Multicriteria Algorithms with Applications

Journal Homepage: sciencesforce.com/mawa

Multicriteria. Algo. Appl. Vol. 2 (2024) 29–42.

Paper Type: Original Article

Harness Ambition of Soft Computing in Multi-Factors of Decision-Making Toward Sustainable Supply Chain in the Realm of Unpredictability

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Received: 05 Aug 2023 **Revised:** 09 Dec 2023 **Accepted:** 07 Jan 2024 **Published:** 12 Jan 2024

Abstract

Major and expensive disturbances have a significant impact on supply chain management (SCM) and jeopardise the sustainability of any business. As COVID-19 pandemic, administrators are required to have strategies and techniques for safeguarding supply chains (CSs) and avoiding chain failures at every stage to be competitive in the market. Sustainability through SCM is described as a general practice that is emerging from the integration of pertinent, contemporary regenerative approaches and strategies. Therefore, it is possible to comprehend the idea of sustainable supply chain management (SSCM) as a business strategy for increasing eco-efficiency and productivity by recycling, reproducing and repurposing techniques under the circular economy. In order for SSCM practices to be successfully adopted in any organization, this study intends to evaluate the critical success factors (CSFs). Herein, nine CSFs were chosen following an exhaustive examination of the literature. The determined CSFs are analysed and evaluated through our constructed mathematical evaluator framework (MEF) based on Multi-Factors of Decision Making (MFoDM) methods, which are fortified with triangular neutrosophic sets (TriNSs) in obscurity and uncertainty situations. MEF conducts evaluation through several stages based on a set of MFoDM methods under the fortress of TriNSs. The best-worst method (BWM) is analysing nine CSFs, and the obtained weights assigned to nine CSFs represent the analysis's outcome. Posteriorly, measurement alternatives and ranking according to compromise solution (MARCOS) to prioritize and rank SCs as alternatives. Ultimately, we verified the validity of the constructed MEF through its application to reality throughout five SCs.

Keywords: Sustainable Supply Chain; Critical Success Factor; MFoDM; BWM; MARCOS; Triangular Neutrosophic Sets.

1 | Introduction

A multitude of issues have a profound impact on supply chain management (SCM) as catastrophes, which is considered the first factor in this study and other studies [1]. Also, the study of [2] emphasized that epidemic-related catastrophes differ from other types of disasters because of two factors: extended disruptions to the affected areas and accelerated disease transmission. While SCs and communities are severely disrupted when these calamities are not controlled. This means that there might be irreversible losses. Additionally [3], this results in decrease and rise in the rate of unemployment. Environmental issues, as in [4], which in turn threaten

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https://doi.org/10.61356/j.mawa.2024.26561

SC. Hence, [5] risk management became apparent under these circumstances as a result of the growing public awareness of environmental concerns and the hazards that polluting industries pose. From the perspective of [6], one of the most important challenges and worries for nations worldwide is controlling and decreasing pollution in order to save the environment and stop global warming. Consequently, SC became green and led to green SC (GSC). According to [7], integrating eco-friendly elements of operations into a conventional SC is the fundamental objective of GSCM. While another perspective [8] asserted that whereas green just addresses environmental issues, sustainability also considers the social, economic, and environmental effects of a product. Hence, SSC is declared a far more comprehensive concept than green supply chain management (GSCM), encompassing the effects of SC activities on the environment, society, and economy. Confirmation of this [9]: SSCM permits enterprises to deal with challenging circumstances, including acquiring raw materials, fostering relationships with employees, and figuring out work opportunities in the community. Due to [10], the triple bottom line (TBL) notion pertains to sustainability and assesses it via the consideration of social, financial, and environmental aspects. The metrics used to quantify sustainability include profitability, employee engagement, and global influence. Hence, sustainability can be defined as the extent to which current organizational decisions have an impact on the overall condition of the environment, society, and business success in the future.

The controversy of how enterprises may handle social and environmental problems outside of their boundaries and thereby extend sustainability requirements to their supply chain has been covered in academic work on sustainable supply chain management (SSCM). The environment is ever-changing, and with supply chains becoming increasingly complex, it is becoming more difficult to use SSCM methodologies. For instance, [11] stated that strategies for SSCM might support businesses in the post-COVID-19 global economic environment. As is the situation in [12], Sustainable production in SC is made possible by a growing number of green techniques, including ecological manufacturing, green design, and green logistics, as well as government regulations and an emphasis on sustainable relationships among SCM partners.

Recently and as in [13], the sustainable development goals (SDGs) have been attained in part by industrial firms thanks to their tactical and strategic execution of environmental, circular economy, and corporate social responsibility initiatives. Thus [8], it is essential to identify and assess the critical success factors (CSFs) for the effective adoption and use of sustainability practices, as they might operate as obstacles to the achievement of sustainable development goals if they are not controlled effectively.

