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Neutrosophic Autocratic Multi-Attribute Decision-Making Strategies for Building Material Supplier Selection

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Abstract: Because of the intricate nature of real-world scenarios, experts could encounter many ambiguities throughout the decision-making (DM) process. Adopting a DM strategy in conditions of indeterminacy so that the decision makers are limited to a small number of experts is always helpful in real life. Neutrosophic conception is a convenient technique for handling inconsistent, ambiguous, and uncertain values. This research presents an autocratic DM strategy based on Neutrosophic Sets (NSs) to address these ambiguities. The essential component of the suggested technique is the conversion of diverse management decision and weight matrices into a unified evaluation matrix. Supplier Selection (SS) is a multi-criteria decision-making problem where a limited number of alternative suppliers are evaluated using a limited set of criteria. The suggested methodology based on different score functions is applied to SS issues involving construction materials. The numerical illustrations indicate the success of the introduced method in selecting the best supplier with the least computational complexity. The important point obtained in this research is that adopting a suitable score function appropriate to the characteristics of the data plays an important role in the decision-making process.

Keywords: decision making; construction supply chain; neutrosophic sets; building management; score function; autocratic strategy

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1. Introduction

Decision making (DM) is essential to daily life activities. Making decisions may be complicated, mainly when several decision indicators exist. Authorities may be attentive when deciding on permissible limits for assessing alternative characteristics based on time and location. Because of the complicated nature of natural phenomena, experts could encounter many ambiguities throughout the DM process.

Supplier selection (SS) is one of the most crucial DM difficulties in supply chain management (SCM), requiring executives to identify the most effective and suitable source for the source element or final goods. SS is a highly challenging, intricate, and multifunctional judgment call process in which several choice factors must be considered. Administrators often encounter major data-accessing issues when attempting objective evaluation of service quality, which are not present with subjective evaluation. To overcome such challenges, administrators create linguistic opinion expression sets that enable users to convey their views about the effectiveness of vendors and involve decision criteria with more accuracy and dependability. Numerous analyses have been performed in the literature to tackle SS problems. The primary objectives of SCM are to substantially optimize company activities, increase rotation and inventory status, enhance profits and revenue, minimize production costs, enhance customer happiness, and satisfy customer requirements. Some criteria must be established for the SCM decision-making process, particularly in complicated sectors. A suitable procurement system is one of the prerequisites for a productive SC. The acquiring agency is significant in ensuring the firm selects the most cost-effective suppliers.

Identifying the ideal supplier for building projects can be considered the most crucial viable strategy in the building process.

SS in systematic analysis includes the analytic hierarchy process (AHP) [1], the supplier performance matrix approach [2], vendor profile analysis [3], the matrix approach [4], the weighted point method, and taxonomy [5]. SS problems are diverse and contain the characteristics of multi-indicator standards, complexity, and non-structure.

1.1. The Motivation for Using Neutrosophic Sets in Decision Making

Owing to the complexity of living systems, judgment calls are associated with various challenges, particularly when making decisions using incomplete, ambiguous, or inaccurate data. The Fuzzy Set (FS) theory, as well as its implementation, which includes Interval-Valued Fuzzy Sets (IVFS), Intuitionistic Fuzzy Sets (IFS), Interval-Valued Intuitionistic Fuzzy Sets (IVIFS), type n-fuzzy sets, etc., provides important mechanisms for handling incomplete information. However, so far, conventional frameworks are still incapable of dealing with inaccurate and inconsistent data. Smarandache [6] developed the notion of Neutrosophic Sets (NSs) to remedy this constraint. NS theory is a helpful tool for coping with inconsistent, ambiguous, and insufficient data. Wang et al. [7] established Single-Valued Neutrosophic Sets (SVNSs) to tackle real challenges in engineering and science. Lately, SVNSs have emerged as a significant research area, attracting considerable interest in DM challenges. NS and its implementation have garnered substantial interest in recent years. Hence, we can deal with incomplete data by employing NSs, which is an integral part of DM.

In recent years, several DM methods have been presented. Yazdani et al. [8] suggested a green product-assessment framework with multiple criteria and a fuzzy neutrosophic (IVFN) framework. The structural model employs Criteria Importance Through Inter-criteria Correlation (CRITIC) and combination compromised solution (CoCoSo) in an IVFN system to analyze and choose dairy firm providers. Nabeeh et al. [9] provided a neutrosophic AHP of the IoT in businesses to assist decision makers in estimating the influencing aspects. The estimate of essential elements may impact the startup's IoT-related performance. Their approach integrates AHP and neutrosophic methodologies to accurately display the criteria associated with basic features. The proposed possibilities are offered based on neutrosophic procedures that fulfill the predicted significant criteria for a successful firm. Abdel-Basset et al. [10] introduced a novel neutrosophic Multi-Criteria Decision-Making (MCDM) methodology that combines a collection of neutrosophic Analytical Network Process (ANP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) under bipolar neutrosophic values. In the practical example of the Elsewedy Electric Group in Egypt, the suggested MCDM approach was used to identify the chief executive officer (CEO). The recommended method enables administrators to compile individual assessments of decision makers and, as a result, to conduct precise individual considerations. Zhu et al. [11] investigated an innovative three-way multi-attribute decision-making approach (3W-MADM-R) according to the regret concept, which leverages heart disease information to make conclusions in fuzzy situations. Cheng [12] offered an autocratic DM method for hotel location selection based on interval-valued intuitionistic FSs. Mufazzal et al. [13] suggested a Fuzzy Proximity Index ranking approach to aid in multi-criteria decision making in a fuzzy setting. The suggested technique emerged from the proximity score technique by using the fuzzy idea to account for ambiguity in expertise. To explore its performance, the approach is applied to different multi-criteria decision-making issues drawn from the available literature. Jin et al. [14] introduced an innovative group decision-making approach that utilizes an exponential uniformity modification method and a Charnes-Cooper-Rhodes data envelopment analysis simulation for evaluating the long-term viability of small and medium-sized businesses in hesitant fuzzy linguistic circumstances. Valipour et al. [15] propose a dual-phase strategy for identifying and prioritizing safety, health, and environmental hazards in order to allocate the organization's assets to significant risks, rather than non-essential tasks, and overcome the drawbacks of the standard ranking.

