

# A neutrosophic approach to evaluate the factors affecting performance and theory of sustainable supply chain management: application to textile industry

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## Abstract

**Purpose** – Sustainable supply chain management (SSCM) practices and policies are necessary for businesses that seek to take part in international markets and ensure any form of competitiveness. Over time, and especially in the recent past, researchers, governments, and other policymakers have made use of broad and systematic approaches and come to appreciate the value-enhancing activities of sustainability.

**Design/methodology/approach** – Businesses have embraced the integration of sustainable policies and practices within the supply chain as a critical step in ensuring the efficiency of their operations. It is clear in previous studies and operational programs of enterprises that SSCM practices accord businesses certain benefits including improving their environmental, social, and economic performance, and increasing their ecological awareness by way of influencing performance elements within supply networks in enterprises. The study examines the factors influencing performance and theories of SSCM using a neutrosophic method in the textile industry.

**Findings** – SSCM performance is thus of great importance in ensuring business success and competitiveness, realizing customer satisfaction, and leaving the environment in a desirable state for future generations. Performance management, by assisting in the decision-making by managers and ensuring an adequate level of internal interaction, is an integral part of assimilating sustainability management into businesses. SSCM theories also have a strong impact on the determination of the sources of competitive advantage through effective utilization of business capabilities to solve environmental and social challenges that may affect business performance.

**Originality/value** – In line with the benefits highlighted, this study seeks to evaluate and select the factors affecting SSCM performance and theory in textile enterprises with corporate identity in Ordu and Giresun provinces following a neutrosophic approach. To this end, the elements obtained from the literature review are evaluated using the MULTIMOORA-mGqNN method.

**Keywords** Sustainable supply chain management, Supply chain performance, Supply chain theory, Neutrosophic set, MULTIMOORA-mGqNN method

**Paper type** Research paper



## 1. Introduction

Along with the phenomenon of globalization came the pressure to produce more in order to satisfy the ever-increasing demands of the world's growing population. Consequently, the world has witnessed extraordinary developments in technological, economic, and social orders. Servicing such a vast market requires a strong supply chain. The success of a supply chain management (SCM) is determined by its ability to coordinate its processes, and create customer value while eliminating unnecessary costs (Brewer and Speh, 2000), hence supply chain management performance factors such as cost, quality, flexibility and efficiency have become key issues for companies seeking sustainability which is one of the key indicators of competitiveness and the success of SCM performance (Korucuk, 2019).

Sustainable supply chain management (SSCM) is the strategic integration of the social, economic and environmental objectives of the organization in the systematic coordination of business processes among the players along the supply chain in order to improve the long-term economic performance of the supply chain activities of a company (Seuring and Müller, 2008; Brandenburg *et al.*, 2014; Rodríguez *et al.*, 2016). In another definition, SSCM may be defined as the management and coordination of material, information, and capital flow between businesses along the supply chain, while regarding the objectives of all three (economic, environmental and social) dimensions of sustainable development arising from customer and stakeholder needs (Seuring and Müller, 2008).

Models that holistically cover sustainability dimensions have gained a lot of interest in recent years. Ecological and social dimensions are commonly modeled on general factors, whereas economic aspects are examined in both microeconomic and macroeconomic spaces (Brandenburg *et al.*, 2014). Recent studies have proposed models that simultaneously consider the microeconomics terms of the three sustainability dimensions of organizational performance (social, environmental, and economic) and to balance the performances of these dimensions (Blewitt, 2014; Wilson, 2015). According to Seuring and Gold (2013), to monitor the sustainability of the entire supply chain, businesses mostly demand information about what their suppliers are doing in the social, environmental and economic fields. Standards and certifications are used as a tool to draw wider attention to environmental and social issues. In particular, standards are important for responding to social and environmental issues in global supply chains. According to Wolf (2014), there is a significant positive relationship between the adoption of SSCM methods and economic success.

The literature is also littered with several theories explaining the different aspects of SSCM. The theories play a critical role in the production, consumption, and application of knowledge regarding SSCM. According to Colquitt and Zapata-Phelan (2007), most of the theories are expressed in macro terms – they are more organizational and strategic rather than concerned with the individual and behavioral perspectives. Some of the theories include stakeholder theory, institutional theory, resource-based (and natural resource-based view) theory, and transaction cost theory (Maignan and Ferrel, 2004; Lai *et al.*, 2005; Ceran, 2010; Becan, 2011; Düzer, 2018).

One of the factors that motivate this study is the aim to solve a multi-criteria decision-making (MCDM) problem by evaluating and selecting the factors influencing the SSCM performance and theory. Secondly, the study proposes a strong and practical decision-making model, considering existing performance indicators and theories in SSCM. It, thus, contributes to the resolution of the relevant decision-making problems for the textile industry at a desirable level, permanently and reliably. The study aims to present a strong and effective methodological framework to fill the theoretical gaps in the literature by using the advantages of the methods used herein.

In addition, we demonstrate the relationships between the criteria and alternatives with SSCM and determined the interdependencies between them. Accordingly, the study is

developed as a roadmap for the selection of SSCM performance factors and theory for the textile industry.

The study's unique value stems from the fact that it is the only one of its kind, to our knowledge, in the textile sector, as well as the applicability of its structure for comparisons with other industries. In line with the expertise, experience, and knowledge of decision-makers, important performance indicators that emerge from SSCM performance and theory are considered promising in providing customer satisfaction, increasing competitiveness, and cost advantage to textile enterprises. The study thus purposes to provide a roadmap towards increasing SSCM performance and choosing the right theory.

Choosing the right SSCM theory is a critical process for any business, but the process is upset by a complex structure that involves many conflicting criteria. Getting the right fit means evaluating many contradictory qualitative and quantitative criteria and choosing the most appropriate. It is vital to create and use an effective decision-making model that can overcome the above-mentioned complex alternatives and criteria to obtain reliable, logical and reasonable results.

In this study, MULTIMOORA is selected as the MCDM method rather than other methods such as TOPSIS, MARCOS, CoCoSo, and TRUST. It is based on the theory of dominance and enables us to summarize MOORA, composed of a ratio system, reference point and full multiplicative form. The robustness of the MULTIMOORA method has been verified proving that the accuracy of aggregated approaches is larger compared to the accuracy of single ones. Consequently, the MULTIMOORA method has a strong advantage over the other methods as it summarizes three approaches. It has also been widely applied to evaluate decisions related to engineering technology or management problems using a single approach or its combinations with other MCDM methods (Brauers and Zavadskas, 2012; Zavadskas *et al.*, 2015).

The model that we propose in this study has many valuable theoretical contributions which is based on  $m$ -Generalized  $q$ -Neutrosophic Sets (mGqNSs) and MULTIMOORA method and called *MULTIMOORA-mGqNN*. MULTIMOORA-mGqNN was developed by Zavadskas *et al.* (2020) for multi-criteria decision problems. MULTIMOORA-mGqNN is a robust framework for multi-criteria decision problems that has the generality and flexibility that is expected (Zavadskas *et al.*, 2020). In addition to its theoretical contributions, the study has very important implications for decision-makers and other practitioners in the textile industry. On top of the opportunity to evaluate the performance of SSCM in the textile industry, the study also presents a path to the selection of the optimal alternative in SSCM theory. It provides a flexible decision-making environment that considers different views. In addition, the current study presents a completely updated and new set of criteria suitable for real-world decision-making problems encountered in the textile industry and may also be inspiring for future authors and different sectors and industries.