Determining the critical success factors (CSFs) for sustainability in SC operations is the purpose of this study. Based on a literature review, conversations with experts and decision-makers, and talks with professionals, appropriate critical success factors are identified. Additionally, a hybrid multi-criteria decision-making framework is used to evaluate these critical factors. Herein, the proposed framework entails MEF. This framework showcases the integration of BWM with MARCOS under neutrosophic environment. The BWM is utilized to weight the CSFs of supply chain sustainability. The weight that found from the BWM is utilized to rank five alternate supply chains in order to verify the proposed framework. The traditional MARCOS is not sufficient enough to avoid the uncertainty issue of evaluation decision making process. As a result, this framework is applied under neutrosophic environment.

Generally speaking, the following points provide a summary of the study's foremost contributions:

- Through survey has been conducted for earlier studies, CSFs which responsible for achieving sustainability for SCM by virtue of its involvement in SC's strategies and Practices.
- The determined and influenced CSFs should be evaluate toward retain sustainability of SC.
- For conducting process of evaluation, MEF is constructed through volunteering MFoDM under authority of neutrosophic as uncertainty theory.
- In order to guarantee MEF 's correctness, we are implementing the constructed MEF on real case study of SC.

This study is organized into a set of sections. Each one is responsible for a certain role in achieving the study's objectives. Section 2 analyses the related works on SSC and its CSFs. Research framework has been discussed in Section 3 while Section 4 presents the application of the proposed framework and the results. Section 5 provides a conclusion and future research direction.

2 | Relevant Theoretical Underpinnings: Literature Reviews

The purpose of this section is to clarify the significant underpinnings on which our study is based.

2.1 | Toward Competitiveness: Sustainable Supply Chain

One of the management sciences' most active study fields for a long time has been SCM. Evidence of this [14], which describes the activities that occur throughout SC, from the procurement of resources to the manufacture and distribution of completed goods to consumers, offers a treasure trove of research material that stimulates scholars and professionals alike. . Of these, research on SSCM became more and more prevalent. SSCM originated from the integration of the sustainability perspective into SCM, with a primary focus on environmental challenges alongside traditional economic topics. It later expanded to include social concerns as well, especially after the TBL concept was presented. Although this perspective on supply chain sustainability is certain, there are two possible interpretations of it according to [15]. The close relationship between sustainability and the impacts of human activities on the environment is one approach. The matter of "limitations" is closely linked to the other.

In the years when three primary issues were the focus, supply chain sustainability research grew. The first issue was with the methods and strategies used by businesses to minimize their environmental impact. Second, the methods businesses have utilized to involve stakeholders in the supply chain besides the company and its suppliers have been highlighted. Third, research projects aimed at enhancing supply chain sustainability performance [16]. For instance, Sachin and Rajesh [17] explore the situation of Indian enterprises when examining empirically the effect of sustainable supply chain practices on financial performances. The scholars' study of [18] seeks to get a better understanding of the possible development potential of new Industry 4.0 digital technologies and how Vietnamese supply chain companies are using them. whereas [19] study's primary objective was to comprehend the implications of several sustainability practices (i.e., environmental, social, and economic) on company performance (i.e., financial and operational). As a result, SC's sustainability is crucial, which prompted [20] to analyze SSC through the development of a methodology that integrated environmental, social, and operational risk throughout the whole SC.

2.2 | For Preserving SSC: Critical Success Factors of SSC

Several studies discussed SC's CSFs in different industries. As an illustration, [21] examined the essential success criteria and business needs for deploying blockchain (BC) for SC tracking.

A framework that illustrates the relationship between the CSFs and reverse logistics in the context of the circular SC is provided in the article by [22], which also developed a taxonomy for the CSFs of reverse logistics capable of adding value to the company and its SC. Furthermore, [23] investigated CSFs for the implementation of green supply chain management (GSCM) in an emerging economy's electronics industry. In the same vein, [24] sought to ascertain the needs of the stakeholders and CSFs for SSC in the context of the COVID-19 pandemic emergency. Scholars' [25] investigation of the CSFs influencing the adoption of artificial intelligence made a substantial contribution to the Food Supply Chain (FSC).

Researchers have studied a variety of critical factors for implementing SSC in numerous industries over the past 20 years. To identify the necessary CSFs for implementing SSC in diverse industries, articles published between 2010 and 2022 in the Scopus and Google Scholar databases were investigated. Finally, nine general critical success factors for various types of SSC implementation were selected for further analysis using the BWM-MARCOS framework after investigation, as shown in Table 1.

Table 1. Critical success factors of supply chains sustainability.