1.2. The Motivation for Using Autocratic Strategy in Decision Making

Considering the problem's context and choosing an acceptable DM strategy is essential. Although the final judgment may be determined using various DM strategies, the incorrect application of specific procedures, independent of the issue circumstances, enhances computing complexity and negatively impacts the final results. The main concern, however, is the best way to address the financial and organizational challenges determined by a solitary person or a small group of people. In recent years, the autocratic technique for handling collective DM difficulties has garnered significant attention. Furthermore, this methodology has been used to solve other significant DM problems based on fuzzy sets and their expansions. According to the research conducted in the literature and the results of this analysis, the following are the advantages of the autocratic procedure:

1. Running time reduction in the decision-making procedure. The lack of opposition allows administrators to make decisions more rapidly and comprehensively. This ability might be helpful when immediate decisions are required. Some situations are perilous or very unpleasant and demand a manager in leadership.
2. Efficient Object Setup. When a particular entity or a small group of supportive social people establishes goals, it is straightforward to concentrate and offer suggestions. In this environment, the opportunity for clear structures and strategies is considerable.
3. Realism in an authoritative position. The authoritarian rule defines who is in charge and reduces confusion associated with receiving orders from multiple authorities. This ability allows those in authoritative positions to convey direction and issue orders without facing different perspectives on the same topic.
4. A rational explanation for an individual's conduct.

1.3. The Objectives of This Research

This research presents an autocratic DM method for selecting the best supplier for a construction project using SVNSs. Incorporating multiple score functions in the autocratic algorithm and analyzing their impact on the final result is one of the main aims of this research.

Even though we deal with an extensive class of problems in employing NSs, the suggested solution is less complicated and much more adaptable for real-world applications. Although the research is illustrated by a case study of building material supplier selection, the introduced method can be used to select suppliers in other industries, such as food production, medical equipment production, automobile production, agricultural equipment production, military equipment production, etc. More comprehensively, the introduced method can be used in all units that need a supplier of raw materials to produce a product.

1.4. The Contributions of This Research

Although the final order may be reached through various decision-making techniques, employing particular methods improperly, independent of the circumstances surrounding the challenge, makes computations a more complicated task and, consequently, negatively affects the outcome. However, the fundamental problem currently involves dealing with managerial and commercial problems determined by an individual or a limited number of members. One of the production techniques that has drawn significant notice recently is the autocratic approach to addressing issues with collective decision making. Moreover, using neutrosophic sets, this method has been used to resolve various decision-making issues structured under an indeterminacy environment. In addition, adopting a suitable tool for data ranking in a way that minimizes the complexity of the decision-making process is among the factors that have yet to be investigated. This research offers the following contributions by presenting an autocratic group multi-attribute decision-making method based on single-valued neutrosophic numbers.

(1) Presenting a practical framework for recognizing the best supplier in the construction industry.
(2) Developing an autocratic neutrosophic decision-making method under group recommendation.
(3) Investigating the effect of different score functions on the decision-making procedure.

To have a comparative understanding of the proposed methods, a summary of some studies done in supplier management is presented in Table 1.

Table 1. Some studies have been done on supplier selection management.

Authors (Years)	Group Decision Making	Unidentical DMs	Deal with Uncertainty	Deal with Indeterminacy	Weighted Attributes	Nondeterministic Attributes
Haeri and Rezaei (2019) [16]	√	×	√	×	√	√
Memari et al. (2018) [17]	√	√	√	×	√	×
Yu et al. (2019) [18]	√	√	√	√	√	√
Yazdani et al. (2022) [19]	×	×	√	×	√	×
Pamucar et al. (2022) [20]	×	×	√	×	√	×
Perçin (2022) [21]	√	×	√	×	×	×
Asadabadi et al. (2022) [22]	√	×	√	√	√	√
Alikhani et al. (2019) [23]	×	×	√	×	√	√
Stević et al. (2020) [24]	×	√	√	×	√	×
Tong et al. (2022) [25]	×	×	√	×	√	√
Giri et al. (2022) [26]	×	√	√	√	√	×
Afrasiabi et al. (2022) [27]	√	×	√	×	√	√
Proposed Research	√	√	√	√	√	√

