a}_{ij}^1 \oplus \cdots \oplus w_1\widetilde{a}_{ij}^t =$$

$$\langle \sum_{k=1}^{t} w_k T_{ij}^{+(k)}, \sum_{k=1}^{t} w_k I_{ij}^{+(k)}, \sum_{k=1}^{t} w_k F_{ij}^{+(k)}, \sum_{k=1}^{t} w_k T_{ij}^{-(k)}, \sum_{k=1}^{t} w_k I_{ij}^{-(k)}, \sum_{k=1}^{t} w_k F_{ij}^{-(k)} \rangle. \quad (11)$$

3.2 Bipolar neutrosophic SWARA

Subjective, objective, or mixed methods are used to weight the criteria. Subjective evaluations of experts or decision-makers are frequently used to weight the criteria in MCDM problems. Keršuliene et al. (2010) developed the Stepwise Weight Assessment Ratio Analysis (SWARA), one of the techniques that provides subjective weighting. BNSs, as the extension of the fuzzy sets, bipolar fuzzy sets, IFSs and NSs, are utilized in this study to model uncertainty, F, and I in assessments. The BN-SWARA extension was first proposed to address the shortcoming of classical (crisp) SWARA in modeling uncertainty. The studies of Salamai (2021), Ayyıldız (2022), and Rani et al. (2020) were used in the development of BN-SWARA. SWARA ensures that the weights of the criteria are allocated in order of importance. In cases where identifying the weight values of the criteria subjectively is difficult, SWARA allows the weights to be determined effectively based on expert evaluations. Furthermore, for decision-makers who are unfamiliar with decision analysis methods, it has an understandable and easily applicable structure. The steps of the BN-SWARA process are outlined in the following section:

Step 1. Define the criteria The criteria to be taken into account in the decision-making problem are identified. In this context, first of all, an analyst or facilitator makes a list of all criteria that can be considered in the decision-making problem. Then, some criteria are eliminated by taking into account the evaluator's (decision-maker/expert) opinion on the criteria and the relationship between the criteria. Subsequently, the list of criteria is complete.

Step 2. Evaluate importance levels of criteria Experts assess the criteria in terms of their importance. Experts employ the linguistic terms in Table 2 to identify the importance levels of the criteria. In this context, $\zeta_j^{(k)}$ stands for the linguistic evaluations of k-th expert ($k = 1, \dots, t$) for j-th criterion ($j = 1, \dots, n$), where $\zeta_j^{(k)} = \langle T_j^{+(k)}, I_j^{+(k)}, F_j^{+(k)}, T_j^{-(k)}, I_j^{-(k)}, F_j^{-(k)} \rangle$.

Step 3. Integrated evaluations of experts The weights of the experts' evaluations (v_k) concerning the decision-making problem are determined, where $v_k \geq 0$ and $\sum_{k=1}^{t} v_k = 1$. For this purpose, linguistic terms in Table 2 can be utilized. In this study, we gave equal weights to the expert's evaluations. Expert evaluations for importance levels of criteria are aggregated using BNWAO defined in Eq. (11). In this context, the aggregated importance levels for each criterion (ι_j) are computed using Eq. (12) to aggregate $\zeta_j^{(k)}$ BNNs, where $j = 1, \dots, n$:

$$\begin{aligned}\iota_j =& \langle \sum_{k=1}^{t} v_k T_j^{+(k)}, \sum_{k=1}^{t} v_k I_j^{+(k)}, \sum_{k=1}^{t} v_k F_j^{+(k)}, \\ & \sum_{k=1}^{t} v_k T_j^{-(k)}, \sum_{k=1}^{t} v_k I_j^{-(k)}, \sum_{k=1}^{t} v_k F_j^{-(k)} \rangle.\end{aligned} \tag{12}$$

Step 4. Compute score function for each criterion The score function defined in Eq. (8) is used for crisp importance values of criteria $\varsigma(\iota_j)$.

Step 5. Rank the criteria The criteria are ranked in descending order based on $\varsigma(\iota_j)$ values. Here, s_j shows the ranking places of criteria. Accordingly, the most important criterion is denoted as s_1.

Step 6. Determine the comparative significance coefficient for criteria The comparative significance value for each criterion (c_j) is calculated by subtracting the score of the second important criterion from the score of the first important criterion in the pairwise comparison based on the criteria rankings.

Step 7. Create k_j values Here, k_j values are calculated for each criterion using Eq. (13):

$$k_j = \begin{cases} 1, & \text{if } s_j = s_1, \\ c_j + 1, & \text{if } s_j \neq s_1. \end{cases} \tag{13}$$

Step 8. Create q_j values Here, q_j values are calculated for each criterion using Eq. (14):

$$q_j = \begin{cases} 1, & \text{if } s_j = s_1, \\ \frac{q_{j-1}}{k_j}, & \text{if } s_j \neq s_1. \end{cases} \tag{14}$$

Step 9. Obtain criteria weights The weight coefficients of criteria are computed using Eq. (15):

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}. \tag{15}$$

Table 2 Linguistic terms

Linguistic Terms for Evaluating Criteria	Codes	Linguistic Terms for Evaluating Alternatives	Codes	BNS					
				T^+	I^+	F^+	T^-	I^-	F^-
Excessively High Importance	EHI	Excessively High	EH	0.9	0.15	0	0	-0.85	-0.95
Very High Importance	VHI	Very High	VH	1	0	0.15	-0.25	-0.85	-0.95
Midst High Importance	MHI	Midst High	MH	0.85	0.55	0.65	-0.15	-0.85	-0.95
Enough Importance	EI	Enough	E	0.75	0.65	0.55	-0.25	-0.55	-0.65
Not Enough Importance	NEI	Not Enough	NE	0.55	0.25	0.35	-0.35	-0.15	-0.35
Low Importance	LI	Low	L	0.45	0.45	0.35	-0.55	-0.25	-0.15
Midst Low Importance	MLI	Midst Low	ML	0.35	0.15	0.95	-0.45	-0.25	-0.15
Very Low Importance	VLI	Very Low	VL	0.25	0.35	0.45	-0.85	-0.65	-0.45
Excessively Low Importance	ELI	Excessively Low	EL	0.15	0.95	0.85	-0.95	-0.25	-0.15

3.3 Bipolar neutrosophic TOPSIS

Hwang and Yoon (1981) developed TOPSIS to deal with the MCDM problem by selecting the alternative that is closest to the ideal and farthest from the anti-ideal solutions. The understandable and simple-to-apply structure of TOPSIS has led to its popularity in solving a wide range of problems. Furthermore, many TOPSIS extensions have been developed in the context of various fuzzy sets and problems. Akram et al. (2018) proposed the BN-TOPSIS as one of them. The implementation steps of BN-TOPSIS are given below (Akram et al. 2018):

Step 1. Construct the decision matrix The experts evaluate the alternatives with the help of the linguistic terms given in Table 2. Here, $Z = \left[\zeta_{ij}^{(k)}\right]_{m\times n}$ stands for the linguistic decision matrix for the k-th expert, such that $(i = 1, \ldots, m)$, $(j = 1, \ldots, n)$ and $(k = 1, \ldots, t)$ represents the alternatives, criteria and experts, respectively. Afterwards, $X^{(k)} = \left[x_{ij}^{(k)}\right]_{m\times n}$ is built up for each expert using BNNs, where $x_{ij}^{(k)} = \langle T_{ij}^{+(k)}, I_{ij}^{+(k)}, F_{ij}^{+(k)}, T_{ij}^{-(k)}, I_{ij}^{-(k)}, F_{ij}^{-(k)}\rangle$.