	CSFs	Description	References
CSF_1	Energy efficiency	The major characteristics of sustainable energy, such as solar energy, include reliance on environmentally friendly energy, limitless and easily extendable, highly flexible and increasingly low-cost.	[26, 27]
CSF_2	Financial and tax advantages	Taxes on non-green goods and subsidies for green ones are determined by the government, which also considers the interests of society.	[28, 29]
CSF_3	Logistics sustainability	Green logistics reduce carbon emissions by using alternative fuels in place of fossil fuels, cutting operational costs, and modifying transportation to promote sustainability.	[30, 31]
CSF_4	The government controls	As a major actor in the green supply chain, the government may simply force companies to comply by influencing their external and internal resources.	[32]
CSF_5	Skilled workforce	The availability of manpower trained to deal with the stages of the SSC increases the efficiency of the supply chain	[33]
CSF_6	Implementation of green technologies	new technologies such as big data, cloud computing, AI, and others, are has become a significant change in many industries SC	[34]
CSF_7	Choosing sustainable suppliers	SCs can effectively manage their environmental impact by concentrating on their commercial interactions with suppliers who use green SCM (GSCM).	[35]
CSF_8	Waste management	encompasses all necessary procedures and activities to handle waste at every step of SC, from creation to disposal.	[36]
CSF_9	Universal competition element	Global competition of SCs is more complex since suppliers and partners are located in different countries and environmental and economic factors greatly influence sourcing and distribution	[37]

2.3 | Evaluation of CSFs: Leveraging MFoDM in SSC

Since it is defined by comparing their respective priorities among a limited number of alternatives, the selection of the most SSC can be thought of as an MFoDM problem. There are various MFoDM methods that have been utilized to select the optimal SSC among multiple alternatives. In order to choose sustainable alternative aviation fuels, [38] provided a novel hybrid five-phase fuzzy Multi-Criteria Decision Making (MCDM) technique that integrates interval-valued triangular fuzzy numbers (IVTFNs), IVTFN-AHP, IVTFN-TOPSIS, and cumulative prospect theory. Moreover, [39] provides a framework and uses fuzzy analytical network processes (FANP) for appraisal in order to identify and appraise the barriers in CSs and improve the implementation of sustainable production and consumption. The study conducted by [40] presented a novel fuzzy TOPSIS and fuzzy SAW approach for choosing the best sustainable supplier based on the combination of intuitionistic fuzzy sets and cumulative prospect theory. There are two stages [41]. The first phase examines how the epidemic has affected SC resilience. A combined ANP-TOPSIS framework is suggested in the second phase to help prioritise the solutions that consider the intricate interactions between the many components engaged in the decision-making process.

3 | Evaluation Methodology: Mathematical Evaluator Framework

The research's suggested framework is used to assess the critical success factor for supply chain sustainability. The sustainability of SC general critical success factors is determined using a systematic literature review. The best-worst method (BWM) is used in the first step of the proposed framework to assess the critical success factor of supply chain sustainability. The neutrosophic MARCOS is used in the second phase to evaluate five alternative supply chains in order to validate the suggested framework. Figure 1 shows the proposed research framework, and this section goes into further information about each stage.