The rest of this study is organized as follows. Section 2 presents a review of the literature on SSCM performance and theory. Section 3 explains the methods utilized in the research. In section 4, the obtained results are described step by step. The discussion of the obtained results is made in section 5. The conclusion, implications of the study, and recommendations for future research are given in section 6.

## 2. Literature review

SSCM is affected by the fact that the responsibilities of institutions now cover not only their own activities but also the activities of the supply chains they are in. Today, a brand established in a European country is also held responsible for all its activities in the Far East, Central Asia, and African countries, where it carries out different stages of production processes (Altuntaş and Türker, 2012). There are many stakeholders, objectives and

constraints to a sustainable supply chain, and businesses must use optimization techniques to improve these multiple conflicting goals (Aydin and Tirkolaee, 2022). While seeking to achieve economic sustainability and profit targets, businesses are faced with the task of using their resources optimally to attain environmental sustainability – produce less waste and pay attention to their carbon emissions (Zhou *et al.*, 2000).

According to Carter and Easton (2011), great consideration should be given to the fundamental dimensions of sustainable development in the performance of the firm's supply chain operations. The SSCM initiative addresses the social issues, economic goals, and ecological issues within the firms' supply chain activities. The remainder of the literature on SSCM performance and theory is summarized in Table 1 including the studies and their objectives.

Recently, scholars have been working on the extensions of fuzzy logic to develop MCDM techniques for designing sustainable systems (Das *et al.*, 2020; Ghosh *et al.*, 2022; Tirkolaee and Torkayesh, 2022).

A detailed review of the literature revealed the absence of and the need for a study on the determination of the importance levels of SSCM performance criteria, and the selection of the most ideal SSCM theory based on the identified criteria. In addition to the outlined objectives of the study, the results also take cognizance of the current COVID-19 pandemic. The method used as well as the area of application is also considered areas in which the study contributes to the literature.

### 3. Methodology

The neutrosophic set (NS) was first proposed by Smarandache (1998) and then was studied by many researchers for real-life applications (Edalatpanah, 2019, 2020; Hezam *et al.*, 2022; Zhang *et al.*, 2022; Bhaumik *et al.*, 2021; Torkayesh *et al.*, 2021). NS allows for the treatment of the problem at hand with varying degrees of truth (T), indeterminacy (I), and falsity (F). NS differs from intuitionistic fuzzy sets in that the degree of uncertainty can be handled independently of truth and indeterminacy, they have a more flexible structure, and they can process more information. According to Smarandache (2019), NSs stand for the generalization of classical fuzzy, intuitionistic fuzzy (IFS),  $q$ -rung orthopair fuzzy, and Pythagorean fuzzy sets. Saha *et al.* (2020) extended this type of generalization and introduced a notation for the  $m$ -Generalized  $q$ -NSs based on this concept; i.e. mGqNSs. Then, Zavadskas *et al.* (2020) suggested integrating mGqNSs into the MULTIMOORA method, labeled MULTIMOORA-mGqNN. Single-valued NS, interval-valued NS, and type-2 NS are handled as effective in order to deal with uncertainty, vagueness, and non-rigid boundaries of the initial information, but in some cases, they lack the desirable generality and flexibility, and cannot cover all recently proposed cases of the fuzzy sets. mGqNS overcomes these limitations and also works as the generalization of fuzzy set, Pythagorean fuzzy set, IFS,  $q$ -rung orthopair fuzzy set, single-valued NS, single-valued  $n$ -hyperspherical NS, and single-valued spherical NS (Turskis *et al.*, 2022; Zavadskas *et al.*, 2020).

The MULTIMOORA-mGqNN method is utilized in this study to evaluate and select SSCM performance and theory. Descriptions of mGqNSs are provided in the next sub-section followed by the application steps for the MULTIMOORA-mGqNN.

#### 3.1 The $m$ -generalized $q$ -neutrosophic sets

The mGqNNs are generalizations of fuzzy sets. A single-valued NS is defined within the form.

$\psi = \{x, \zeta(x), \vartheta(x), \eta(x) : x \in U\}$ , where  $U$  is a universe set and  $x \in U$ . Moreover,  $\zeta(x)$  is truth membership degree,  $\vartheta(x)$  denotes indeterminacy membership degree, and  $\eta(x)$  describes falsity membership degree, where  $\zeta, \vartheta, \eta : U \rightarrow [0, 1]$ , and  $0 \leq \zeta(x) + \vartheta(x) + \eta(x) \leq 3$  (Zavadskas *et al.*, 2020).

| Author(s)                    | Year | Objective   | Method(s)  |
|------------------------------|------|---|--|
| Lee <i>et al.</i>            | 2009 | Evaluating the economic and environmental performance in SCM                            | Fuzzy AHP method   |
| Sasikumar and Haq            | 2011 | Evaluating the economic and environmental performance in SCM                            | Fuzzy VIKOR and mixed-integer linear programming (MILP)                        |
| Altuntaş and Türker          | 2012 | Examining SSCM through sustainability reports   | Content analysis   |
| Govindan <i>et al.</i>       | 2013 | Measuring the sustainable performance of suppliers                                      | Fuzzy MCDM   |
| Wolf                         | 2014 | Examining SSCM in terms of the sustainability performance of the enterprise             | Statistical analysis   |
| Hussain <i>et al.</i>        | 2015 | Presenting and evaluating various SSCM alternatives                                     | Statistical analysis   |
| Su <i>et al.</i>             | 2016 | Selecting suppliers in SSCM   | Hierarchical Gray DEMATEL  |
| Uçal Sarı <i>et al.</i>      | 2017 | Investigating the criteria for evaluation of suppliers in SSCM                          | DEMATEL  |
| Song <i>et al.</i>           | 2017 | Examining the critical risk factors in SSCM.  | DEMATEL  |
| Şişman                       | 2018 | Evaluating the most appropriate alternative activities for improving SSCM performance   | Fuzzy TOPSIS method  |
| Kamble <i>et al.</i>         | 2018 | Examining studies that conceptually discussed the issue of sustainability               | Qualitative analysis   |
| Eğilmez and Koca             | 2018 | Evaluating the challenges to industry 4.0 initiatives for an SSCM in emerging economies | Exploratory factor analysis and analytical hierarchy process (AHP) method      |
| Sajjad <i>et al.</i>         | 2019 | Identifying factors that encourage or prevent businesses from using SSCM practices      | Qualitative analysis   |
| Abdel-Baset <i>et al.</i>    | 2019 | Investigating the sustainable supplier selection problem in the field of imports        | Neutrosophic ANP and VIKOR   |
| Seçkin                       | 2019 | Studying the development of the concept of sustainability in SCM and supplier selection | Qualitative analysis   |
| Tseng <i>et al.</i>          | 2020 | Researching sustainable service SCM   | Fuzzy Delphi, fuzzy DEMATEL, and data envelopment analysis (DEA)               |
| Ahmad <i>et al.</i>          | 2020 | Discussing the optimal closed-loop SCM in the presence of uncertainty                   | Neutrosophic fuzzy optimization  |
| Zhang <i>et al.</i>          | 2020 | Scanning the literature and conducted a bibliometric analysis of SSC                    | Bibliometric analysis  |
| Zeng <i>et al.</i>           | 2020 | Evaluating the sustainable supplier selection problem                                   | Neutrosophic fuzzy data and entropy  |
| Yazdani <i>et al.</i>        | 2021 | Evaluating the sustainable supplier selection problem                                   | Interval-valued neutrosophic   |
| Gedik                        | 2021 | Studying SSCM and the effects of sustainability on supply chains                        | Qualitative analysis   |
| Rojas-Gualdron <i>et al.</i> | 2021 | Investigating the uncertainty in supply chain risk management                           | Neutrosophic probabilistic expert system                                       |
| Rejeb <i>et al.</i>          | 2021 | Assessing the sustainability of the halal food supply chain                             | Bibliometric analysis  |
| Pehlivan and Yalçın          | 2022 | Studying the discount market chain sustainable supplier selection                       | Neutrosophic TOPSIS method   |
| Ergen and Yeşiltuna          | 2022 | Conducting a bibliometric analysis of SSCM studies                                      | Bibliometric analysis  |
| Ghadir <i>et al.</i>         | 2022 | Evaluating the impacts of COVID-19 outbreak on supply chain risks                       | Modified failure mode and effects analysis (FMEA), and best-worst method (BWM) |
| Ahmad                        | 2022 | Studying the multi-objective programming problem in pharmaceutical SCM                  | Neutrosophic set   |