Step 2. Create the aggregated BN decision matrix The assessments of alternatives by experts are aggregated through Eq. (16):

$$x_{ij} = \langle \sum_{k=1}^{t} v_k T_{ij}^{+(k)}, \sum_{k=1}^{t} v_k I_{ij}^{+(k)}, \sum_{k=1}^{t} v_k F_{ij}^{+(k)}, \sum_{k=1}^{t} v_k T_{ij}^{-(k)}, \sum_{k=1}^{t} v_k I_{ij}^{-(k)}, \sum_{k=1}^{t} v_k F_{ij}^{-(k)}\rangle, \tag{16}$$

where $x_{ij} = (T_{ij}^{+}, I_{ij}^{+}, F_{ij}^{+}, T_{ij}^{-}, F_{ij}^{-}, I_{ij}^{-})$.

Step 3. Construct the weighted BN decision matrix The elements of weighted BN decision matrix $(x_{ij}^{(w)})$ are achieved using Eq. (17), where w_j denotes weight coefficients of criteria:

$$x_{ij}^{(w)} = \langle 1 - \left(1 - T_{ij}^{+}\right)^{w_j}, \left(I_{ij}^{+}\right)^{w_j}, \left(F_{ij}^{+}\right)^{w_j}, -\left(-T_{ij}^{-}\right)^{w_j}, -\left(-I_{ij}^{-}\right)^{w_j}, -\left(1 - \left(1 - \left(-F_{ij}^{-}\right)\right)^{w_j}\right)\rangle$$

$$= \langle T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-}\rangle. \tag{17}$$

Step 4. Find ideal and anti-ideal solutions The Bipolar Neutrosophic Anti-Ideal Solution (BNAS) and the Bipolar Neutrosophic Ideal Solution (BNIS) are defined respectively using Eqs. (18)-(19), where J^{+} denotes benefit-criteria and J^{-} represents cost-criteria:

$$BNAS = \begin{cases} \langle \min\limits_i \left(T_{ij}^{w_j+}\right), \max\limits_i \left(I_{ij}^{w_j+}\right), \max\limits_i \left(F_{ij}^{w_j+}\right), \max\limits_i \left(T_{ij}^{w_j-}\right), \min\limits_i \left(I_{ij}^{w_j-}\right), \min\limits_i \left(F_{ij}^{w_j-}\right)\rangle & j \in J^{+}, \\ \langle \max\limits_i \left(T_{ij}^{w_j+}\right), \min\limits_i \left(I_{ij}^{w_j+}\right), \min\limits_i \left(F_{ij}^{w_j+}\right), \min\limits_i \left(T_{ij}^{w_j-}\right), \max\limits_i \left(I_{ij}^{w_j-}\right), \max\limits_i \left(F_{ij}^{w_j-}\right)\rangle & j \in J^{-}, \end{cases}$$

$$= \langle T_{ij}^{AS+}, I_{ij}^{AS+}, F_{ij}^{AS+}, T_{ij}^{AS-}, I_{ij}^{AS-}, F_{ij}^{AS-}\rangle, \tag{18}$$

$$BNIS = \begin{cases} \langle \max\limits_i \left(T_{ij}^{w_j+}\right), \min\limits_i \left(I_{ij}^{w_j+}\right), \min\limits_i \left(F_{ij}^{w_j+}\right), \min\limits_i \left(T_{ij}^{w_j-}\right), \max\limits_i \left(I_{ij}^{w_j-}\right), \max\limits_i \left(F_{ij}^{w_j-}\right)\rangle & j \in J^{+}, \\ \langle \min\limits_i \left(T_{ij}^{w_j+}\right), \max\limits_i \left(I_{ij}^{w_j+}\right), \max\limits_i \left(F_{ij}^{w_j+}\right), \max\limits_i \left(T_{ij}^{w_j-}\right), \min\limits_i \left(I_{ij}^{w_j-}\right), \min\limits_i \left(F_{ij}^{w_j-}\right)\rangle & j \in J^{-}, \end{cases}$$

$$= \langle T_{ij}^{IS+}, I_{ij}^{IS+}, F_{ij}^{IS+}, T_{ij}^{IS-}, I_{ij}^{IS-}, F_{ij}^{IS-}\rangle. \tag{19}$$

Step 5. Calculate distances of alternatives from ideal and anti-ideal solutions The Euclidean distances of alternatives from BNAS and BNIS are computed respectively using Eqs. (20)-(21):

$$d\left(S_i, BNAS\right) = \sqrt{\frac{1}{6n} \sum_{j=1}^{n} \left\{ \left(T_{ij}^{w_j+} - T_{ij}^{AS+}\right)^2 + \left(I_{ij}^{w_j+} - I_{ij}^{AS+}\right)^2 + \left(F_{ij}^{w_j+} - F_{ij}^{AS+}\right)^2 + \left(T_{ij}^{w_j-} - T_{ij}^{AS-}\right)^2 + \left(I_{ij}^{w_j-} - I_{ij}^{AS-}\right)^2 \left(F_{ij}^{w_j-} - F_{ij}^{AS-}\right)^2 \right\}}, \tag{20}$$