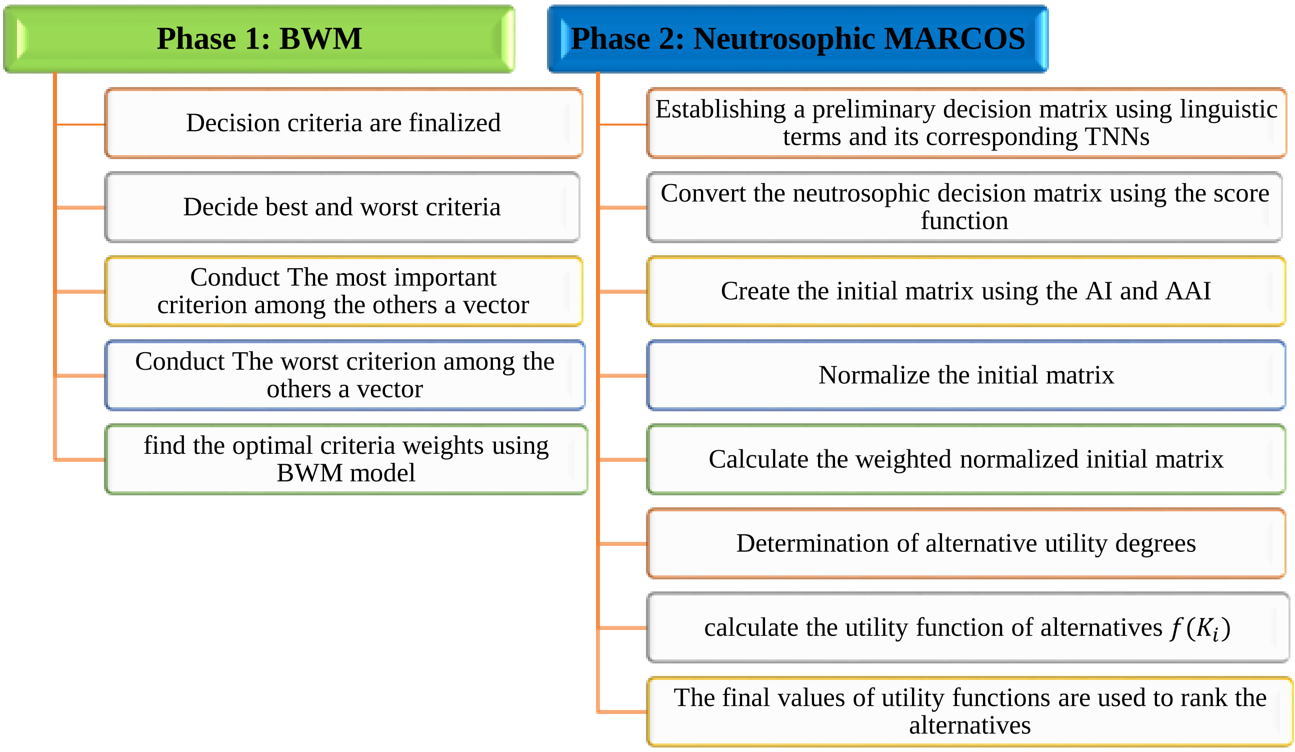

Figure 1. The phases of the proposed framework.

3.1 | Phase 1: The Best-Worst method (BWM)

Techniques such as multi criteria decision making (MCDM) are applied when faced with complicated challenges and given the responsibility of choosing the best option from an extensive range of alternatives. Rezai in [42] developed a new MCDM technique called the "Best Worst Method" that is used to determine how much each criterion is worth. Rezaei outlines several steps for putting this concept into practice, which are covered below:

Step 1: Decision criteria are finalized and denoted as {c1, c2, …..,cn} for *n* main criteria. In our study the set of criteria are the critical success factors of the supply chain sustainability.

Step 2: Deciding which primary and secondary criteria are the best and worst. So, the most and least influencer CSF will be determined.

Step 3: On a scale of 1 to 9, indicate your choice for the best criterion over other criteria. Determine which criteria are preferred over all others on a scale from 1 to 9. The most important criterion among the others a vector can be expressed as: $A_B = (a_{B1}, a_{B2}, \ldots\ldots, a_{Bn})$, Where a_{Bj} represents the rating of best criteria B over any other criteria j. Here, $a_{BB} = 1$.

Step 4: Calculate the ratings of all other criteria over the worst criteria, which will be selected by the expert, similarly using a range of 1 to 9. The vector that represents the comparison of other criteria to the worst criteria is as follows: $A_W = (a_{1W}, a_{2W}, \ldots\ldots, a_{nW})$. Where a_{jW} represents the rating of any criteria j with the worst criteria W. Here, $a_{WW} = 1$.

Step 5: Using BWM model [36] to find the optimal criteria weights ($W1^*$, W_2^*, … , W_n^*).

$$\min \max \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\}$$

s.t.

$$\sum_j w_j = 1 \; w_j \geq 0 \text{ , for all j} \tag{1}$$

The equivalent model is:

Min ε

s.t.

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \leq \varepsilon \text{ , for all j}$$

$$\left| \frac{w_j}{w_w} - a_{jW} \right| \leq \varepsilon \text{ , for all j}$$

$$\sum_j w_j = 1 \tag{2}$$

$$w_j \geq 0 \text{ , for all j}$$

3.2 | Phase 2: Neutrosophic MARCOS Method

The MARCOS method is based on figuring out how references values and alternatives (both ideal and anti-ideal alternatives) connect to one another. This method's decision-making is mostly based on the idea of a utility function. One alternate viewpoint for both ideal and anti-ideal solutions is the utility function. The option that is closest to the ideal point (and, thus, farthest from the anti-ideal point) is the greatest decision [43]. MARCOS has advantages over traditional MCDM techniques in that it is straightforward, efficient, and simple to sort and improve the steps involved. At the very beginning of the development of an initial matrix, it also takes both ideal and anti-ideal solutions into account and permits the consideration of enormous qualities and alternatives while maintaining its stability [44]. The steps of MARCOS method as follows:

- Establishing a preliminary decision matrix. A collection of n criteria and m alternatives are defined. When making decisions as a group, a group of specialists should be assembled to assess the alternatives in light of the criteria. In our study, one of the contributions is to handle the uncertainty in evaluation process, thus, this decision matrix is applied using linguistic terms and its corresponding triangular neutrosophic numbers as shows in Table 2.

- Convert the neutrosophic decision matrix using the score function as Eq. (3) shows.

$$S(a) = \frac{1}{8} \times (a_1 + a_2 + a_3) \times (2 + T - I - F) \tag{3}$$

Table 2. Evaluation scale based on TriNN.