Haeri and Rezaei [16] suggested a complete, grey-based sustainable supplier selection methodology combining financial and ecological factors. They proposed a unique weight attribution approach by merging the best-worst technique with fuzzy grey cognitive maps to represent the interconnections between the parameters. Memari et al. [17] suggested an intuitive fuzzy TOPSIS method for selecting the greenest automobile spare contract manufacturer based on indicators and thirty sub-criteria. Their technique offers a precise rating of reliable vendors and a dependable methodology for creating sustainable procurement choices, proven by a specific circumstance. Implementing an expanded Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) under an interval-valued Pythagorean fuzzy environment, Yu et al. [18] created a unique group decision-making green supplier selection approach. Yazdani et al. [19] suggested a two-phase sustainable multi-tier supplier evaluation approach for food supply chains, focused on an aggregated expert judgment with multi-criteria views, that considers ecological sustainability, vendors, and sub-suppliers. The method computes supplier selection criterion weights during the initial phase by combining stepwise weight assessment ratio analysis (SWARA) and level-based weight assessment (LBWA) with D-numbers. The Characterization of Options and Pricing based on the Workable Compromise (MARCOS)-D approach is used in the second phase to get a scoring sequence of various tier providers. Pamucar et al. [20] created a unique decision-making strategy employing assessing acceptability via a causal analysis method (MACBETH) and a special complimentary distance-based evaluation tool to handle the supplier selection issue during the COVID-19 outbreak. Owing to significant ambiguity and ambiguous and partial evidence for decision-making issues during the COVID-19 episode, the created decision-making technique is applied under fuzzy rough numbers as a preferable ambiguity factor to the conventional fuzzy set and rough numbers. Percin [21] recommended a group decision framework based on an integrated Analytic Hierarchy Process (AHP) and Complex Proportional Assessment (CPA) methods under an Interval-Valued Intuitionistic Fuzzy-Sets (IVIFS) environment for addressing ambiguity that influences the evaluations of decision makers when tackling the linear supplier selection problem. Asadabadi et al. [22] established a unique criterion decision framework to aid in assessing suppliers in businesses, considering future potential occurrences. The structure includes the graded multi-criteria decision-making approach, the best-worst approach, and the strategy for ranking choices by approximation to the optimal answer. Alikhani et al. [23] suggested a MADM method based on quantitative empirical investigations and analytical modeling. They utilized interval type-2 fuzzy sets to quantify decision makers' inputs and presented an extension of the DEA model, including desirable and undesirable inputs and outputs to evaluate suppliers. For a sustainable SS in a polyclinic, Stević et al. [24] recommended ranking possibilities based on an acceptable solution method. The advantages of the proposed approach include the capacity to consider numerous requirements and substitutes without compromising the method's security, the examination of an anti-ideal and an ideal solution at the beginning of creating an initial matrix, and a closer determination of the effectiveness level of both responses. Tong et al. [25] established a structure for small and medium-sized enterprises to evaluate potential suppliers, and they suggested an expanded PROMETHEE II technique to develop a sustainable SS system. To address the supplier selection problem facing sustainable supply chain management, Giri et al. [26] proposed the Pythagorean fuzzy set-based DEMATEL approach. In this context, they explored the Pythagorean fuzzy set for addressing uncertainty in individual choices and managing ambiguous and limited data while choosing supplier criteria. Afrasiabi et al. [27] provide an extensive framework for evaluating suppliers, according to environmentally conscious and resilient parameters, incorporating well-defined and robust fuzzy MCDM approaches.

The remainder of this research is presented as follows. Section 2 outlines the fundamental concepts and properties of NSs. Section 3 describes an autocratic DM process based on SVNSs. Section 4 explains the implementation of the suggested algorithm for selecting the most suitable construction supplier and then examines the sensitivity of the suggested method. The conclusion is provided in the last section of this work, Section 5.

2. Preliminaries

This section briefly describes the essential concepts, including neutrosophic sets theory, which are applied throughout this research.

Definition 1 [28]: *Let O be a set of objectives. A NS A* in *O is defined by three independent components such as truth, indeterminacy, and falsity membership functions that are represented by $\alpha_A : O \to]0^-, 1^+[$, $\beta_A : O \to]0^-, 1^+[$ and $\gamma_A : O \to]0^-, 1^+[$, respectively, where $0^- \le \alpha_A(o) + \beta_A(o) + \gamma_A(o) \le 3^+, \forall o \in O$.*

Definition 2 [29]: *A SVNS A in O can be demonstrated by $A = \{\langle o, \alpha_A(o), \beta_A(o), \gamma_A(o)\rangle; o \in O\}$, where $\alpha_A : O \to]0^-, 1^+[$, $\beta_A : O \to]0^-, 1^+[$, $\gamma_A : O \to]0^-, 1^+[$, and $0 \le \alpha_A(o) + \beta_A(o) + \gamma_A(o) \le 3, \forall o \in O$. $\alpha_A(o)$, $\beta_A(o)$ and $\gamma_A(o)$ represent the degree of truth, falsity, and indeterminacy membership of o to A, respectively.*

Definition 3 [30]: *For a SVNS A, the trinary $(\alpha_A(o), \beta_A(o), \gamma_A(o))$ can be assumed as a Neutrosophic Triplets Number (NTN). For convenience, the triplet $(\alpha_A(o), \beta_A(o), \gamma_A(o))$ is often denoted by (α, β, γ).*

Definition 4 [31]: *The mathematical operators between two NTNs $A = (\alpha, \beta, \gamma)$ and $A' = (\alpha', \beta', \gamma')$ can be defined as follows:*

$$A \oplus A' = (\alpha + \alpha' - \alpha\alpha', \beta\beta', \gamma\gamma'), \tag{1}$$

$$A \otimes A' = (\alpha\alpha', \beta + \beta' - \beta\beta', \gamma + \gamma' - \gamma\gamma'), \tag{2}$$

$$\lambda A = \left(1 - (1-\alpha)^{\lambda}, \beta^{\lambda}, \gamma^{\lambda}\right), \ \lambda > 0, \tag{3}$$

$$A^{\lambda} = \left(\alpha^{\lambda}, 1 - (1-\beta)^{\lambda}, 1 - (1-\gamma)^{\lambda}\right), \ \lambda > 0. \tag{4}$$