Table 3 Criteria and alternatives appertaining to ASCM

Codes	Criteria	Explanations	References
C11	Senior Management's Active Support	It is related to the communication established by top management on the subject	Yoon et al. (2004)
C12	Agile SCM Unity Of Purpose, Commitment and Organizational Culture	Applications for organizational culture, commitment, and unity of purpose in the context of ASCM	Power et al. (2001)
C13	Proactive Continuous Improvement	Efforts to improve existing business practices	Moon et al. (2017)
C14	Effective Communication From The Bottom-Up And The Top-Down	It is the efficient implementation of communication across all business channels	Fayezi et al. (2017)
C21	Computer Aided Design / Methodology	Applications of computer-aided design methodology to all business processes	Mathews (2013)
C22	Computer Controlled Machines	Using computer control to direct the machines	Sarıışık and Özkan (2015)
C23	Local Area Network	It refers to local area computer networks	Power et al. (2001)
C24	Electronic Data Interchange (EDI)	Electronic data exchange between organizations is used for routine processes in a predetermined format	Ilhan and Ünsaçar (2011)
C31	Collaborate with Suppliers	Creating close collaborations with suppliers	Korucuk and Memiş (2018)
C32	Process Improvement and Supplier Relationship Effectiveness	It refers to the effectiveness of process improvement and supplier collaboration	Carr and Johansson (1997)
C33	Supplier Product Quality Measurement	This refers to the measurement of supplier product quality	Kraft (2019)
C34	Effective Resource Management	It refers to the efficient and balanced use of resources	Mearns et al. (2001)
C41	Just-in-Time Contribution to Improved Factory Operations	It refers to making timely contributions to improved factory operations	Power et al. (2001)
C42	Just-in-Time Logistics Process	It refers to just-in-time logistics processes	Barreto et al. (2017)
C43	Maximum utilization of manufacturing technologies	It refers to maximizing the utilization of manufacturing technologies	Power et al. (2001)
C44	Increasing capacity utilization rate	It refers to increasing the rate of capacity utilization	Sinan (2020)
Codes	**Alternatives**	**Explanations**	**References**
A1	Balancing Strategy	In SCM, it refers to dividing risk, which has a one-way option	Shah (2009)
A2	Postponement Strategy	It refers to providing a cost-effective and time-efficient emergency plan that permits the product to be reconfigured rapidly in case of a supply disruption	Tang (2006)
A3	Resource and Natural Resource Based Theories	It refers to improving company performance by transforming a company's unique resources into distinct capabilities	Güleş and Özilhan (2010)
A4	Buffer Strategy	It refers to providing additional resources to reduce the risks concerncing supply chain capacity and performance problems	Shah (2009)

$$d(S_i, BNIS) = \sqrt{\frac{1}{6n}\sum_{j=1}^{n}\left\{\left(T_{ij}^{w_j+} - T_{ij}^{IS+}\right)^2 + \left(I_{ij}^{w_j+} - I_{ij}^{IS+}\right)^2 + \left(F_{ij}^{w_j+} - F_{ij}^{IS+}\right)^2 + \left(T_{ij}^{w_j-} - T_{ij}^{IS-}\right)^2 + \left(I_{ij}^{w_j-} - I_{ij}^{IS-}\right)^2\left(F_{ij}^{w_j-} - F_{ij}^{IS-}\right)^2\right\}}. \quad (21)$$

Step 6. Compute closeness degree of alternatives Eq. (22) is applied for computing the closeness degree of each alternative:

$$y_i = \frac{d(S_i, BNAS)}{\max\{d(S_i, BNAS)\}} - \frac{d(S_i, BNIS)}{\min\{d(S_i, BNIS)\}}. \quad (22)$$

Table 4 Experts' evaluations of importance levels of criteria

	C11	C12	C13	C14	C21	C22	C23	C24	C31	C32	C33	C34	C41	C42	C43	C44
DM1	VHI	EI	VHI	VHI	VHI	EI	EI	EI	EI	EI	EI	EI	EI	EI	EI	NEI
DM2	VHI	VHI	VHI	EHI	VHI	EI	VHI	VHI	EHI	VHI	EHI	EHI	EHI	EHI	VHI	EHI
DM3	VHI	MHI	VHI	EHI	VHI	EI	EHI	EHI	EHI	EHI	EHI	VHI	VHI	EHI	EHI	EI
DM4	VHI	VHI	EHI	VHI	EI	EI	VHI	VHI	VHI	VHI	EHI	EHI	EHI	EHI	VHI	EHI
DM5	EHI	VHI	EHI	EHI	EHI	EHI	EHI	VHI	VHI	VHI	EHI	EHI	VHI	EHI	EHI	VHI
DM6	VHI	EI	VHI	VHI	VHI	VHI	EI	NEI	NEI	MHI	VHI	EHI	EHI	VHI	EHI	MHI

Step 7. Compute revised closeness degree of alternatives The revised closeness degrees of alternatives are computed using Eq. (23):

$$r_i = \frac{y_i}{\min_i (y_i)}. \tag{23}$$

Alternatives are prioritized in an ascending order in regard to r_i values. In this context, the best alternative is the one with the smallest r_i value.

4 Results

This section represents the numerical results of the study based on the developed methodology. Accordingly, Table 3 illustrates the explanations of the criteria and alternatives considered in the solution of the decision-making problem.

The experts whose evaluations were used in the scope of the study are individuals with at least 10 years of managerial experiences in their fields. Six experts were consulted for their opinions, including production personnel (5) and the business manager (1). The "Web of Science" and "Scopus" databases, which are generally regarded as the most trustworthy sources of scientific knowledge, were used in the study to conduct a literature review. Furthermore, Turkish publications were reviewed using the "Dergipark" database. A preliminary study was conducted with production personnel and the business manager while specifying the criteria and alternatives in the research.

Expert opinions were preferred to ensure that the criteria and alternatives determined based on the literature were compatible with real-world conditions. As a result, the study's criteria and alternatives are given in Table 3. The experts' evaluations of the importance levels of the criteria taken into account in the problem solution are presented in Table 4.

The BN importance values of the criteria are formed by integrating the evaluations of the decision-makers, as given in Table 5.

The BN-SWARA results are illustrated in Table 6.

Table 6 shows that C14 is the most important criterion, whereas C22 is the least important. Table 7 now provides the linguistics evaluations for the various alternatives. The equal weights were given to all decision-makers' evaluations. BNWAO is also used to construct the aggregated BN matrix. Table 8 shows the aggregated BN decision matrix.

Following the BN-TOPSIS implementation steps, the ranking solution is obtained. Table 9 displays the results of the ranking, where A4 is takes first place and A4≻A2≻A3≻A1.