Linguistic terms	Triangular neutrosophic Number (TriNN)
Very low influence (VLI)	((0.10, 0.30,0.35), 0.1,0.2,0.15)
Low influence (LI)	((0.3,0.4,0.10), 0.6,0.2,0.3)
Partially influence (PI)	((0.40,0.35,0.50), 0.6,0.1,0.2)
Medium important (MI)	(0.5,0.50,0.50),0.8,0.1,0.1)
High influence (HI)	((0.70,0.65,0.80),0.9,0.2,0.1)
Very high influence (VHI)	((0.90,0.85,0.90),0.7,0.2,0.2)
Absolute influence (AI)	((0.95,0.90,0.95),0.9,0.10,0.10)

- Defining the ideal (AI the best alternative) and anti-ideal (AAI the worst alternative) solution results in the creation of an initial matrix (X)using Eqs. (4) and (5). (B is beneficial criteria while C is cost criteria).

$$AAI = \min x_{ij} \text{ if } j \in B \text{ and } \text{man}\, x_{ij} \text{ if } j \in C \quad (4)$$

$$AI = \text{man}\, x_{ij} \text{ if } j \in B \text{ and } \min x_{ij} \text{ if } j \in C \quad (5)$$

- $N = [n_{ij}]_{m\times n}$ is the normalization of the initial matrix (X) using Eqs. (6) and (7).

$$n_{ij} = \frac{x_{ai}}{x_{ij}} if\ j \in C \quad (6)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} if\ j \in B \quad (7)$$

- Calculate the weighted normalized matrix $V = [v_{ij}]_{m\times n}$using Eq. (8).

$$v_{ij} = n_{ij} * w_j \quad (8)$$

- Determination of alternative utility degrees K_i. The utility degrees of an alternative in regard to the anti-ideal and ideal options are determined using Eqs. (9) and (10). S_i is the total of the weighted matrix V's elements.

$$K_i^- = \frac{S_i}{S_{aai}} \quad (9)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (10)$$

- Using Eq. (11), calculate the utility function of alternatives $f(K_i)$.

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad (11)$$

where, $f(K_i^+)$and $f(K_i^-)$as Eqs. (12) and (13) show

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (12)$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (13)$$

- The final values of utility functions are used to rank the alternatives.

4 | Comprehensive Analysis and Results: Mathematical Evaluator Framework Application

The topic of SSC is one that has a lot of CSFs that could have an impact on how it operates. As a result, this study presents the implementation of a novel MFoDM framework composed of two key methodologies, such as BWM and MARCOS, in the evaluation of the critical factors affecting supply chain sustainability. The study provides an empirical example of how the BWM-MARCOS framework can be used to assess the sustainability of CSFs in an uncertain environment. The CSFs presented in Table 1 have been utilized to assess the CSFs of SSC based on an extensive literature review. Each CSF's definition and examples of previous studies are given, along with sources.

4.1 | Phase 1: the Best-Worst method (BWM)

The aim of this research is to evaluate the critical success factors of supply chain sustainability. From the literature reviews, nine general CSFs of supply chain sustainability are evaluated using the BWM. The experts who would evaluate the CSFs were identified among the personnel. This study involved two researchers who's focusing on their studies in SCM field: The first expert has a long experience in studying SC logistics and operations. The second expert is studying the technological revolution and its effect on SCM. The application of the first phase is stated as follows:

- The researchers studied the nine specified critical success factors of supply chain sustainability and determine that CSF2 (Financial and tax advantages) is the best and most effective factor whilst CSF8 (waste management) is the worst or least influencer factor that affect SSC.
- Then, the best-to-other vector and others-to-worst vector are determined from range 1 to 9 as Tables 3 and 4 show.

Table 3. Best-to-other vector.

Best to others	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
CSF2	7	1	8	2	6	3	4	9	5

Table 4. Others-to-worst vector.

Others to the worst	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
CSF8	3	9	2	8	4	7	6	1	5

- Finally, the optimal weight of the nine CSFs is determined according to the Rezaie model, as Eqs. (1) and (2) show. Table 5 shows the weight of the CSFs. The weight of the best CSF2 is 0.3146, followed by CSF4 and CSF6, with weights of 0.1915 and 0.1277, respectively. The weights of the nine CSFs are summarized in Figure 2.

Table 5. Weights of the nine CSFs of the supply chain sustainability.