**Table 1.**  
The literature on SSCM performance and theory

On the other hand, the mGqNs is defined as  $\psi = \{x, \zeta(x), \vartheta(x), \eta(x) : x \in U\}$ , where  $\zeta, \vartheta, \eta : U \rightarrow [0, r]$ , and  $0 < r \leq 1$ .  $\zeta, \vartheta, \eta$  are functions, follows the conditions  $0 \leq (\zeta(x))^q + (\vartheta(x))^q + (\eta(x))^q \leq \frac{3}{m}, 0 \leq \zeta(x), \vartheta(x), \eta(x) \leq 1$ , and  $m, q \geq 1$ . Here,  $\zeta(x)$  is  $m$ -generalized truth

membership degree,  $\vartheta(x)$  denotes  $m$ -generalized indeterminacy membership degree, and  $\eta(x)$  describes  $m$ -generalized falsity membership degree. In this context,  $\psi = \zeta, \vartheta, \eta$  is described as  $m$ -Generalized  $q$ -Neutrosophic Number (mGqNN), where  $m$  and  $q$  can be taken into account to define different fuzzy sets as follows (Saha et al., 2020; Zavadskas et al., 2020):

- (1) For a single-valued NS:  $m = r = 1$  and  $q = 3$  (Wang et al., 2010),
- (2) For an intuitionistic fuzzy set:  $m = 3, r = q = 1$  and  $\eta(x) = 0 (\forall x \in U)$  (Atanassov, 1986),
- (3) For a fuzzy set:  $m = 3, r = q = 1$  and  $\eta(x) = \vartheta(x) = 0 (\forall x \in U)$  (Zadeh, 1965),
- (4) For a Pythagorean fuzzy set:  $m = 3, r = 1, q = 2$  and  $\eta(x) = 0 (\forall x \in U)$  (Yager, 2013),
- (5) For a  $q$ -rung orthopair fuzzy set:  $m = 3, r = 1$  and  $\eta(x) = 0 (\forall x \in U)$  (Yager, 2016),
- (6) For a single-valued  $n$ -hyperspherical NS:  $m = 3, r = \sqrt[n]{3}$  and  $q = 3n$ , where  $n \geq 1$  (Smarandache, 2019),
- (7) For a single-valued spherical NS:  $m = 1, r = \sqrt{3}$  and  $q = 6$  (Smarandache, 2019),

The operations between mGqNNs are defined as follows, where  $\psi_1 = \zeta_1, \vartheta_1, \eta_1$  and  $\psi_2 = \zeta_2, \vartheta_2, \eta_2$  are two mGqNNs and  $\lambda$  is a positive real number (Zavadskas et al., 2020; Turskis et al., 2022):

$$\psi_1 \oplus \psi_2 = (1 - (1 - \zeta_1^q)(1 - \zeta_2^q))^{\frac{1}{q}}, \vartheta_1 \vartheta_2, \eta_1 \eta_2, \tag{1}$$

$$\psi_1 \otimes \psi_2 = \zeta_1 \zeta_2, (1 - (1 - \vartheta_1^q)(1 - \vartheta_2^q))^{\frac{1}{q}}, (1 - (1 - \eta_1^q)(1 - \eta_2^q))^{\frac{1}{q}}, \tag{2}$$

$$\lambda * \psi_1 = (1 - (1 - \zeta_1^q)^\lambda)^{\frac{1}{q}}, \vartheta_1^\lambda, \eta_1^\lambda, \tag{3}$$

$$\lambda \odot \psi_1 = \zeta_1^\lambda, (1 - (1 - \vartheta_1^q)^\lambda)^{\frac{1}{q}}, (1 - (1 - \eta_1^q)^\lambda)^{\frac{1}{q}}, \tag{4}$$

$$\psi_1^c = \eta_1, 1 - \vartheta_1, \zeta_1. \tag{5}$$

The mGqNN score function is calculated using Eq. (6):

$$S(\psi) = \frac{3 + 3\zeta^q - 2\vartheta^q - \eta^q}{6}. \tag{6}$$

Ranking among two or more mGqNNs is done in descending order based on score function values. Those with the same value are assigned the same rank (Zavadskas et al., 2020). The  $m$ -generalized  $q$ -neutrosophic weighted averaging aggregation operator (mGqNWAA) is defined in Eq. (7), where  $\psi_k = \zeta_k, \vartheta_k, \eta_k, k = 1, \dots, p$  (Saha et al., 2020):

$$\text{mGqNWAA}(\psi_1, \dots, \psi_p) = \left( \frac{3}{m} - \prod_{k=1}^p \left( \frac{3}{m} - \frac{\zeta_k^q}{m} \right)^{w_k} \right)^{\frac{3}{qm}}, \prod_{k=1}^p \vartheta_k^{w_k}, \prod_{k=1}^p \eta_k^{w_k}. \tag{7}$$

In Eqs (7)–(8),  $w = (w_1, \dots, w_p)^T$  is the weight vector of  $(\psi_1, \dots, \psi_p)$ , while the conditions  $w_k \geq 0$  and  $\sum_{k=1}^p w_k = 1$  should be satisfied. Hence, the  $m$ -Generalized  $q$ -Neutrosophic Weighted Geometric Aggregation (mGqNWGA) operator is defined in Eq. (8):

$$mGqNWGA(\psi_1, \dots, \psi_p) = \prod_{k=1}^p \zeta_k^{w_k} \left( \frac{3}{m} - \prod_{k=1}^p \left( \frac{3}{m} - \vartheta_k^{\frac{qm}{3}} \right)^{w_k} \right)^{\frac{3}{qm}}, \tag{8}$$

$$\left( \frac{3}{m} - \prod_{k=1}^p \left( \frac{3}{m} - \eta_k^{\frac{qm}{3}} \right)^{w_k} \right)^{\frac{3}{qm}}.$$

3.2 The mGqNN subjective weighting

It is possible to use expert opinions in the weighting of the criteria. The mGqNN subjective weighting approach is used in weighting the criteria because the experts prefer methods that are simple to understand. Although the experts are well-versed in the research field, they are unfamiliar with the methods to be used. As a result, the validity of the assessments decreases as the complexity of the methods increases. There are particular difficulties when using weighting or prioritization methods that involve iterative or sequential comparison. The study’s method allows the experts to feel at ease and express their preferences in a valid and secure way. The following process steps are employed to obtain criteria weights values:

*Step 1.* Obtaining the linguistic assessments of experts: The experts evaluate the importance levels of criteria using the linguistic expressions in Table 2. In this context,  $\zeta_j^{(k)}$  denotes the linguistic assessments of  $k$ th expert for  $j$ th criterion, where the criteria ( $j = 1, \dots, n$ ), and experts ( $k = 1, \dots, p$ ),  $\zeta_j^{(k)} = \zeta_j^{(k)}, \vartheta_j^{(k)}, \eta_j^{(k)}$ .