4.1 Comparative Sensitivity Analysis

To analyze the robustness, validity, and stability of the developed model, a comprehensive three-stage sensitivity analysis is conducted. The effects of changes in the weight values of the criteria are examined in the first stage. Second, the proposed model is subjected to a rank reversal problem

Table 5 Aggregated evaluation matrix for criteria importance

C11	C12	C13	C14	C21	C22	C23	C24
(0.98, 0.03, 0.13, -0.21, -0.85, -0.95)	(0.89, 0.31, 0.37, -0.23, -0.75, -0.85)	(0.97, 0.05, 0.10, -0.17, -0.85, -0.95)	(0.95, 0.08, 0.08, -0.13, -0.85, -0.95)	(0.94, 0.13, 0.19, -0.21, -0.80, -0.90)	(0.82, 0.46, 0.39, -0.21, -0.65, -0.75)	(0.88, 0.27, 0.23, -0.17, -0.75, -0.85)	(0.87, 0.18, 0.23, -0.23, -0.68, -0.80)
C31	**C32**	**C33**	**C34**	**C41**	**C42**	**C43**	**C44**
(0.85, 0.20, 0.20, -0.18, -0.68, -0.80)	(0.92, 0.23, 0.28, -0.19, -0.80, -0.90)	(0.89, 0.21, 0.12, -0.08, -0.80, -0.90)	(0.89, 0.21, 0.12, -0.08, -0.80, -0.90)	(0.91, 0.18, 0.14, -0.13, -0.80, -0.90)	(0.89, 0.21, 0.12, -0.08, -0.80, -0.90)	(0.91, 0.18, 0.14, -0.13, -0.80, -0.90)	(0.83, 0.29, 0.28, -0.17, -0.68, -0.80)

Table 6 Criteria weights

Criteria	Score	c_j	k_j	q_j	w_j	Rank
C14	0.9125	0.0000	1.0000	1.0000	0.0676	1
C13	0.9083	0.0042	1.0042	0.9959	0.0673	2
C11	0.9042	0.0042	1.0042	0.9917	0.0670	3
C33	0.8639	0.0403	1.0403	0.9533	0.0644	4
C34	0.8639	0.0000	1.0000	0.9533	0.0644	4
C42	0.8639	0.0000	1.0000	0.9533	0.0644	4
C41	0.8597	0.0042	1.0042	0.9494	0.0641	7
C43	0.8597	0.0000	1.0000	0.9494	0.0641	7
C21	0.8514	0.0083	1.0083	0.9415	0.0636	9
C32	0.8208	0.0306	1.0306	0.9136	0.0617	10
C23	0.8028	0.0181	1.0181	0.8974	0.0606	11
C31	0.7917	0.0111	1.0111	0.8875	0.0600	12
C24	0.7875	0.0042	1.0042	0.8839	0.0597	13
C12	0.7639	0.0236	1.0236	0.8635	0.0583	14
C44	0.7611	0.0028	1.0028	0.8611	0.0582	15
C22	0.6931	0.0681	1.0681	0.8062	0.0545	16

analysis. Finally, the results are compared to the results of some prominent BN-based approaches.

To investigate the effects of changing the weights of the criteria, 15 different sets ($n - 1$) are created using the weight values from Table 6 obtained during the problem-solving process. To create these sets, the weight values of the other criteria specified in Table 6 are used only once for each criterion. Furthermore, Set 16 is created using equal weighting, and Set 17 is produced using BN-Entropy (Abdel-Monem and Gawad 2021). With this approach, a holistic evaluation

Table 7 Linguistic evaluations provided by experts

		C11	C12	C13	C14	C21	C22	C23	C24	C31	C32	C33	C34	C41	C42	C43	C44
DM1	**A1**	MH	E	E	E	NE	E	E	NE	E	E	E	E	NE	E	E	NE
	A2	ML	L	L	L	NE	E	NE	NE	NE	NE	NE	NE	NE	L	NE	NE
	A3	MH	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	A4	E	NE	NE	NE	NE	NE	E	NE	E	NE	NE	E	NE	NE	NE	NE
DM2	**A1**	EH	VH	EH	EH	VH	E	VH	VH	VH	VH	EH	EH	EH	EH	EH	EH
	A2	VH	E	NE	VH	VH	E	VH	E	E	MH	VH	EH	VH	EH	EH	VH
	A3	VH	VH	EH	VH	E	E	VH	VH	VH	VH	EH	EH	EH	EH	E	EH
	A4	VH	VH	EH	VH	VH	E	VH	E	VH	VH	EH	EH	EH	EH	EH	EH
DM3	**A1**	VH	VH	EH	EH	MH	MH	VH	VH	EH	EH	EH	EH	VH	EH	EH	VH
	A2	EH	VH	EH	EH	E	VH	E	VH	VH	EH	VH	EH	EH	EH	EH	VH
	A3	VH	EH	MH	EH	MH	E	E	E	VH	EH	VH	EH	EH	EH	EH	VH
	A4	MH	VH	E	EH	MH	MH	VH	E	EH	EH	EH	EH	EH	EH	EH	VH
DM4	**A1**	VH	VH	EH	VH	E	E	VH	VH	VH	VH	EH	EH	EH	EH	VH	EH
	A2	E	E	E	VH	E	E	VH	VH	E	MH	VH	EH	VH	EH	VH	VH
	A3	VH	VH	EH	VH	E	E	VH	VH	VH	VH	EH	EH	EH	EH	VH	EH
	A4	VH	VH	EH	VH	E	E	VH	VH	VH	VH	EH	EH	EH	EH	VH	EH
DM5	**A1**	EH	VH	EH	EH	EH	EH	EH	VH	VH	VH	EH	EH	VH	EH	EH	VH
	A2	EH	VH	EH	EH	EH	EH	EH	VH	VH	MH	EH	EH	VH	EH	EH	VH
	A3	EH	MH	EH	EH	EH	EH	EH	VH	VH	VH	EH	EH	EH	EH	EH	VH
	A4	EH	VH	EH	EH	VH	VH	EH	VH	MH	VH	EH	EH	VH	EH	EH	VH
DM6	**A1**	E	E	VH	NE	E	E	L	NEL	VL	E	VH	E	NE	NEE	NE	NEE
	A2	L	NEE	E	E	E	VH	NEL	NEL	NE	NE	L	E	E	NEE	NE	NEE
	A3	E	NEE	NEE	NE	E	E	E	L	L	L	L	NEE	NE	NEE	NEE	NEE
	A4	E	L	L	NE	NE	NE	NEL	L	E	NE	NEL	NEL	NEL	E	E	NEE