Definition 5. *The complement of a SVNS A can be shown by A^c and is defined by $\alpha^c_A(o) = \gamma_A(o)$, $\beta^c_A(o) = 1 - \beta(o)$, $\gamma^c_A(o) = \alpha_A(o)$ for all $o \in O$. Therefore, $A^c = \{\langle o, \gamma_A(o), 1 - \beta_A(o), \alpha_A(o)\rangle; o \in O\}$.*

Definition 6 [32]: *Let $A = (\alpha, \beta, \gamma)$ be a neutrosophic triplet. The score function S for ranking the triplet A is defined by:*

$$S(A) = \frac{1 + \alpha - 2\beta - \gamma}{2}. \tag{5}$$

Definition 7 [33]: *Let $A = (\alpha, \beta, \gamma)$ be a neutrosophic triplet. The improved score function N for ranking the triplet A is defined by:*

$$N(A) = \frac{1 + (\alpha - 2\beta - \gamma)(2 - \alpha - \gamma)}{2}. \tag{6}$$

Definition 8 [34]: *Let$A = (\alpha, \beta, \gamma)$ be a neutrosophic triplet. The optimized score function AZ for ranking the triplet A is defined by:*

$$AZ(A) = \frac{(4 + \alpha - 2\beta - \gamma)(2 - \beta)(2 - \gamma)}{5}. \tag{7}$$

Definition 9 [35]: *For a neutrosophic triplet $A = (\alpha_A(o), \beta_A(o), \gamma_A(o))$, one has*

1. *The triplet A is empty if $\alpha_A(o) = 1, \beta_A(o) = 0$, and $\gamma_A(o) = 0$ for all $o \in O$.*
2. *The triplet A is absolute if $\alpha_A(o) = 0, \beta_A(o) = 1$, and $\gamma_A(o) = 1$ for all $o \in O$.*

Definition 10. *For two neutrosophic triplets $A = (\alpha_A(o), \beta_A(o), \gamma_A(o))$ and $B = (\alpha_B(o), \beta_B(o), \gamma_B(o))$, one has:*

$A = B$ if and only if $A \subseteq B$, and $B \subseteq A$.

3. The Proposed Strategy for Autocratic Decision Making

Owing to the complexity of living systems, managers may encounter a variety of ambiguities while considering an application with insufficient information. The FS theory and several extensions have been available, in recent decades, for dealing with incomplete data. However, real-world systems produce inaccurate and inconsistent data that existing frameworks cannot accommodate. Motivated to cope with such shortcomings, Smarandache [6] proposed the concept of NSs. NSs are effective for dealing with inconsistent, imprecise, and vague values. Evaluation and ranking the numbers, structured and based on such sets, requires a precise tool and mechanism. The score functions often rank the neutrosophic numbers in Multi-Attribute Decision-Making (MADM) procedures.

By analyzing the score functions presented in the literature and highlighting their shortcomings, Nafei et al. [34] introduced an optimized score function. Subsequently, they offered an extension of the TOPSIS approach that is structured based on neutrosophic values. However, the performance of this function in other decision-making methods has yet to be investigated. Understanding the conditions of the problem and choosing a suitable solution method are always considered essential. Using an incorrect strategy to address selection challenges leads to enhanced computing complexity and negatively impacts the ideal answer. Logically, the method of solving a problem based on a public survey differs from the process of solving a problem in which the decision is made by a small group of individuals. In recent years, autocratic leadership as a resolution for joint decision-making problems has garnered a great deal of attention as one of the most successful approaches. One of the essential advantages of this method is its high computational speed in announcing the final result. Using different score functions in the autocratic algorithm and analyzing their effect on the definitive answer is one of our most important goals in this research.

This section presents our strategy based on an autocratic idea in group decision making using single-valued neutrosophic numbers. This is despite the decision makers in the first stage not being prioritized over one another; in other words, they have the same weights. In this regard, suppose that group decision problems consist of $\{a_l | l = 1, 2, \ldots, L\}$ alternatives evaluated based on $\{c_m | m = 1, 2, \ldots, M\}$ attributes. Furthermore, assume that there exist a set of decision makers, such as $\{D_n | n = 1, 2, \ldots, N\}$, that are considered experts in the decision process. Let $w_n = (w_j^n)_{1\times M}$ be a vector of weights given by D_n for existing attributes. Assume that ρ_n is a valuation matrix provided by D_n as follows:

$$\rho_n = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_L \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_M \end{array} \\ \begin{bmatrix} g_{11}^n & g_{12}^n & \cdots & g_{1M}^n \\ g_{21}^n & g_{22}^n & \cdots & g_{2M}^n \\ \vdots & \vdots & \ddots & \vdots \\ g_{L1}^n & g_{L2}^n & \cdots & g_{LM}^n \end{bmatrix} \end{array}. \quad (8)$$

where, $g_{lm} = (\alpha_{lm}, \beta_{lm}, \gamma_{lm})$ is defined as a neutrosophic triplet. In addition, $W_c^{(r)}$ represents the weight of the decision maker D_c at the r$^{\text{th}}$ row, where $W_c^{(r)} \in [0,1]$ and $\sum_{c=1}^{C} W_c = 1$.