*Step 2.* Determining weights of experts’ evaluation: The importance levels for expert evaluations are determined by using the linguistic expressions in Table 2.  $\xi_k = (\zeta_k, \vartheta_k, \eta_k)$  denotes the knowledge and experience of the  $k$ th expert. Thus, the weight for the  $k^{th}$  expert is computed using Eq. (9):

$$\dot{u}_k = \frac{3+3\zeta_k^q - 2\vartheta_k^q - \eta_k^q}{6} \bigg/ \sum_{k=1}^p \frac{3+3\zeta_k^q - 2\vartheta_k^q - \eta_k^q}{6} \quad (k = 1, 2, \dots, p), \tag{9}$$

**Table 2.**  
Linguistic terms for evaluating criteria and alternatives

| Linguistic terms for assessing the importance levels of criteria | Linguistic terms for rating the alternatives | Neutrosophic number $\zeta, \vartheta, \eta$ |
|--|--|--|
| Extremely high importance (EHI)                                  | Extremely good (EG)                          | <1, 0, 0>                                    |
| Very very high importance (VVH)                                  | Very very good (VVG)                         | <0.9, 0.1, 0.1>                              |
| Very high importance (VHI)                                       | Very good (VG)                               | <0.8, 0.15, 0.2>                             |
| High importance (HI)   | Good (G)                                     | <0.7, 0.25, 0.3>                             |
| Above average importance (AAI)                                   | Medium good (MG)                             | <0.6, 0.35, 0.4>                             |
| Average importance (AI)  | Fair (F)                                     | <0.5, 0.5, 0.5>                              |
| Below average importance (BAI)                                   | Medium low (ML)                              | <0.4, 0.65, 0.6>                             |
| Low importance (LI)  | Low (L)                                      | <0.3, 0.75, 0.7>                             |
| Very low importance (VLI)  | Very low (VL)                                | <0.2, 0.85, 0.8>                             |
| Very very low importance (VVL)                                   | Very very low (VVL)                          | <0.1, 0.9, 0.9>                              |
| Extremely low importance (ELI)                                   | Extremely low (EL)                           | <0, 1, 1>                                    |

*Step 3.* Integrating experts' assessments: The integrated importance levels for criteria ( $\omega_j$ ) is obtained using Eq. (10) to aggregate  $\omega_j^k$  mGqNNs:

$$\omega_j = \left( \frac{3}{m} - \prod_{k=1}^p \left( \frac{3}{m} - \zeta_j^{(k)} \right)^{\frac{3}{qm}} \right)^{\frac{3}{qm}}, \prod_{k=1}^p \vartheta_j^{(k)\frac{3}{qm}}, \prod_{k=1}^p \eta_j^{(k)\frac{3}{qm}} \quad (j = 1, 2, \dots, n), \quad (10)$$

where  $\omega_j = \zeta_j, \vartheta_j, \eta_j$ .

*Step 4.* Calculating criteria weights: Finally, criteria weights are calculated using Eq. (11):

$$w_j = \frac{3 + 3\zeta_j^q - 2\vartheta_j^q - \eta_j^q}{6} \bigg/ \sum_{j=1}^n \frac{3 + 3\zeta_j^q - 2\vartheta_j^q - \eta_j^q}{6} \quad (j = 1, 2, \dots, n), \quad (11)$$

where  $w_j \geq 0$  and  $\sum_{j=1}^n w_j = 1$ .

### 3.3 MULTIMOORA-mGqNN

MULTIMOORA integrates the multi-objective optimization on the basis of ratio analysis (MOORA) method and the full multiplicative form. MOORA is also implemented by combining the ratio and reference point techniques. MULTIMOORA combines the outcomes of these three techniques (Brauers *et al.*, 2012). MULTIMOORA has been applied recently by many researchers in areas including the selection of electric vehicle charging stations (Rani and Mishra, 2021), assessment of solid waste management techniques (Garg and Rani, 2022), comparison of nuclear reactors (Fernández and Vergara, 2021), hotel selection (Peng *et al.*, 2021), developing a risk evaluation methodology for the healthcare industry (Zolfaghari and Mousasvi, 2021), exploring governments' role in mergers and acquisitions (Opoku-Mensah *et al.*, 2021), supplier selection (Liu *et al.*, 2021; Shang *et al.*, 2022), strategic evaluation of green ICT adoption in the textile industry (Karabasevic *et al.*, 2021), medical institution selection (Tian *et al.*, 2022). Zavadskas *et al.* (2020) developed MULTIMOORA-mGqNN for multi-criteria decision problems. MULTIMOORA-mGqNN provides a robust framework for multi-criteria decision problems with the desired generality and flexibility (Zavadskas *et al.*, 2020). The steps for processing the MULTIMOORA-mGqNN are summarized as follows (Zavadskas *et al.*, 2020; Mishra *et al.*, 2022):

*Step 1.* Constructing the decision matrix: The experts assess the alternatives using the linguistic expressions in Table 2. Here,  $\Omega = [t_{ij}^{(k)}]_{m \times n}$  denotes the linguistic decision matrix for the  $k$ th expert, where ( $i = 1, \dots, m$ ) are the alternatives, ( $j = 1, \dots, n$ ), the criteria, and ( $k = 1, \dots, p$ ) the experts. Then,  $X^{(k)} = [x_{ij}^{(k)}]_{m \times n}$  is constructed for each expert using neutrosophic numbers, where  $x_{ij}^{(k)} = (t_{ij}^{(k)}, \vartheta_{ij}^{(k)}, f_{ij}^{(k)})$ .

*Step 2.* Determining weights of experts' evaluation: The importance levels for expert evaluations are determined as specified in Step 2 of mGqNN subjective weighting.

*Step 3.* Constructing the integrated mGqNN decision matrix: The evaluations of alternatives by experts are integrated using Eq. (12):

$$x_{ij} = \left( \frac{3}{m} - \prod_{k=1}^p \left( \frac{3}{m} - t_{ij}^{(k)\frac{qm}{3}} \right)^{\dot{u}_k} \right)^{\frac{3}{qm}}, \prod_{k=1}^p b_{ij}^{(k)\dot{u}_k}, \prod_{k=1}^p f_{ij}^{(k)\dot{u}_k} \quad (12)$$

$(i = 1, 2, \dots, m; j = 1, 2, \dots, n),$

where  $x_{ij} = (t_{ij}, b_{ij}, f_{ij})$ .