Weights	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
CSFs	0.0547	0.3146	0.0479	0.1915	0.0638	0.1277	0.0958	0.0274	0.0766

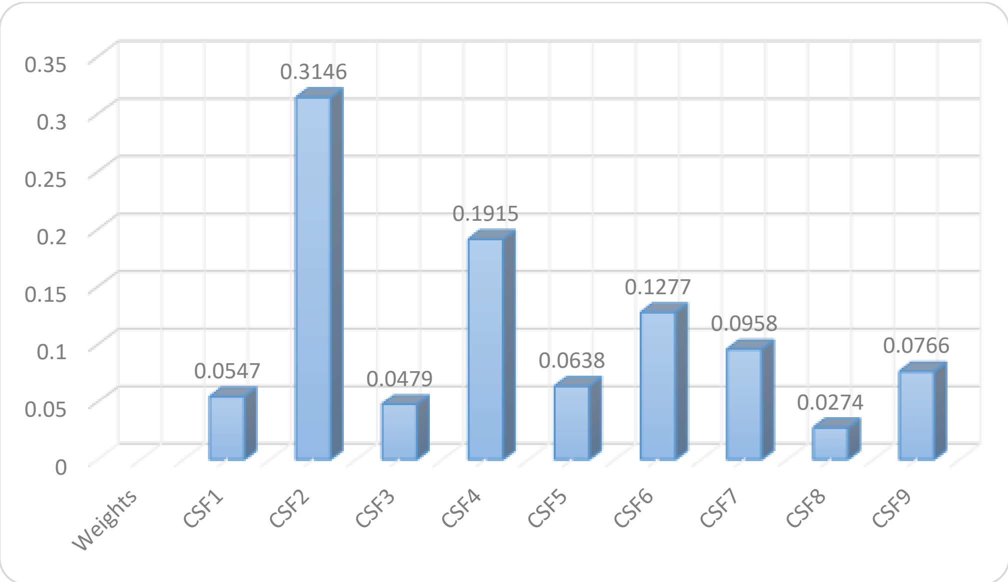

Figure 2. Phase 1 result summarization.

4.2 | Phase 2: Neutrosophic MARCOS

In the second phase of the proposed framework we apply the neutrosophic MARCOS method. In order to verify the proposed framework, we evaluate 5 alternative supply chain to measure their sustainability based on the weight of the nine critical success factors that found in the previous stage. This phase is applied by the assistance of the two researchers that defines before. The details of this phase is discussed in details in this section.

- The two researchers are participate in the evaluation of the five alternative supply chain and using the linguistic terms that defined in Table 2 are utilized. The decision matrix of the two researchers as Table 6 shows.

Table 6. Decision matrix of the two researchers.

Researcher 1	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
A1	VHI	LI	LI	VHI	MI	HI	VHI	LI	HI
A2	LI	VHI	MI	AI	VLI	VHI	LI	MI	HI
A3	PI	LI	LI	AI	MI	PI	PI	AI	VLI
A4	VHI	HI	VHI	VLI	VHI	VLI	MI	VLI	VHI
A5	VHI	HI	LI	VHI	MI	VHI	LI	VHI	MI
Researcher 2	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
A1	HI	LI	MI	VHI	MI	VHI	VHI	LI	VHI
A2	HI	MI	MI	AI	LI	VHI	VLI	MI	VHI
A3	LI	PI	LI	VHI	MI	PI	MI	AI	LI
A4	HI	VHI	VHI	LI	VHI	VLI	PI	VLI	VHI
A5	LI	VHI	LI	VHI	MI	VHI	LI	VHI	MI

- The second step is to create the initial matrix, after converting the neutrosophic evaluation matrix into crisp values using Eq. (3). Table 7 shows the initial matrix using the AAI and AI. While Table 8 shows the normalized initial matrix of the two researchers. The weighted normalized initial matrix is calculated based on the weights that found from the previous stage of BWM as shown in Table 9.

Table 7. Initial evaluation matrix including the AAI and AI.

Researcher 1	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
AAI	0.210	0.210	0.210	0.164	0.164	0.164	0.210	0.164	0.164
A1	0.762	0.210	0.210	0.762	0.488	0.699	0.762	0.210	0.699
A2	0.210	0.762	0.488	0.945	0.164	0.762	0.210	0.488	0.699
A3	0.359	0.210	0.210	0.945	0.488	0.359	0.359	0.945	0.164
A4	0.762	0.699	0.762	0.164	0.762	0.164	0.488	0.164	0.762
A5	0.762	0.699	0.210	0.762	0.488	0.762	0.210	0.762	0.488
AI	0.762	0.762	0.762	0.945	0.762	0.762	0.762	0.945	0.762
Researcher 2	**CSF1**	**CSF2**	**CSF3**	**CSF4**	**CSF5**	**CSF6**	**CSF7**	**CSF8**	**CSF9**
AAI	0.210	0.210	0.210	0.210	0.210	0.164	0.164	0.164	0.164
A1	0.699	0.210	0.488	0.762	0.488	0.762	0.762	0.210	0.762
A2	0.699	0.488	0.488	0.945	0.210	0.762	0.164	0.488	0.762
A3	0.210	0.359	0.210	0.762	0.488	0.359	0.488	0.945	0.164
A4	0.699	0.762	0.762	0.210	0.762	0.164	0.359	0.164	0.210
A5	0.210	0.762	0.210	0.762	0.488	0.762	0.210	0.762	0.488
AI	0.699	0.762	0.762	0.945	0.762	0.762	0.762	0.945	0.762

Table 8. Normalized initial matrix.