Table 8 Aggregated neutrosophic decision matrix

	C11	C12	C13	C14	C21	C22	C23	C24
A1	(0.90, 0.25, 0.25, -0.15, -0.80, -0.90)	(0.92, 0.22, 0.28, -0.25, -0.75, -0.85)	(0.89, 0.21, 0.12, -0.08, -0.80, -0.90)	(0.83, 0.23, 0.18, -0.14, -0.68, -0.80)	(0.80, 0.38, 0.38, -0.21, -0.63, -0.75)	(0.79, 0.55, 0.48, -0.19, -0.65, -0.75)	(0.85, 0.21, 0.23, -0.26, -0.70, -0.77)	(0.82, 0.07, 0.32, -0.30, -0.63, -0.72)
A2	(0.73, 0.26, 0.33, -0.25, -0.60, -0.63)	(0.80, 0.38, 0.40, -0.28, -0.65, -0.72)	(0.72, 0.38, 0.30, -0.23, -0.53, -0.62)	(0.83, 0.23, 0.20, -0.22, -0.70, -0.77)	(0.78, 0.39, 0.36, -0.23, -0.58, -0.70)	(0.86, 0.35, 0.33, -0.21, -0.70, -0.80)	(0.76, 0.20, 0.36, -0.26, -0.58, -0.67)	(0.78, 0.18, 0.38, -0.30, -0.63, -0.72)
A3	(0.92, 0.23, 0.28, -0.19, -0.80, -0.90)	(0.86, 0.25, 0.33, -0.19, -0.73, -0.85)	(0.83, 0.30, 0.28, -0.11, -0.73, -0.85)	(0.82, 0.13, 0.17, -0.20, -0.62, -0.75)	(0.76, 0.48, 0.44, -0.21, -0.58, -0.70)	(0.74, 0.50, 0.43, -0.23, -0.53, -0.65)	(0.83, 0.28, 0.29, -0.23, -0.63, -0.75)	(0.79, 0.23, 0.28, -0.32, -0.58, -0.67)
A4	(0.88, 0.33, 0.34, -0.19, -0.75, -0.85)	(0.83, 0.12, 0.22, -0.32, -0.63, -0.72)	(0.74, 0.30, 0.21, -0.19, -0.58, -0.67)	(0.82, 0.13, 0.17, -0.20, -0.62, -0.75)	(0.78, 0.28, 0.37, -0.27, -0.57, -0.70)	(0.74, 0.39, 0.43, -0.27, -0.52, -0.65)	(0.83, 0.16, 0.33, -0.24, -0.70, -0.77)	(0.75, 0.33, 0.35, -0.32, -0.53, -0.62)
	C31	**C32**	**C33**	**C34**	**C41**	**C42**	**C43**	**C44**
A1	(0.82, 0.19, 0.24, -0.31, -0.77, -0.82)	(0.90, 0.24, 0.26, -0.21, -0.75, -0.85)	(0.89, 0.21, 0.12, -0.08, -0.80, -0.90)	(0.85, 0.32, 0.18, -0.08, -0.75, -0.850)	(0.82, 0.13, 0.17, -0.20, -0.62, -0.75)	(0.87, 0.30, 0.20, -0.07, -0.80, -0.90)	(0.83, 0.23, 0.18, -0.14, -0.68, -0.80)	(0.87, 0.18, 0.22, -0.17, -0.73, -0.85)
A2	(0.77, 0.30, 0.35, -0.28, -0.52, -0.65)	(0.76, 0.38, 0.44, -0.19, -0.62, -0.75)	(0.82, 0.14, 0.19, -0.28, -0.63, -0.72)	(0.82, 0.25, 0.15, -0.10, -0.68, -0.80)	(0.87, 0.18, 0.23, -0.23, -0.68, -0.80)	(0.82, 0.27, 0.17, -0.12, -0.75, -0.82)	(0.80, 0.16, 0.14, -0.16, -0.62, -0.75)	(0.90, 0.13, 0.27, -0.25, -0.73, -0.85)
A3	(0.83, 0.12, 0.22, -0.32, -0.63, -0.72)	(0.82, 0.14, 0.19, -0.28, -0.63, -0.72)	(0.78, 0.19, 0.14, -0.19, -0.63, -0.72)	(0.83, 0.23, 0.17, -0.08, -0.73, -0.85)	(0.78, 0.18, 0.12, -0.12, -0.62, -0.75)	(0.83, 0.23, 0.17, -0.08, -0.73, -0.85)	(0.83, 0.29, 0.28, -0.17, -0.68, -0.80)	(0.87, 0.18, 0.22, -0.17, -0.73, -0.85)
A4	(0.88, 0.33, 0.34, -0.19, -0.75, -0.85)	(0.83, 0.11, 0.19, -0.24, -0.62, -0.75)	(0.75, 0.17, 0.22, -0.13, -0.63, -0.72)	(0.78, 0.23, 0.25, -0.12, -0.70, -0.77)	(0.77, 0.14, 0.24, -0.18, -0.63, -0.72)	(0.82, 0.23, 0.15, -0.10, -0.68, -0.80)	(0.83, 0.23, 0.18, -0.14, -0.68, -0.80)	(0.87, 0.18, 0.22, -0.17, -0.73, -0.85)

Table 9 Ranking results

Alternatives	d_N (S_i, BNAS)	d_N (S_i, BNIS)	r_i	Ranks
A1	0.0405	0.0499	1.0000	4
A2	0.0496	0.0476	0.3922	2
A3	0.0385	0.0423	0.7172	3
A4	0.0470	0.0413	0.1315	1

is obtained, and the change of solutions can be examined (Mishra et al. 2020; Aytekin 2022a; Gündoğdu and Aytekin 2022). The weights of criteria according to different scenarios are presented in Table 10.

SCE 0 displays the weighting results obtained in Table 10 using the proposed methodology. Figure 1 depicts the ranking results.

When the results in Fig. 1 are examined, it is clear that the rankings of the alternatives in SCE 10, 12, and 17 have changed slightly. The ideal risk reduction strategy is determined by and sensitive to these set of criteria weight sets. In general, the offered approach is stable with different weight sets as seen in Fig. 1. The resistance of the model to the rank reversal problem was tested in the second stage. For this purpose, possible alternative subtraction is performed, leaving at least two alternatives to be ranked. In this context, Table 11 shows how the rank order of the available alternatives changes. In this table, w/o denotes "without".

As seen in, Table 11 when alternatives are excluded from the problem, the BN-TOPSIS method encountered no rank reversal problem. In the final phase, we implement some prominent methods based on the BNs such as BN-VIKOR (Pramanik et al. 2018), BN-MABAC (Rahim et al. 2020), BN-WSM (Abdel-Monem and Gavad 2021) and BN-TODIM (Pramanik et al. 2016) to compare the results of the suggested methodology. The ranking results obtained via these methods are given in Table 12.

Table 12 shows that the methods gave differing results in the rankings. When different MCDM methods are employed to solve the same decision problem, different results can be obtained (Mahmoud and Garcia 2000; Mulliner et al. 2016; Zanakis et al. 1998). When the ranking differences for the problem in the study are examined, it is discovered that BN-MABAC normalized one as 0 and the other as 1 due to the 0.01345 difference between the two alternatives. On the other hand, the BN-TOPSIS employed in the study is one the basis of distances and does not involve such a normalization step. Furthermore, the methods except for the BN-TOPSIS in Table 12 use the crisp values given by the score function following the integrated matrix or BN decision matrix. BN-TOPSIS, on the other hand, gives a solution based on computing the BN distances between the alternatives and the optimal solution. In this context, BN-TOPSIS is thought to be more appropriate for this problem than other methods.