*Step 4.* Application of the ratio system: The ratio system is applied using Eq. (13):

$$Q_i = \sum_{j \in J_b} w_j x_{ij} + \left( \sum_{j \in J_c} w_j x_{ij} \right)^c \quad (i = 1, 2, \dots, m), \quad (13)$$

where  $J_b$  denotes benefit criteria, while  $J_c$  shows cost criteria.

*Step 5.* Application of the reference point: The deviation from the reference point and the Min-Max metric of the Tchebycheff norm is calculated using Eq. (14):

$$\min_i \left( \max_j |D(r_j - w_j x_{ij})| \right) \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n).. \quad (14)$$

The reference point for the benefit criteria is calculated using Eq. (15):

$$r_j = \max_j (w_j x_{ij}) \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n).. \quad (15)$$

The reference point for the cost criteria is calculated using Eq. (16):

$$r_j = \min_j (w_j x_{ij}) \quad (i = 1, 2, \dots, m; j = 1, 2, \dots, n).. \quad (16)$$

Eq. (17) is used to calculate the distance between two mGqNSs:

$$D(\psi_1, \psi_2) = \sqrt{\frac{1}{3} \left( (\zeta_1^q - \zeta_2^q)^2 + (\vartheta_1^q - \vartheta_2^q)^2 + (\eta_1^q - \eta_2^q)^2 \right)}.. \quad (17)$$

The score function is utilized to match the neutrosophic members, just as it is in Eq. (6).

*Step 6.* Application of the full multiplicities form: The minimization of a purely multiplicative utility function is employed to implement the full multiplicities form. As a result, Eq. (18) can be used to describe the overall utility function for each of the alternatives:

$$U_i = \frac{s(A_i)}{s(B_i)} \quad (i = 1, 2, \dots, m), \quad (18)$$

where  $A_i$  is calculated using Eq. (19), while  $B_i$  is obtained by Eq. (20):

$$A_i = \prod_{j \in J_b} w_j x_{ij} \quad (i = 1, 2, \dots, m), \quad (19)$$

$$B_i = \prod_{j \in J_c} w_j x_{ij} \quad (i = 1, 2, \dots, m).. \quad (20)$$

*Step 7. Ranking alternatives:* The integrated solution is obtained within the dominance theory framework. As a result, the ratio, the reference point, and the full forms are employed to rank the alternatives based on the calculations using Eqs (13)–(20). The dominance condition is examined in these rankings, and integrated rankings of the alternatives are obtained (Brauers and Zavadskas, 2011).

#### 4. Results

In this section, the final evaluations are made based on Table 3 which represents the criteria and explanations for SSCM.

Individuals with ten years or more of field and managerial experience in their areas were asked to provide expert assessments in the study. Face-to-face interviews were conducted with seven experts, including production personnel (3), business managers (3), and an academician (1). To determine the appropriate criteria and alternatives in the study, an in-depth examination of the literature, as well as a preliminary study with the production personnel (1) and the business manager (1) was conducted. Table 4 illustrates the experts' assessments of the importance levels of the criteria considered in the problem solution.

The evaluations of all decision-makers were judged as "extremely high importance" and equal weight results were obtained using Eq. (9). All calculations were done with  $m = 1$  and  $q = 2$  according to Zavadskas *et al.* (2020). Criteria N2, N3, and N6 are cost-oriented whereas the others are benefit-oriented. The values in Table 5 were obtained by combining the linguistic assessments in Table 4 in the context of mGqNSs and using Eqs (10)–(11).

As seen in Table 5, the most significant criterion is E5, while the least important is N1. Now, the linguistics evaluations for alternatives are given in Table 6.

The integrated decision matrix is given in Table 7.

The integrated solution is obtained following dominance theory. As a result, the ratio, reference point, and full forms are employed in order to rank the alternatives. In these rankings, the dominance condition is examined, and integrated rankings of the alternatives are obtained, as shown in Table 8 and Figure 1.

#### 5. Discussion

Sustainability and SCM are guided by the concepts of corporate governance, ethical principles, and "Stakeholder Theory". In other words, SSCM is taken into consideration as being responsible for the environment and stakeholders with which it interacts (Hatch *et al.*, 2011). According to Su *et al.* (2016), from a strategic perspective, SSCM is charged with ensuring the development of corporate sustainability, keeping up with the demands of the environment as they occur, expeditiously responding to customer needs and requests, ensuring the connection between resources and guaranteeing continuous production, defining and updating the process flow, and evaluating how all these activities are applied to the development of sustainability.

Some environmental and social initiatives contribute to the establishment of closer relations with consumers by sponsoring environmental activities and allocating grants for local environmental projects/activities (Al-Odeh and Smallwood, 2012). In addition, Seuring and Müller (2008) emphasized the need for companies to develop cooperation between their supply chain networks in order to achieve the goal of sustainable development.

The findings of the study were evaluated and compared to the literature to identify areas of similarities and differences. Table 3 shows the final weights of SSCM. The study concluded that the most important criteria are "Market Share", "Employee Satisfaction" and "Profit Level and Margin", respectively, which were found to be compatible with the literature – "Market Share" (Uchida and Ferraro, 2007; Tseng *et al.*, 2020), "Employee Satisfaction"

| Codes | Criteria  | Explanation   | Reference (s)  |
|-------|---|---|--|
| E1    | Cost/quality improvement                          | Cost reduction/quality improvement  | Zhu and Sarkis (2004), Tao (2009), Fabbe-Costes <i>et al.</i> (2014)           |
| E2    | Level of flexibility and agility                  | Adapting to changes in the environment and working quickly  | Chan (2003), Devaraj <i>et al.</i> (2007)                                      |
| E3    | Competitive capabilities                          | Ability of the enterprise to increase its market share, profitability, and growth potential from its previous level       | Rosenzweig <i>et al.</i> (2003)  |
| E4    | Delivery possibilities                            | Efficiency of the delivery processes  | Askariadzad and Wanous (2009), Korucuk (2019)                                  |
| E5    | Market share                                      | Domain of the enterprise in the market  | Kristal <i>et al.</i> (2010)   |
| E6    | Profit level/margin                               | Difference between the income from the sale of products and services, their cost and revenue ration                       | Tao (2009), Korucuk (2019)   |
| N1    | Close cooperation with suppliers                  | Close cooperation with suppliers  | Vachon and Klassen (2008), Aljoghaiman <i>et al.</i> (2020), Lee and Ha (2020) |
| N2    | Identifying innovative environmental technologies | Identifying innovative environmental technologies   | Junge and Straube (2020)   |
| N3    | Reducing the level of environmental waste         | Reducing the level of environmental waste   | Yang and Chang (2013), Korucuk and Memiş (2019)                                |
| N4    | Reducing energy consumption                       | Reducing energy consumption   | Chang and Jhang (2016)   |
| N5    | Resource efficiency                               | Effective use of resources  | Anastasopoulos <i>et al.</i> (2011), Korucuk and Memiş (2019)                  |
| N6    | Pollution control                                 | Pollution control   | Jacobs <i>et al.</i> (2010)  |
| S1    | Work ethic  | Evaluation of the processes and operations of the enterprise and the results of these activities with respect to morality | Dias-Sardinha and Reijnders (2005)   |
| S2    | Business practices/ethical codes and policies     | Work performance/ethical codes and policies   | Dias-Sardinha and Reijnders (2005)   |
| S3    | Employee satisfaction                             | The attitude of the employee to the opportunities and services received in return for work done                           | Walker and Jones (2012)  |
| S4    | Communication/reporting                           | Communication/reporting levels  | Walker and Jones (2012), Silvestre (2015)                                      |
| S5    | Non-governmental organizations                    | non-governmental organizations  | Dias-Sardinha and Reijnders (2005)   |
| S6    | Community-focused results                         | Community-focused result levels   | Almasri (2019)   |