Researcher 1	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
AAI	0.276	0.276	0.276	0.174	0.215	0.215	0.276	0.174	0.215
A1	1.000	0.276	0.276	0.806	0.640	0.917	1.000	0.222	0.917
A2	0.276	1.000	0.640	1.000	0.215	1.000	0.276	0.516	0.917
A3	0.472	0.276	0.276	1.000	0.640	0.472	0.472	1.000	0.215
A4	1.000	0.917	1.000	0.174	1.000	0.215	0.640	0.174	1.000
A5	1.000	0.917	0.276	0.806	0.640	1.000	0.276	0.806	0.640
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Researcher 2	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
AAI	0.276	0.276	0.276	0.222	0.276	0.215	0.215	0.174	0.215
A1	0.917	0.276	0.640	0.806	0.640	1.000	1.000	0.222	1.000
A2	0.917	0.640	0.640	1.000	0.276	1.000	0.215	0.516	1.000
A3	0.276	0.472	0.276	0.806	0.640	0.472	0.640	1.000	0.215
A4	0.917	1.000	1.000	0.222	1.000	0.215	0.472	0.174	0.276
A5	0.276	1.000	0.276	0.806	0.640	1.000	0.276	0.806	0.640
AI	0.917	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 9. Weighted normalized decision matrix.

Researcher 1	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9
AAI	0.0151	0.0867	0.0132	0.0332	0.0137	0.0275	0.0264	0.0047	0.0165
A1	0.0547	0.0867	0.0132	0.1544	0.0408	0.1171	0.0958	0.0061	0.0703
A2	0.0151	0.3146	0.0306	0.1915	0.0137	0.1277	0.0264	0.0141	0.0703
A3	0.0258	0.0867	0.0132	0.1915	0.0408	0.0602	0.0452	0.0274	0.0165
A4	0.0547	0.2886	0.0479	0.0332	0.0638	0.0275	0.0613	0.0047	0.0766
A5	0.0547	0.2886	0.0132	0.1544	0.0408	0.1277	0.0264	0.0221	0.0490
AI	0.0547	0.3146	0.0479	0.1915	0.0638	0.1277	0.0958	0.0274	0.0766
Researcher 2	**CSF1**	**CSF2**	**CSF3**	**CSF4**	**CSF5**	**CSF6**	**CSF7**	**CSF8**	**CSF9**
AAI	0.0151	0.0867	0.0132	0.0426	0.0176	0.0275	0.0206	0.0047	0.0165
A1	0.0502	0.0867	0.0306	0.1544	0.0408	0.1277	0.0958	0.0061	0.0766
A2	0.0502	0.2013	0.0306	0.1915	0.0176	0.1277	0.0206	0.0141	0.0766
A3	0.0151	0.1484	0.0132	0.1544	0.0408	0.0602	0.0613	0.0274	0.0165
A4	0.0502	0.3146	0.0479	0.0426	0.0638	0.0275	0.0452	0.0047	0.0211
A5	0.0151	0.3146	0.0132	0.1544	0.0408	0.1277	0.0264	0.0221	0.0490
AI	0.0502	0.3146	0.0479	0.1915	0.0638	0.1277	0.0958	0.0274	0.0766

- The ranking of alternatives using the MARCOS method is based on the utility function $f(K_i)$. Table 10 and 11 show the ranking of five alternatives using the BWM-MARCOS framework. From researcher 1 perspective, alternative 2 (A_2) is the most sustainable supply chain based on the 9 evaluated CSFs with utility function 0.7691. While alternative 3 (A3) is the least sustainable supply chain with utility function 0.4853. The ranking of alternatives from researcher 1 perspective is $A_2 > A_5 > A_4 > A_1 > A_3$.
- From researcher 2 evaluation, Table 11 shows that alternative 5 (A5) is the most sustainable supply chain based on the 9 CSFs that evaluated in the first stage with utility function 0.7301. While, alternative

2 (A_3) is the least sustainable supply chain with utility function 0.5139. The ranking of researcher 2 is: $A_5 > A_2 > A_1 > A_4 > A_3$.

- In order to find the ranking of the 5 alternatives according to the two researcher evaluation, the average utility function is calculated and the result shows in Figure 3.
- As the results show, the ranking of the two researcher and their average is almost the same. For instance, the ranking of researcher 2 and the average utility function have is the same.

Table 10. Result of the MARCOS and rank of alternatives according to researcher 1 evaluation.

Researcher 1	K-	K+	f(k-)	f(k+)	f(k)	Rank
A1	2.6950	0.6391	0.1917	0.8083	0.6113	4
A2	3.3907	0.8041	0.1917	0.8083	0.7691	1
A3	2.1395	0.5074	0.1917	0.8083	0.4853	5
A4	2.7764	0.6584	0.1917	0.8083	0.6298	3
A5	3.2761	0.7769	0.1917	0.8083	0.7431	2

Table 11. Result of the MARCOS and rank of alternative according to researcher 2 evaluation.