5 Discussion

ASCs are needed to meet ever-increasing customer expectations, changing market requirements, and decreasing product lead times in today's fast-changing business environments along with the emergence of Industry 4.0 (Ahn et al. 2012). The ASC is a dynamic structure formed by the merger of companies as a result of rapidly changing markets. Firm flexibility is a critical component of achieving agility in manufacturing businesses. Hence, companies can effectively respond to changes caused by customer-designed products and limited production capacity for new product launches (Vinodh et al. 2013). The supply chain must be agile and able to respond quickly to short product life cycles, variable demand, and unpredictable market ups and downs in order for the company to produce according to consumer needs (Tarafdar and Qrunfleh 2017).

It is critical to compare the obtained findings to those found in the literature in order to assess similarities and differences. The final weights of critical success factors for ASCM are shown in Table 6. As a result, the most important criterion is "Effective Communication From The Bottom-Up And The Top-Down". Similar findings were reported by Elmuti et al. (2008), Fayezi et al. (2017), Bicocchi et al. (2019) and Valtiner and Reidl (2021). The continuous emergence of novel technologies such as the use of service programs and social media in ASCs has forced businesses to become even more effective in their communication with the organization and with their supply chain partners by undergoing a digitalization process (Obal and Lancioni 2013). With "Effective Communication From The Bottom-Up And Top-Down", the agile supply chain becomes more successful, resulting in a two-way interaction with both the manager influencing the personnel and the personnel informing the manager. As a result, effective communication emerges as a success element affecting both internal and external stakeholders throughout the ASCM process. In other words, feelings, thoughts, and information may be transmitted between individuals, groups, and organizations both within and beyond the enterprise, and ASCM can be extended to all processes and stakeholders.

As part of ASCM, effective communication between units/departments and internal and external customers, internal marketing, and customer focus in the business or organization should all be developed. "Effective Communication From The Bottom-Up And Top-Down" can assist employees in gathering information while serving customers and learning about the company's policies and strategies. It can also improve work performance. "Proactive Continuous Improvement" was determined to be the second most important criterion. This achievement is consistent with the findings of Power et al. (2001), Moon et al. (2017) and Alzoubia and Yanamandrab (2020).

Table 10 Scenarios for changing criteria weights

Scenarios	Criteria															
	C11	C12	C13	C14	C21	C22	C23	C24	C31	C32	C33	C34	C41	C42	C43	C44
SCE 0	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582
SCE 1	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670
SCE 2	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583
SCE 3	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673
SCE 4	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676
SCE 5	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636
SCE 6	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545
SCE 7	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606
SCE 8	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597
SCE 9	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600
SCE 10	0.0644	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617
SCE 11	0.0644	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644
SCE 12	0.0641	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644
SCE 13	0.0644	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641
SCE 14	0.0641	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644
SCE 15	0.0582	0.0670	0.0583	0.0673	0.0676	0.0636	0.0545	0.0606	0.0597	0.0600	0.0617	0.0644	0.0644	0.0641	0.0644	0.0641
SCE 16	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625	0.0625
SCE 17	0.1343	0.0821	0.2623	0.0025	0.0201	0.1192	0.0368	0.0616	0.0905	0.0824	0.0749	0.0121	0.0057	0.0067	0.0083	0.0005

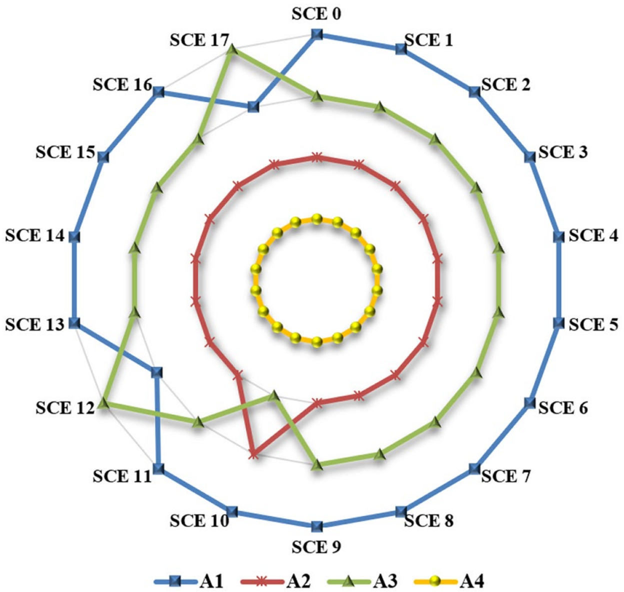

Fig. 1 Ranking results of the alternatives under various criteria weights

Table 12 Ranking results obtained via different methods

Alternatives	Methods				
	BN-TOPSIS	BN-VIKOR	BN-MABAC	BN-WSM	BN-TODIM
A1	4	4	4	1	1
A2	2	1	1	4	4
A3	3	3	3	2	2
A4	1	2	2	3	3

One of the positive results of ASCM practices is the integration of dexterity to changes (opportunities/challenges) on the production line. This refers to both environmental responsiveness and the ability to use resources (proactively/reactively). The immediate response to such changes increases procurement as well as information sharing, and also allows a supplier to change the quantity and delivery time of orders, leading to improved supply chain performance. Proactive practices are critical constructs in achieving a resilient and innovative supply chain (Alzoubia and Yanamandrab 2020; Waqar and Sehrish 2021). This practice, in particular, includes success factors that contribute to the diffusion of organizational success across the entire supply chain. This approach strives to improve all processes while attempting to maximize service quality within the framework of ASCM. The study provides significant benefits to the relevant organizations in terms of quality, service level, and process design.

Furthermore, this finding is related to the effectiveness of capacity management in businesses, taking productivity opportunities, ensuring customer satisfaction, business continuity, information security, and accessibility management in the context of ASCM. The third most important criterion, according to the criteria weight values, is "Senior Management's Active Support". The findings are consistent with previous studies by Čiarnienė and Vienažindienė (2015), Özkan and Orhaner (2018), Marei et al. (2021) and Chatterjee et al. (2022). Obtaining top management support in enterprises will not only help with the effective implementation of ASCM, but will also benefit the business as a whole. Senior management support is essential for operational processes and leadership orientation.