| Codes | Alternatives            | Explanation  | Author (s)  |
|-------|-------------------------|--|---|
| A1    | Shareholder theory      | Helping the organization strengthen its relationships with its internal and external environment to develop a competitive advantage  | Maignan and Ferrel (2004), Lai <i>et al.</i> (2005), Ceran (2010), Becan (2011), Düzer (2018) |
| A2    | Institutional theory    | Institutional theory: an organizational theory that explains how and why businesses are affected by their environment and examines the institutions that apply various pressures to the business in the market environment | Maignan and Ferrel (2004), Lai <i>et al.</i> (2005), Ceran (2010), Becan (2011), Düzer (2018) |
| A3    | Resource-based theory   | An alternative way to improve the work system and ensure a competitive advantage using the resources, capabilities, and capacity of the organization   | Maignan and Ferrel (2004), Lai <i>et al.</i> (2005), Ceran (2010), Becan (2011), Düzer (2018) |
| A4    | Transaction cost theory | Determining the effort and cost required for both buyer and seller to complete an activity   | Maignan and Ferrel (2004), Lai <i>et al.</i> (2005), Ceran (2010), Becan (2011), Düzer (2018) |

**Table 3.**  
Criteria and alternatives related to SSCM

|     | E1  | E2  | E3  | E4  | E5  | E6  | N1  | N2  | N3 | N4 | N5  | N6  | S1  | S2  | S3  | S4 | S5  | S6  |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|-----|-----|-----|-----|-----|----|-----|-----|
| DM1 | HI  | HI  | HI  | HI  | VHI | VHI | HI  | AI  | AI | HI | HI  | HI  | HI  | VHI | HI  | AI | AI  | HI  |
| DM2 | AAI | AAI | HI  | AAI | AI  | AI  | HI  | VHI | HI | AI | AI  | AI  | BAI | AAI | AAI | HI | HI  | AAI |
| DM3 | HI  | AI  | AI  | AI  | HI  | HI  | AAI | AI  | HI | LI | LI  | LI  | AAI | HI  | VHI | HI | VHI | HI  |
| DM4 | HI  | LI  | AAI | LI  | HI  | HI  | BAI | BAI | LI | LI | LI  | AAI | HI  | HI  | VHI | HI | HI  | AAI |
| DM5 | VHI | BAI | AAI | BAI | VHI | HI  | AI  | AI  | AI | AI | AAI | AAI | HI  | HI  | HI  | AI | HI  | AI  |
| DM6 | AI  | HI  | HI  | HI  | AAI | AAI | AI  | AI  | AI | LI | HI  | AAI | HI  | AAI | AI  | AI | AI  | HI  |
| DM7 | AI  | HI  | AI  | HI  | VHI | AAI | AI  | AI  | HI | HI | AI  | AAI | LI  | LI  | HI  | HI | AI  | AAI |

**Table 4.**  
Linguistic evaluations  
for the criteria

**Table 5.**  
Criteria weights

|            | E1                 | E2                 | E3                 | E4                 | E5                 | E6                 |
|------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Integrated | (0.64, 0.30, 0.34) | (0.55, 0.39, 0.42) | (0.61, 0.34, 0.38) | (0.55, 0.39, 0.42) | (0.70, 0.23, 0.28) | (0.66, 0.28, 0.33) |
| $\omega_j$ | 0.6571             | 0.5738             | 0.6270             | 0.5738             | 0.7130             | 0.6706             |
| $u_j$      | 0.0601             | 0.0525             | 0.0573             | 0.0525             | 0.0652             | 0.0613             |
|            | N1                 | N2                 | N3                 | N4                 | N5                 | N6                 |
| Integrated | (0.56, 0.40, 0.43) | (0.53, 0.44, 0.45) | (0.55, 0.39, 0.42) | (0.47, 0.49, 0.50) | (0.51, 0.44, 0.46) | (0.55, 0.39, 0.43) |
| $\omega_j$ | 0.5691             | 0.5414             | 0.5724             | 0.4879             | 0.5310             | 0.5722             |
| $u_j$      | 0.0520             | 0.0495             | 0.0523             | 0.0446             | 0.0485             | 0.0523             |
|            | S1                 | S2                 | S3                 | S4                 | S5                 | S6                 |
| Integrated | (0.58, 0.35, 0.39) | (0.63, 0.30, 0.35) | (0.68, 0.25, 0.30) | (0.63, 0.31, 0.35) | (0.60, 0.35, 0.38) | (0.63, 0.32, 0.37) |
| $\omega_j$ | 0.6030             | 0.6458             | 0.6987             | 0.6434             | 0.6154             | 0.6411             |
| $u_j$      | 0.0551             | 0.0590             | 0.0639             | 0.0588             | 0.0563             | 0.0586             |