The recommended autocratic algorithm for tackling the aforementioned challenge in decision making consists of the following steps:

Step 1. Based on the valuation matrix, the vector of weights given by experts, and also the multiplication operator, create the weighted evaluating matrix as follows:

$$WE_n = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_L \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \cdots & c_M \end{array} \\ \begin{bmatrix} I_{11}^n & I_{12}^n & \cdots & I_{1M}^n \\ I_{21}^n & I_{22}^n & \cdots & I_{2M}^n \\ \vdots & \vdots & \ddots & \vdots \\ I_{L1}^n & I_{L2}^n & \cdots & I_{LM}^n \end{bmatrix} \end{array}. \quad (9)$$

where $I_{lm}^c = g_{lm}^c \otimes w_m^c$.

Step 2. Create the aggregated grading matrix AG of all experts by using the addition operator defined in Equation (1) as follows:

$$AG = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_L \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & \ldots & D_N \end{array} \\ \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1N} \\ T_{21} & T_{22} & \cdots & T_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ T_{L1} & \rho_{L2} & \cdots & T_{LN} \end{bmatrix} \end{array}. \tag{10}$$

where, $T_{\text{ln}} = \gamma^n_{l1} \oplus \gamma^n_{l2} \oplus \cdots \oplus \gamma^n_{lY}$.

Step 3. Generate the aggregated grading score matrix using a desired score function as described in the following:

$$R(AG) = \begin{array}{c} \\ a_1 \\ a_2 \\ \vdots \\ a_L \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & \cdots & D_N \end{array} \\ \begin{bmatrix} R(T_{11}) & R(T_{12}) & \cdots & R(T_{1N}) \\ R(T_{21}) & R(T_{22}) & \cdots & R(T_{2N}) \\ \vdots & \vdots & \ddots & \vdots \\ R(T_{L1}) & R(T_{L2}) & \cdots & R(T_{LN}) \end{bmatrix} \end{array}. \tag{11}$$

Step 4. Classify the alternatives according to the opinion of each decision maker and also the obtained score values as follows:

$$\theta^n = \begin{array}{c} \begin{array}{cccc} a^n_k & a^n_{k-1} & \cdots & a^n_{k-L} \end{array} \\ \begin{bmatrix} v^n_1 & v^n_2 & \ldots & v^n_L \end{bmatrix} \end{array}. \tag{12}$$

Step 5. Obtain the aggregated score value, $\varphi_l = \sum\limits_{n=1}^{N} \left({W_n}^{(r)} \times R(T_{\text{ln}}) \right)$, of all alternatives and establish the group prioritization vector in the following manner:

$$\tau = \begin{array}{c} \begin{array}{cccc} a_1 & a_2 & \cdots & \mathrm{a}_L \end{array} \\ \begin{bmatrix} \varphi_1 & \varphi_2 & \ldots & \varphi_L \end{bmatrix} \end{array}. \tag{13}$$

Step 6. Determine the weighted degree of similarities between the values of θ^n and τ based on the following structure:

$$\begin{cases} S(\theta^n, \tau) = 0, & \varphi_l \neq v^n_l, \\ S(\theta^n, \tau) = S(\theta^n, \tau) - (L - (k-1)), & \varphi_l = v^n_l = k. \end{cases} \tag{14}$$

Step 7. Compute the degree of communal majority consensus $(\Re^{(r)})$ of all DMs at the r $^{\text{th}}$ row as follows:

$$\Re^{(r)} = \sum_{n=1}^{N} \left(\nu_n \times W^{(r)}_n \right). \tag{15}$$

where,

$$\nu_n = \frac{S(\theta^n, \tau)}{S(\theta^1, \tau) + S(\theta^2, \tau) + \ldots + S(\theta^N, \tau)}. \tag{16}$$

By considering a crisp value $H \in [0, 1]$ as a group agreement threshold value, consider the evaluation method so that if $\Re^{(r)} < H$ then go to the next step. Otherwise, the largest φ_l of alternative a_l concerning all decision makers in step 5, has the best preference order of alternative a_l.

Step 8. Update the weight of the experts using the following formula:

$$W^{(r+1)}_n = \frac{{\omega_n}^{r+1}}{\sum\limits_{n=1}^{N} {\omega_n}^{r+1}}. \tag{17}$$

where, $\omega^{r+1} = W_n^{(r)} \times (1 + \nu_n)$. Then, let $(r = r + 1)$, and return to step 5.

4. Numerical Execution Example

A building industry investment firm seeks to choose the most appropriate supplier as its investment objective. In this context, four suppliers were selected as alternatives for further examination. The construction organization arranged a specialized group of experts for this task. The expert panel determined the characteristics to be incorporated into the foundation. Consider that the specialized team is comprised of three professionals. The attributes of this comparison are considered to be "score of qualified products", "delivery speed", and "cost of the product". The evaluation values given by various experts are shown in Tables 2–4.

Table 2. Evaluation values given by Expert 1.

Alternatives \ Criteria	Score of Products	Delivery Speed	Cost of the Product
A1	[0.7, 0.9, 0.9]	[0.7, 0.9, 0.2]	[0.3, 0.4, 0.8]
A2	[0.2, 0.2, 0.1]	[0.3, 0.8, 0.2]	[0.1, 0.7, 0.2]
A3	[0.6, 0.4, 0.5]	[0.2, 0.7, 0.8]	[0.9, 0.7, 0.5]
A4	[0.5, 0.6, 0.1]	[0.1, 1.0, 0.6]	[0.1, 0.0, 0.8]

Table 3. Evaluation values given by Expert 2.