Researcher 2	K-	K+	f(k-)	f(k+)	f(k)	Rank
A1	2.8208	0.6689	0.1917	0.8083	0.6398	3
A2	3.0796	0.7303	0.1917	0.8083	0.6985	2
A3	2.2658	0.5373	0.1917	0.8083	0.5139	5
A4	2.6045	0.6176	0.1917	0.8083	0.5908	4
A5	3.2189	0.7633	0.1917	0.8083	0.7301	1

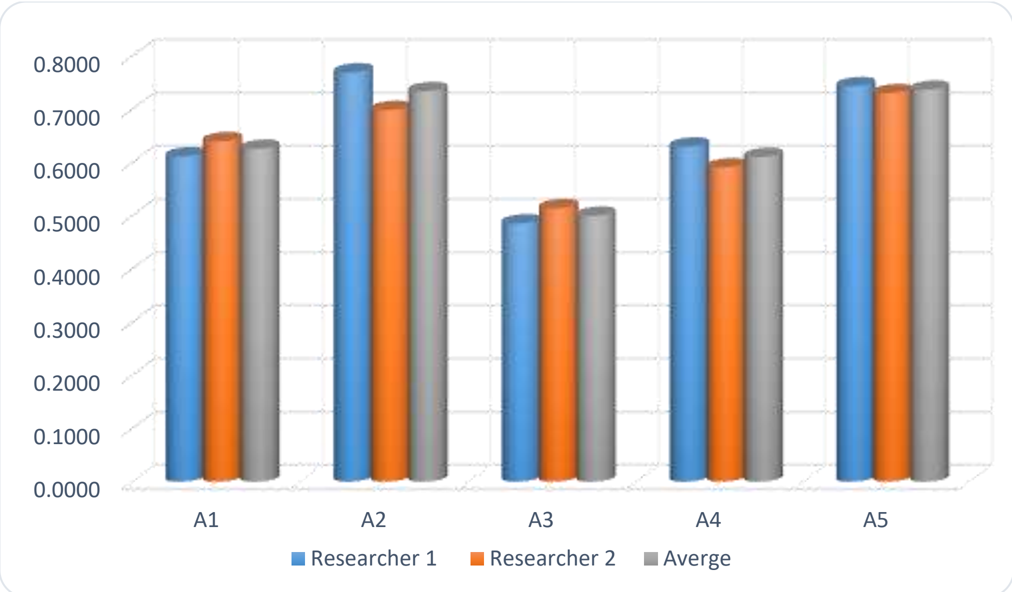

Figure 3. The ranking of alternatives using the proposed framework according to the 2 researchers.

5 | Conclusion and Future Works

The phrase "sustainability" has gained significant traction over the last several years in a variety of political discussions and modern business settings. The damaging ecological impacts of different commercial industries' conventional business practices have previously been recognized by several nations. Many wealthy nations have already taken steps to adopt environmentally friendly practices for the preservation of the environment and the survival of businesses.

This study examined SSC's CSFs through the leveraging ability of MFoDM, especially BWM with MARCOS, for constructing MEF with support of uncertainty theory. Hence, the constructed MEF encompasses two stages. The first stage of this framework is to weight the nine critical success factors of SSC. The nine CSFs were identified from the literature review. The result of this stage shows that the weight of the best CSF2 is 0.3146, followed by CSF4 and CSF6, with weights of 0.1915 and 0.1277, respectively.

In order to prove the reliability and applicability of the proposed framework, five nominees for SC were evaluated based on two researchers who were related to the field. The second stage of the proposed MEF is the utilization of the MARCOS method to rank nominees for alternatives. This phase is applied in a neutrosophic environment in order to provide a more accurate evaluation result and to face the problem of uncertainty. The ranking in this stage is based on the utility function that was calculated based on the weight of the nine CSFs that were found in the previous stage.

Generally speaking, this study is expected to contribute to the literature on SSC and connect the critical success factors with achieving long-term sustainability in different industries. Like all research, this one has some limitations that can be addressed in subsequent studies. This study was done for standard supply chains. Consequently, the results might differ from industry to industry. The study did not analyze all important CSFs; it only looked at nine of them. Future research efforts can examine CSF, which is more significant. This study's evaluation was conducted using the BWM-MARCOS framework. Other MCDM tools, such as DEMATEL and TOPSIS, can be used in subsequent studies.

Acknowledgments

The author is grateful to the editorial and reviewers, as well as the correspondent author, who offered assistance in the form of advice, assessment, and checking during the study period.

Author Contributaion

All authors contributed equally to this work.

Funding

This research has no funding source.

Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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