| DMs | Alternatives | E1 | E2 | E3 | E4 | E5 | E6 | N1 | N2 | N3 | N4 | N5 | N6 | S1 | S2 | S3 | S4 | S5 | S6 |
|-----|--------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| DM1 | A1           | G  | G  | VG | F  | G  | G  | L  | ML | VL | G  | VG | G  | F  | MG | F  | MG | F  | G  |
|     | A2           | L  | MG | G  | G  | G  | VG | ML | ML | F  | F  | L  | G  | G  | MG | F  | MG | L  | G  |
|     | A3           | G  | MG | MG | F  | G  | G  | G  | L  | L  | L  | L  | ML | F  | MG | MG | MG | MG | MG |
|     | A4           | G  | L  | L  | F  | F  | F  | ML | L  | G  | F  | G  | G  | ML | G  | G  | MG | F  | F  |
| DM2 | A1           | F  | ML | MG | F  | G  | VG | L  | F  | L  | F  | G  | F  | L  | L  | L  | L  | F  | MG |
|     | A2           | G  | L  | G  | G  | VG | VG | VG | L  | F  | G  | ML | ML | L  | G  | G  | MG | MG | G  |
|     | A3           | L  | G  | G  | L  | L  | L  | G  | L  | F  | F  | ML | F  | L  | L  | L  | MG | F  | G  |
|     | A4           | G  | L  | G  | L  | VG | L  | VG | VG | G  | F  | VG | ML | ML | G  | G  | MG | MG | G  |
| DM3 | A1           | G  | L  | G  | F  | F  | F  | G  | ML | G  | F  | VG | ML | G  | G  | G  | MG | F  | G  |
|     | A2           | L  | L  | MG | L  | VG | L  | VG | ML | G  | F  | ML | F  | L  | L  | L  | MG | F  | G  |
|     | A3           | G  | L  | G  | F  | VG | G  | VG | VG | G  | F  | VG | ML | G  | G  | G  | MG | MG | G  |
|     | A4           | L  | F  | MG | VG | G  | F  | G  | ML | F  | F  | ML | G  | MG | VG | VG | VG | F  | ML |
| DM4 | A1           | L  | F  | G  | G  | L  | MG | VG | F  | G  | L  | ML | L  | G  | G  | F  | MG | G  | G  |
|     | A2           | L  | F  | G  | G  | L  | VG | G  | VG | G  | L  | L  | F  | MG | MG | F  | MG | L  | L  |
|     | A3           | G  | F  | MG | F  | G  | L  | G  | VG | G  | L  | L  | F  | MG | MG | F  | MG | G  | F  |
|     | A4           | L  | F  | VG | G  | L  | L  | G  | F  | G  | G  | ML | L  | MG | MG | F  | MG | L  | L  |
| DM5 | A1           | L  | F  | MG | F  | G  | L  | L  | VG | G  | VG | ML | L  | G  | F  | F  | MG | L  | VG |
|     | A2           | L  | F  | VG | G  | L  | L  | L  | L  | L  | L  | L  | L  | ML | VL | VL | MG | F  | VG |
|     | A3           | G  | F  | G  | G  | L  | L  | F  | F  | G  | G  | ML | L  | G  | F  | F  | L  | G  | VG |
|     | A4           | L  | F  | VG | G  | L  | L  | G  | L  | L  | L  | L  | L  | ML | VL | VL | MG | F  | VG |
| DM6 | A1           | L  | F  | G  | G  | L  | L  | G  | ML | G  | ML | ML | G  | L  | L  | L  | MG | F  | G  |
|     | A2           | G  | G  | MG | G  | MG | MG | G  | L  | ML | G  | G  | G  | VG | G  | G  | G  | G  | F  |
|     | A3           | L  | G  | G  | G  | L  | L  | L  | L  | L  | L  | ML | ML | L  | G  | G  | G  | G  | F  |
|     | A4           | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  | L  |
| DM7 | A1           | F  | MG | MG | L  | L  | MG | ML | L  | L  | L  | L  | F  | G  | F  | L  | L  | MG | F  |
|     | A2           | F  | MG | MG | F  | F  | F  | G  | ML | L  | L  | L  | F  | L  | MG | G  | L  | MG | MG |
|     | A3           | L  | L  | L  | L  | L  | L  | L  | ML | L  | L  | L  | L  | L  | G  | G  | L  | MG | F  |
|     | A4           | G  | L  | L  | L  | L  | L  | L  | ML | L  | L  | L  | L  | L  | G  | G  | L  | MG | F  |

**Table 6.**  
Linguistic evaluations  
for alternatives

**Table 7.**  
Integrated evaluations  
for alternatives

|    | E1                 | E2                 | E3                 | E4                 | E5                 | E6                 |
|----|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| A1 | (0.54, 0.39, 0.42) | (0.51, 0.45, 0.47) | (0.71, 0.22, 0.27) | (0.61, 0.34, 0.37) | (0.57, 0.35, 0.39) | (0.61, 0.32, 0.37) |
| A2 | (0.45, 0.51, 0.51) | (0.53, 0.43, 0.46) | (0.64, 0.30, 0.35) | (0.61, 0.34, 0.37) | (0.61, 0.31, 0.35) | (0.61, 0.30, 0.34) |
| A3 | (0.48, 0.46, 0.48) | (0.55, 0.39, 0.43) | (0.58, 0.35, 0.40) | (0.57, 0.37, 0.40) | (0.63, 0.32, 0.36) | (0.66, 0.28, 0.33) |
| A4 | (0.55, 0.38, 0.41) | (0.42, 0.54, 0.55) | (0.55, 0.37, 0.41) | (0.51, 0.44, 0.46) | (0.43, 0.57, 0.56) | (0.48, 0.48, 0.50) |
|    | N1                 | N2                 | N3                 | N4                 | N5                 | N6                 |
| A1 | (0.54, 0.38, 0.41) | (0.45, 0.51, 0.51) | (0.49, 0.44, 0.46) | (0.58, 0.35, 0.39) | (0.61, 0.30, 0.35) | (0.61, 0.30, 0.35) |
| A2 | (0.50, 0.45, 0.47) | (0.58, 0.32, 0.36) | (0.52, 0.42, 0.44) | (0.41, 0.57, 0.56) | (0.40, 0.60, 0.58) | (0.40, 0.60, 0.58) |
| A3 | (0.61, 0.31, 0.35) | (0.46, 0.45, 0.47) | (0.50, 0.46, 0.48) | (0.40, 0.62, 0.59) | (0.45, 0.52, 0.53) | (0.45, 0.52, 0.53) |
| A4 | (0.61, 0.32, 0.37) | (0.48, 0.47, 0.48) | (0.63, 0.32, 0.36) | (0.57, 0.37, 0.40) | (0.46, 0.54, 0.53) | (0.46, 0.54, 0.53) |
|    | S1                 | S2                 | S3                 | S4                 | S5                 | S6                 |
| A1 | (0.63, 0.30, 0.34) | (0.60, 0.34, 0.38) | (0.55, 0.39, 0.42) | (0.63, 0.32, 0.37) | (0.63, 0.31, 0.36) | (0.67, 0.26, 0.31) |
| A2 | (0.45, 0.51, 0.52) | (0.57, 0.36, 0.41) | (0.57, 0.35, 0.39) | (0.52, 0.41, 0.45) | (0.51, 0.44, 0.46) | (0.48, 0.48, 0.49) |
| A3 | (0.61, 0.31, 0.36) | (0.63, 0.30, 0.35) | (0.60, 0.33, 0.37) | (0.64, 0.29, 0.33) | (0.58, 0.36, 0.40) | (0.58, 0.37, 0.40) |
| A4 | (0.60, 0.34, 0.37) | (0.57, 0.37, 0.41) | (0.51, 0.42, 0.45) | (0.54, 0.40, 0.43) | (0.57, 0.39, 0.42) | (0.63, 0.31, 0.36) |

(Ramanathan, 2014; Um and Kim, 2018), and “Profit Level and Margin” (Gimenez *et al.*, 2012; Xia *et al.*, 2015; Zeng *et al.*, 2017; Um and Kim, 2018). The concept of sustainability was particularly found to be an important driver of employee satisfaction and reassurance by ensuring long-run market share expansion and profit margin increase. While the increased competitiveness and business performance positively affect a sustainable supply chain, SSCM itself in turn emerges as an indispensable element of competitiveness, productivity, and the satisfaction of both the internal and external customers.