Alternatives \ Criteria	Score of Products	Delivery Speed	Cost of the Product
A1	[0.5, 0.4, 0.9]	[0.4, 0.2, 0.4]	[0.6, 0.6, 0.8]
A2	[0.6, 0.6, 0.4]	[0.2, 0.7, 0.4]	[0.7, 0.3, 0.1]
A3	[0.0, 0.4, 0.7]	[0.8, 0.2, 0.7]	[0.9, 0.2, 0.1]
A4	[0.8, 0.0, 0.4]	[0.7, 0.8, 0.4]	[0.1, 0.1, 0.7]

Table 4. Evaluation values given by Expert 3.

Alternatives \ Criteria	Score of Products	Delivery Speed	Cost of the Product
A1	[0.2, 0.3, 0.7]	[0.1, 0.6, 0.1]	[0.9, 0.2, 1.0]
A2	[0.8, 0.4, 0.3]	[0.4, 0.6, 0.3]	[0.9, 0.9, 0.0]
A3	[0.3, 0.3, 0.6]	[0.1, 0.2, 0.9]	[0.3, 0.9, 0.3]
A4	[0.2, 0.2, 0.1]	[0.5, 0.7, 0.8]	[0.3, 0.7, 0.9]

In addition, the weights given by experts for different criteria are represented in Table 5.

Table 5. Weights of attributes that are given by various experts.

Alternatives \ Criteria	Score of Products	Delivery Speed	Cost of the Product
E1	[0.4, 0.8, 0.7]	[0.9, 0.4, 1.00]	[0.9, 0.2, 0.7]
E2	[0.1, 0.7, 0.5]	[0.4, 0.4, 0.6]	[0.7, 0.2, 0.1]
E3	[0.2, 0.4, 0.8]	[0.2, 0.9, 0.8]	[0.7, 1.0, 0.8]

Based on the provided information, the weighted evaluating matrices are obtained as follows:

$$WE_1 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} [0.28, 0.99, 0.99] & [0.56, 0.94, 0.36] & [0.21, 1.00, 0.94] \\ [0.08, 0.92, 0.91] & [0.24, 0.88, 0.36] & [0.07, 1.00, 0.76] \\ [0.24, 0.94, 0.95] & [0.16, 0.82, 0.84] & [0.63, 1.00, 0.85] \\ [0.20, 0.96, 0.91] & [0.08, 1.00, 0.68] & [0.07, 1.00, 0.94] \end{bmatrix} \end{array},$$

$$WE_2 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} [0.05, 0.64, 0.97] & [0.28, 0.52, 0.52] & [0.30, 0.84, 0.82] \\ [0.06, 0.76, 0.82] & [0.14, 0.82, 0.52] & [0.35, 0.72, 0.19] \\ [0.00, 0.64, 0.91] & [0.56, 0.52, 0.76] & [0.45, 0.68, 0.19] \\ [0.08, 0.40, 0.82] & [0.49, 0.88, 0.52] & [0.05, 0.64, 0.73] \end{bmatrix} \end{array},$$

$$WE_3 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} [0.04, 0.44, 0.91] & [0.04, 0.96, 1.00] & [0.72, 0.84, 1.00] \\ [0.16, 0.52, 0.79] & [0.16, 0.96, 1.00] & [0.72, 0.98, 0.80] \\ [0.06, 0.44, 0.88] & [0.04, 0.92, 1.00] & [0.24, 0.98, 0.86] \\ [0.04, 0.36, 0.73] & [0.20, 0.97, 1.00] & [0.24, 0.94, 0.98] \end{bmatrix} \end{array}.$$

In this regard, the aggregated grading matrix AG is obtained as follows:

$$AG = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{ccc} E_1 & E_2 & E_3 \end{array} \\ \begin{bmatrix} [0.75, 0.93, 0.34] & [0.52, 0.28, 0.41] & [0.74, 0.35, 0.91] \\ [0.35, 0.81, 0.25] & [0.47, 0.45, 0.08] & [0.80, 0.49, 0.63] \\ [0.76, 0.77, 0.68] & [0.76, 0.23, 0.13] & [0.31, 0.40, 0.76] \\ [0.32, 0.96, 0.58] & [0.55, 0.23, 0.31] & [0.42, 0.33, 0.72] \end{bmatrix} \end{array}.$$

The aggregated grading score matrix using the score function AZ proposed in (7) is generated as follows:

$$R(AG) = \begin{array}{c} A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{bmatrix} 0.909 & 1.937 & 1.120 \\ 1.035 & 2.082 & 1.320 \\ 0.827 & 2.767 & 1.102 \\ 0.535 & 2.273 & 1.308 \end{bmatrix}.$$

Based on the obtained score values in the last step, the classification vectors θ^1, θ^2, and θ^3 are generated as follows:

$$\begin{aligned} \theta^1 &= [2 \;\; 1 \;\; 3 \;\; 4], \\ \theta^2 &= [3 \;\; 4 \;\; 2 \;\; 1], \\ \theta^3 &= [2 \;\; 4 \;\; 1 \;\; 3]. \end{aligned}$$