ASCM practices, as well as many other organizational systems, rely on top management participation to be successful. Because it provides direction, support, and commitment for the implementation of innovations, top management support is critical to the success of ASCM. In other words, establishing and actively utilizing infrastructure necessitates the participation of senior management in order to successfully promote ASCM methodologies to both internal and external stakeholders. Furthermore, it is critical for defining new data standards with top management collaboration and preparing for novel ASCM issues. In the absence of commitment and support of the senior management to ASCM, issues of sustainability and financial constraints may not fall in the order of priority, leading to a decline in the effectiveness of the organizational structures and processes and the subsequent regression of ASCM. According to Gürsev (2022), without the support of the top management, the presentation and implementation of the agile transformation process might come at

Table 11 Robustness measurement based on excluding alternatives from the problem

Alternatives	Alternatives exclusion									
	Original	w/o A1	w/o A1 & A2	w/o A1 & A3	w/o A1 & A4	w/o A2	w/o A2 & A3	w/o A2 & A4	w/o A3	w/o A3 & A4
A1	4	-	-	-	-	3	2	2	3	2
A2	2	2	-	2	1	-	-	-	2	1
A3	3	3	2	-	2	2	-	1	-	-
A4	1	1	1	1	-	1	1	-	1	-

great risk. The company management and employees must believe in this transformation together. On the other hand, the most ideal risk reduction strategy for ASCM in companies is “Buffer Strategy”. This result is compatible with the studies of Jüttner et al. (2003), Mishra et al. (2016), Kırılmaz and Erol (2017) and Sharma et al. (2020).

The Buffer Strategy prioritizes the increase of resources (stocks, suppliers and capacity, etc.) and seeks to overcome risks by developing strong bonds with the supply chain parties (Mishra et al. 2016). In other words, improving the demand management capability increases product demand control and creates an environment for different product demands to be met more quickly. Buffer strategy allows for the integration of effective warehouse management practices with advanced technology creating an innovative perspective. This finding is especially significant in terms of increasing capacity and performance while minimizing the risks associated with these issues. Increasing performance and capacity within the context of ASCM can be viewed as a smart solution that contributes to more effective customer delivery with the help of new business models. The core of the buffer strategy is comprised of knowing the market segments that firms target, increasing resources (stocks, suppliers, capacity, etc.), and improving performance. In view of the fact that overcoming risks requires developing strong relationships with parties involved in the supply chain. The risk level can be decreased by establishing objectives that are relevant to the goal and addressing the most specific target group.

6 Conclusions and implications

Although positive transformations in ASCM and risk reduction practices are important today, they are not at the desired level for businesses. ASCM positively influences the cost advantage of flexible supply chain practices in terms of responding quickly to market conditions, customer expectations, and risk reduction. However, there are major gaps in businesses’ ability to recognize these issues. Since integrating ASCM and risk reduction strategies for businesses is an effective practice that not only provides a cost advantage and competitiveness, but also eliminates waste and increases internal and external customer communication. In this context, the study was based on determining the importance levels of critical success factors of ASCM and selecting the most ideal risk reduction strategy, by taking the import and export business in İstanbul, producing and marketing cleaning products with international corporate identity.

Since there are few studies on the evaluation of critical success factors in ASCM and selection of risk reduction strategies, this study is important for future research. Furthermore, the methods used in the study were expected to contribute to the solution of similar problems in the same and different fields, as well as to the literature. Businesses must have smarter and more predictable risk reduction strategies in order to move towards a sustainable globalized market with the efficiency of SCM, ensuring efficiency and capacity in production processes. Besides, businesses can increase both internal and external customer satisfaction by implementing ASCM strategies.

Applying risk reduction strategies with ASCM necessitates the integration of these systems for the highest level of benefit in increasing the cost advantage and market share in businesses. The selection of a risk reduction strategy, and the identification of the importance levels of critical success criteria for ASCM, are critical in this regard. Another contribution of the study was that the current study's findings clearly demonstrate this condition. Furthermore, for decision-makers and practitioners, evaluating the priorities of critical success factors and selecting a risk reduction strategy in ASCM involve a variety of uncertainties and complexities. Therefore, this situation may cause problems in manufacturing businesses in terms of cost, marketing, waste, energy, the environment, performance, capacity, and supplier relationship application levels. It is worth noting that the study’s findings could serve as a guide in overcoming the aforementioned challenges.

The study can serve as a roadmap for businesses adopting ASCM success factors. It also provides support to the understanding of sustainable competition. The study, which deals with risk management in the Age of Industry 4.0, has significant implications for adopting the phenomenon of agility and flexibility in SCM. The results obtained through the BN-SWARA and BN-TOPSIS decision models serve as a guide for the relevant managers, analysts, users, and stakeholders when significant factors such as ensuring resource efficiency, establishing effective communication between internal/external stakeholders and senior management, and integrating demand and technological elements are taken into account.

The selection of risk reduction strategies in the context of critical success factors in ASCM includes a lot of criteria and alternatives. Consequently, determining the most important ones requires assessing a lot of contradictory qualitative and quantitative criteria. Therefore, the study compiled critical success factors and strategies for businesses and scholars to consider in terms of ASCs. In order to attain reliable, valid, and reasonable results in problems involving uncertainty, an effective decision model capable of taking into consideration a large number of complex alternatives and criteria must be developed and used. This work proposed an integrated decision-making model that addresses these needs and motivations. This model includes the BN-SWARA and BN-TOPSIS methods. Within the scope of the study, the proposed model was expected to be useful for modeling uncertainties in the logistics sector as well as many other sectors, and it will make a useful contribution to the background.

6.1 Practical implications and managerial insights

This study aimed to understand how risk reduction strategy selection procedures and critical success factors interact in light of ASCM, novel business models and Industry 4.0 technologies in manufacturing companies. Due to the fact that the study can also be seen as a component of ongoing research into how to obtain critical factors such as efficiency, performance, productivity, capacity, sustainability, and risk levels in enterprises, ensuring workforce satisfaction and resource efficiency, business practices, and competitiveness. The study also provided significant implications for decision-makers, authorities in the manufacturing industry, and those who are interested in the subject. This work renders an opportunity to assess ASCM strategies. Within the scope of critical success factors for ASCM, a fundamental model for selecting a risk reduction strategy is also given. Because of its adaptable and structured decision-making process, it allows for the assessment of a variety of distinct points of view. The developed model enables decision-makers to analyze critical success factors and risk-reduction strategies for ASCM while also taking into account the conditions of a globalizing market.