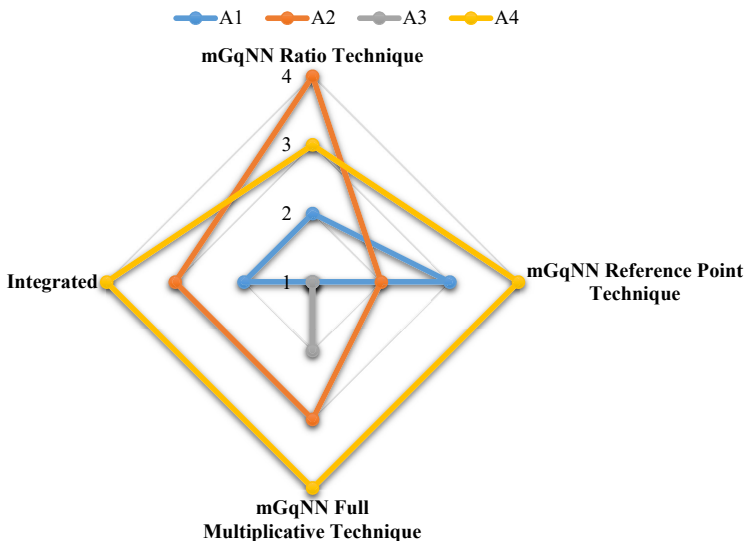
The study determined “*Communication/Reporting*” and “*Non-Governmental Organizations*” as the least important SSCM performance factors. Our results for the “*Communication/Reporting*” criterion do not tally with that of Dossou (2018) and Junge and Straube (2020), whereas that for the “*Civil Society Organizations*” does not support that by Dias-Sardinha and Reijnders (2005). We thus posit that the businesses under consideration in the study need to emphasize the role of digital transformation in their communication and reporting to ensure the complete and uninterrupted operation of SSCM. With the right execution, both improved business performance and support for society could be achieved.

While selecting the most ideal SSCM theory using SSCM performance weights, “*Resource and Natural Resource-Based Theory*” was determined to be the most ideal alternative. The order of the alternatives is  $A3 > A1 > A2 > A4$ .

According to Sarkis *et al.* (2011), businesses need many resources to sustain their operations. These resources could be classified as tangible and intangible assets, which is

| Alts | mGqNN ratio technique |      | mGqNN reference point technique |      | mGqNN full multiplicative technique |      | Integrated Rank |
|------|-----------------------|------|---------------------------------|------|-------------------------------------|------|-----------------|
|      | Score                 | Rank | Score                           | Rank | Score                               | Rank |                 |
| A1   | 0.9145                | 2    | 0.0471                          | 3    | 3.15959E-12                         | 1    | 2               |
| A2   | 0.9047                | 4    | 0.0467                          | 2    | 3.51323E-13                         | 3    | 3               |
| A3   | 0.9225                | 1    | 0.0361                          | 1    | 1.01998E-12                         | 2    | 1               |
| A4   | 0.9116                | 3    | 0.0530                          | 4    | 0                                   | 4    | 4               |

**Table 8.**  
Ranking of alternatives  
using mGqNN-  
MULTIMOORA



**Figure 1.**  
Final ranking of the  
alternatives

what the business owns, and capabilities which refer to what the business can do. The ability to continuously supply the necessary resources and the possession of the capability to adjust to the changes in the incessantly dynamic environment is a core contributor to the pursuit of a competitive edge by the business. The fluctuations in resources affect the performance of the organization; hence, businesses have to seek ways to minimize these fluctuations by having at hand all the necessary resources. The reliance on resources by businesses to achieve sustainable competitive advantage speaks to the significance of the *resource and natural resource-based theory* for businesses. The firm's natural resource-based view also emphasizes the firm's relationship with the natural environment and highlights the firm's three strategic capabilities: pollution prevention, product management, and sustainable development. These strategic capabilities are built on resource clusters that are rare, socially complex, and causally uncertain. Green practices that include these resources and strategic capabilities are valuable for companies in attaining sustainable cost and service advantages (Lai *et al.*, 2010).

## 6. Conclusions

The phenomenon of sustainability is hailed for its benefits to businesses economically, socially, and environmentally as well as the valuable inputs to the society in general. Sustainable practices help improve the performance, efficiency, productivity, competitiveness, and customer satisfaction in businesses while also ensuring that the supply chains work at the desired level without interruption and have become a point of focus for both governments and businesses in the recent past.

This study focused on SSCM performance factors in textile businesses in Ordu and Giresun provinces of Turkey and was based on the choice of the most ideal SSCM theory. The limited number of studies on SSCM performance factors and the absence of any study on the theory make this study an important reference point for future research and allow for comparison with other studies. The method utilized in the study is the other avenue of its contribution to the general literature.

While sustainable practices provide an effective avenue to business survival, the implementation of sustainable systems may require the integration of several systems to ensure the business reaps the maximum benefit in improved cost advantage and market share. The determination of SSCM performance factors and the selection of theories thus become a significant part of business strategy. This revelation by the study is yet another contribution to the literature.

The determination of SSCM performance factors and theory encompasses various uncertainties and complexities occasioned by the large volume of often contradictory qualitative and quantitative criteria and alternatives to consider. This could cause problems for a company in terms of cost, image, environment, performance and efficiency, and the findings of this study can help by providing a road map for overcoming some of the issues mentioned. Whether the results of the study are reliable logical and reasonable depends on the effectiveness of the decision-making model in overcoming the complex alternatives and criteria to be evaluated, and the proposed model for the study which consists of the MULTIMOORA-mGqNN methods has many valuable theoretical contributions in this context.

The practical implications, limitations, and future research are discussed in the following.

### 6.1 Practical and managerial implications

The study sought to determine the relationship and effect of SSCM performance factors and theory in textile enterprises with a view to determine ways to achieve efficiency and agility in enterprises, help reduce energy consumption, ensure employee satisfaction, and resource efficiency and ultimately attain a competitive edge. The results have provided that knowledge.

In addition to its theoretical contributions, the study has very important implications for decision-makers and practitioners in the textile sector and those who are interested in the subject. The study provides an avenue for the evaluation of SSCM performance factors and provides a basic model for the choice of the optimal SSCM theory. The study provides a flexible and structured decision-making environment, one that takes into account different and separate views. Another valuable contribution of the study is that decision-makers can use the proposed model to draw their own program with regard to the evaluation and selection of SSCM performance factors and theory, especially during the COVID-19 pandemic. The study also addresses a critical area as SSCM in the textile industry and presents a new set of criteria suitable for real-world decision-making problems, which may inspire future research into different sectors and industries. Finally, the evaluation, using the method in the study, of the selection processes of SSCM performance factors and theory allows the decision-makers in the textile industry to transfer their practical approaches to a scientific perspective and thus contributes to the interaction of theoretical and practical applications.

### 6.2 Limitations and future research

One of the main limitations of the study is that the number of expert groups interviewed was limited and this number could not be increased due to time constraints. Resulting from the time constraints and the ongoing COVID-19 pandemic, the study was also limited by the population which was restricted to only two provinces in Turkey and just one sector. There was also a lack of existing studies that adequately examined SSCM with respect to performance factors and theory. The implication of this is the absence of a criterion set for the SSCM performance factors and theory selection, both in the opinions of the expert group and in the literature review. It is worth noting that expert judgments are subjective in this context.

Despite the limitations, the results were determined to support the expectations of the DMs in the interviews with expert groups. Future studies can perform comparative analyzes using different decision-making environments (e.g. spherical fuzzy, Fermatean fuzzy and hesitant fuzzy) and methods (e.g. MACBETH, MAIRCA, MEREC and MARCOS). Moreover, the criteria weights were determined using the mGqNN subjective weighting approach that allows for subjective evaluations in this study. Next, studies can bring a different perspective to decision-making by developing extensions of methods such as FUCOM, BWM, and SWARA under mGqNN. Furthermore, the application of robust optimization (Ozmen *et al.*, 2017; Kara *et al.*, 2019) can be taken into account and compared to the studied methodology.

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