By calculating the aggregated score values φ_l, the group prioritization vector τ is established as follows:

$$\varphi_1 = 1.2387, \; \varphi_2 = 1.3771, \; \varphi_3 = 1.4362, \; \varphi_4 = 1.1338.$$

$$\tau = [3 \;\; 2 \;\; 1 \;\; 4].$$

Therefore, the weighted similarity degrees between θ^n and τ are obtained as follows:

$$\begin{aligned} S\left(\theta^1, \tau\right) &= (4 - (4 - 1)) = 1, \\ S\left(\theta^2, \tau\right) &= (4 - (3 - 1)) = 2, \\ S\left(\theta^3, \tau\right) &= (4 - (1 - 1)) = 4. \end{aligned}$$

In this step, the degree of communal majority consensus $\left(\Re^{(r)}\right)$ can be obtained as follows:

$$\Re^{(1)} = 0.2286.$$

Suppose that the value of the considered threshold is equal to $TH = 0.5$. Since $\Re^{(1)} = 0.2286 < TH$, we need to continue the algorithm and update the weight of experts. Otherwise, the largest φ_l of alternative A_l concerning all decision makers in step 5 has the best preference order of alternative A_l.

In order to update the weight of the experts using (17), one has

$$W_1^{(2)} = 0.208,\ W_2^{(2)} = 0.667,\ W_3^{(2)} = 0.124.$$

Repeating this cycle, the proposed algorithm reached the final solution after six iterations, where

$$\varphi_1 = 1.62142292,\ \varphi_2 = 1.76877092,$$
$$\varphi_3 = 2.15585304,\ \varphi_4 = 1.79118635.$$

Because $\varphi_3 > \varphi_4 > \varphi_2 > \varphi_1$, it can be concluded that the order of priority for the selected suppliers is Supplier 3, Supplier 4, Supplier 2, and Supplier 1.

The order of changing the weights of experts is shown in Figure 1. The preference of (expert) decision makers compared to each other remains unchanged until the fourth step. After that, the algorithm continues by shifting the weight prioritization of the first decision maker with that of the second one. However, the total weight of the decision makers in each iteration is always equal to one, and this was always maintained in all iterations. These conditions are consistent with the results obtained by Cheng in [36].

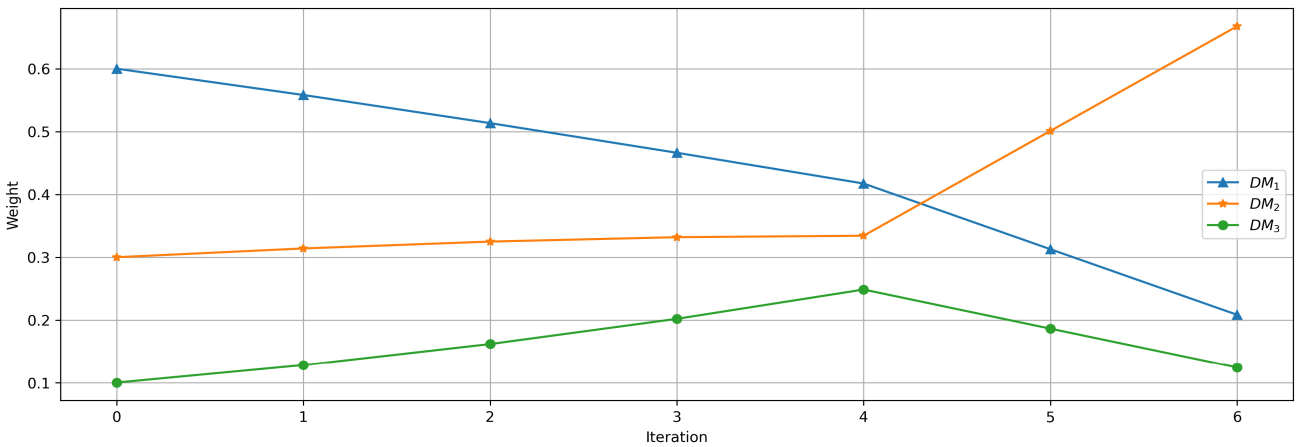

Figure 1. The order of changing the weights of experts in different iterations (the first strategy).

In order to investigate the effect of different thresholds on the weight of decision makers, we ran the algorithm based on a sequence of thresholds. We displayed the results in Figure 2. After TH = 0.5, the weight of the second decision maker increases. In contrast, the importance of the first and third decision makers decreases almost equally until they reach nearly the same weight. The obtained results are consistent with the characteristics of autocratic decision making mentioned by Caillier [37].