Just like the other sectors, recent years have recorded an increased interest in ASCM by businesses involved in the manufacture and marketing of cleaning products. The study offers practical implications as it helps businesses in the relevant industry successfully manage and minimize the risk and uncertainty inherent in supply chain value streams. Therefore, it helps businesses make their supply chain more sensitive to the environment. In order to survive in today's economy, businesses that manufacture and market cleaning products need to learn how to cope with the ongoing challenges. Businesses are forced to choose a new way of working that provides them with the ability to be agile and flexible and to respond rapidly to unforeseen changes. They have to reflect on the role of ASCM success criteria and risk reduction strategies in their ability to be resilient to unexpected disruptions in their supply chains. This work emphasizes the comprehensive scope of the subject matter given how agility and risk reduction affect the ability to meet customer needs as well as other business objectives (e.g., profitability and cost reduction).

This work provides a roadmap to assist related businesses in fulfilling their responsibilities to various internal and external stakeholder groups that can hold them accountable for the success of their ASCM implementation. Furthermore, another practical and theoretical contribution of the study is to persuade users that they are meeting risk reduction expectations with internal and external stakeholders. Another contribution of the study is that businesses may define the ideal degree and usefulness of their services for various stakeholder groups, and users can explain how to apply ASCM and risk mitigation measures to get a valid status. As businesses begin to focus on ASCM success factors and risk reduction strategies, as well as their impact on goals and objectives, engaging with multiple stakeholders in an emerging market can benefit. The findings are useful for business managers interested in ASCM success practices and the factors that conduct their risk reduction methods, as well as the practices and strategies that must be employed to legitimate the relevant actions. The integration of ASCM success practices with risk reduction strategies within the context of sustainability is critical in terms of contributing to a better understanding of the relevant enterprises' corporate image, products, and services, and, most importantly, improving their relationships with various stakeholders.

By concurrently maintaining organizational and financial goals, an enterprise's successful ASCM activities also aid in the process of transforming an intangible asset into a business model. Therefore, the study also leads to presenting an innovative and flexible organizational culture, system, and framework for each business based on ASCM success practices and risk mitigation strategies. It supports the development of a sustainable corporate image culture in Industry 4.0, which is an organizational performance that all employees can relate to and support. The research's findings can be regarded as valuable in developing policies that will assist relevant people and organizations in developing models for ASCM success practices and risk reduction strategies. As a result, businesses can collaborate and reach an agreement on successful ASCM practices and risk mitigation strategy selection.

To date, there is no empirical evidence in the literature showing the relationship between ASC success factors and risk reduction strategies. From an executive's perspective, this study also illustrates why ASC success factors should be carefully considered when the decision to deploy a particular risk reduction strategy is made. The study makes it clear that companies that manage to attain a balance in this relationship are likely to benefit significantly by enhancing customer satisfaction, cost-effectiveness, waste reduction, flexibility, and time-to-market, and subsequently attain sustainable competitive advantages.

The research has important implications for managers, particularly with regard to the minimization of risks with agility in enterprises. They should recognize the importance of the relationship between ASCs and risk reduction strategies. While pursuing their objectives of increasing efficiency through reducing costs, ensuring customer satisfaction, and eliminating waste through ASCs, managers should also examine risk reduction strategies and policies. Successful implementation of ASCM and choosing the right risk reduction strategy will increase both internal and external cooperation and assure the business of resources that cannot be easily imitated by competitors. The framework presented in this study may be useful to managers and stakeholders in evaluating the effectiveness of their risk reduction activities and how they deal with uncertainties throughout the supply chain and take corrective action when necessary.

Furthermore, the study's incorporation of ASCM and risk reduction in the manufacturing sector, as well as the presentation of a set of criteria for the relevant problem, can be regarded as inspiring for future research in a variety of sectors and industries. Eventually, using the methodology in the study to assess the critical success factors of ASCM and risk reduction strategy selection processes, the practical approaches of decision-makers working in the production/marketing sector were moved to a scientific perspective. As a result, it aided decision-makers in understanding how theoretical approaches and practical applications interact.

6.2 Limitations and outlook

One of the main limitations of this work is that it was conducted in a specific city and sector. Another limitation is the inability to address various problems in ASCM due to the focus on critical success factors and risk reduction strategies. Furthermore, the study contains subjectivity because it is based on expert opinions. The study was also limited by its budget and time. Some references regarding ASCM success factors and risk reduction strategies may have been overlooked or excluded (for instance, those that are not indexed in the selected databases or those that do not involve the keywords used). Nevertheless, the use of various databases has been hailed by Thomé et al. (2016) as a way to reduce publication bias, and the choice of keywords to reduce the subjectivity of researcher bias. The subjectivity on account of its classification may be yet another limitation. The classification was decided by a group of researchers.

Future studies may advance by delving deeper into the role played by the relationship between ASCM critical success factors and risk reduction strategies. It would be particularly interesting to analyze their contribution to ASC and risk reduction strategies. This study limited its analysis to the capabilities of ASCM success factors and risk reduction strategies without explicitly addressing the ability of the enterprise to recognize them. The study needs to be developed further to include this ability. Additionally, ASC success factors evaluation criteria should be developed to ensure that the risk reduction strategies selected are suitable for the agility approach adopted by each business.

The COVID-19 pandemic can also be considered a limitation of the study. For the reason that the COVID-19 pandemic has made it difficult to interact with experts and collect data. Besides, it was observed that a set of criteria covering the critical success factors of ASCM and the selection of risk reduction strategies was not determined in the sector or literature during the study's preparation process. This situation can be accepted as a limitation as well as the study's novelty. The results were specified to support the expectations of the decision-makers in the interviews with expert groups.

Future studies could expand the scope to include more businesses from different sectors and countries to increase their generalizability. Similarly, the uniqueness of the study could be put to test through the implementation of its findings in different industries that embrace innovation and advanced technology in ASCM. The study also makes it easier for managers to identify the risk reduction strategies that will make their supply chains more agile, hence pointing to the technologies that they need to adopt in order to achieve their goals within the preferred risk reduction strategies. The managers need to be aware that traditional systems cannot provide agility to the supply chain, and they must be replaced or integrated into other advanced or emerging technologies if they want to achieve agility.

While pointing out the significant role of agility in supporting productivity, new product development, and customer satisfaction, the findings of the study also underscore the implication of technology in risk reduction strategies. Increasing the sample size is another way through which future research could advance the study. This research also presents a new aspect of ASCM for this type of industry and will be an attractive topic for further. Furthermore, it is possible to perform comparative analysis using various decision-making environments such as Fermatean fuzzy, spherical fuzzy and hesitant fuzzy. Besides, various techniques such as COPRAS (Özdağoğlu et al. 2021), PIPRECIA-S (Aytekin 2022b), CoCoSo (Popovic 2021) can be utilized. Furthermore, the methodology proposed in the study is expected to be applicable to problems in different fields.

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Declarations

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