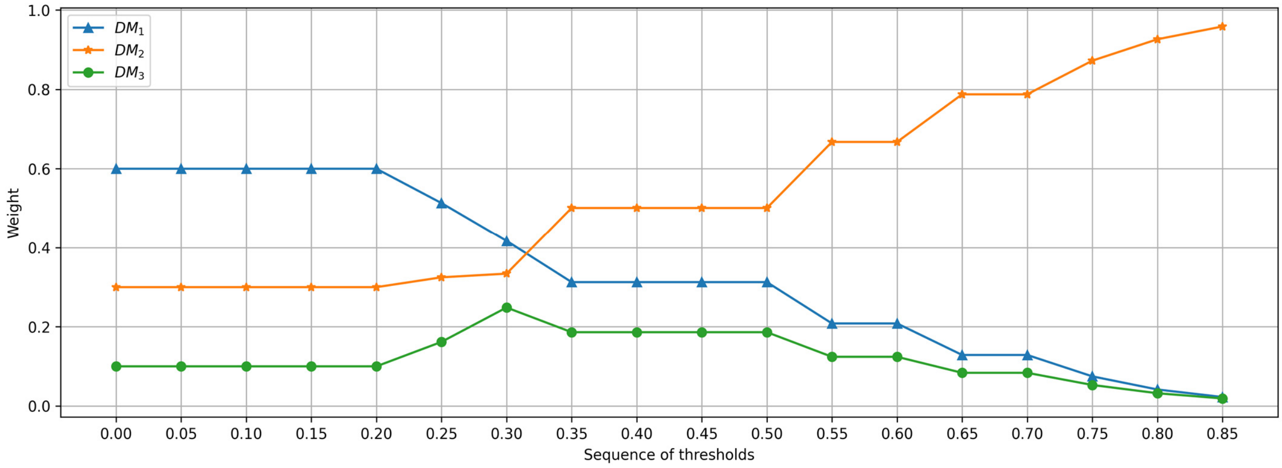

Figure 2. The order of changing the weights of experts based on different thresholds (the first strategy).

To provide further analysis, the process of changing the ranking of alternatives based on different thresholds is demonstrated in Figure 3. The third alternative always has the first rank for all thresholds. The position of the fourth and first alternatives is changed in $TH = 0.275$.

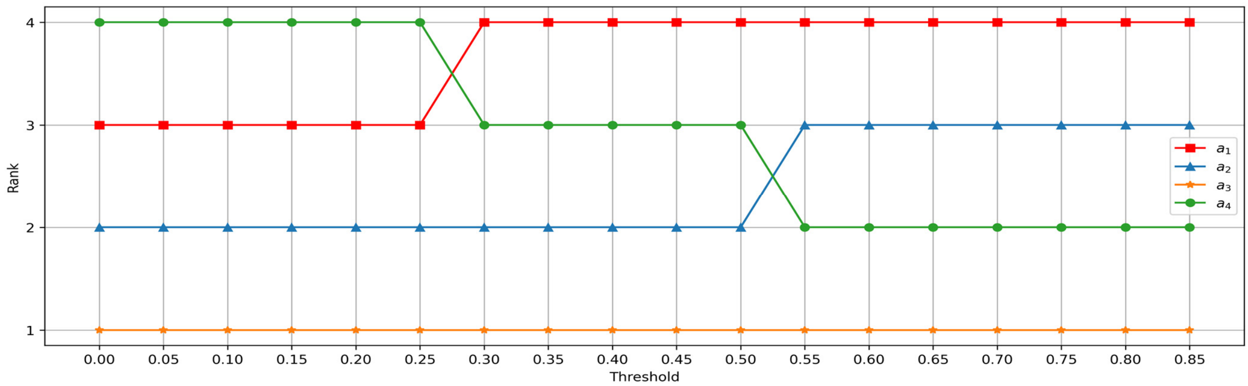

Figure 3. The order of changing the rank of alternatives based on different thresholds (the first strategy).

So far, the results have been based on implementing the autocratic algorithm based on the score function AZ (first strategy). To analyze the impact of other score functions, we reimplemented the autocratic algorithm based on score functions S (second strategy) and N (third strategy). The obtained results are presented in Table 6.

Table 6. The results of implementing the autocratic method.

The Implemented Strategy	Order of Alternatives	Number of Iterations
The autocratic method based on the score function AZ	$a_3 > a_4 > a_2 > a_1$	6
The autocratic method based on the score function S	$a_1 > a_3 > a_2 > a_4$	10
The autocratic method based on the score function N	$a_3 > a_1 > a_2 > a_4$	1

To provide a further review of the autocratic method implemented based on score function S and score function N, the process of changing the weight of experts for different iterations is presented in Figures 4 and 5. Although the demonstrated results are obtained through different score functions, it can be seen that the total weight of the decision makers in each iteration is always equal to one. This condition was always maintained in all iterations that are consistent with the results obtained by Cheng in [36].

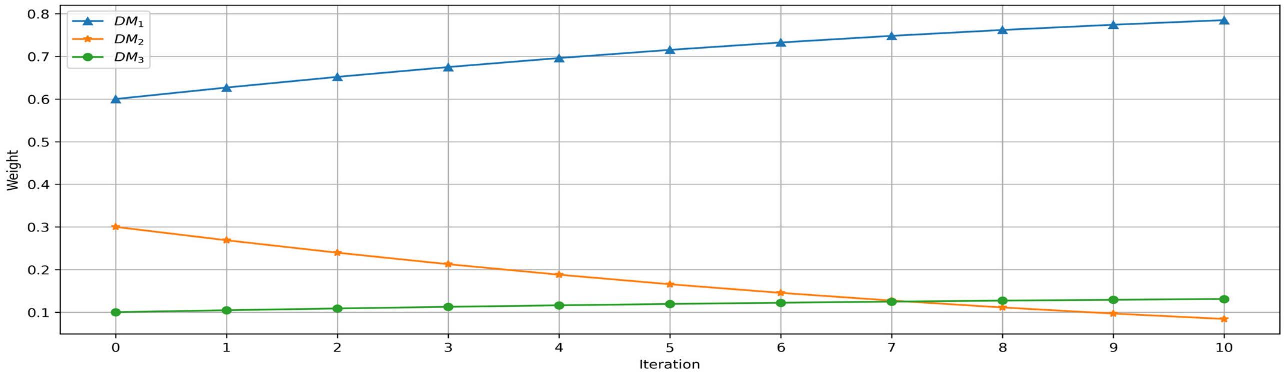

Figure 4. The order of changing the weights of experts in different iterations (the second strategy).

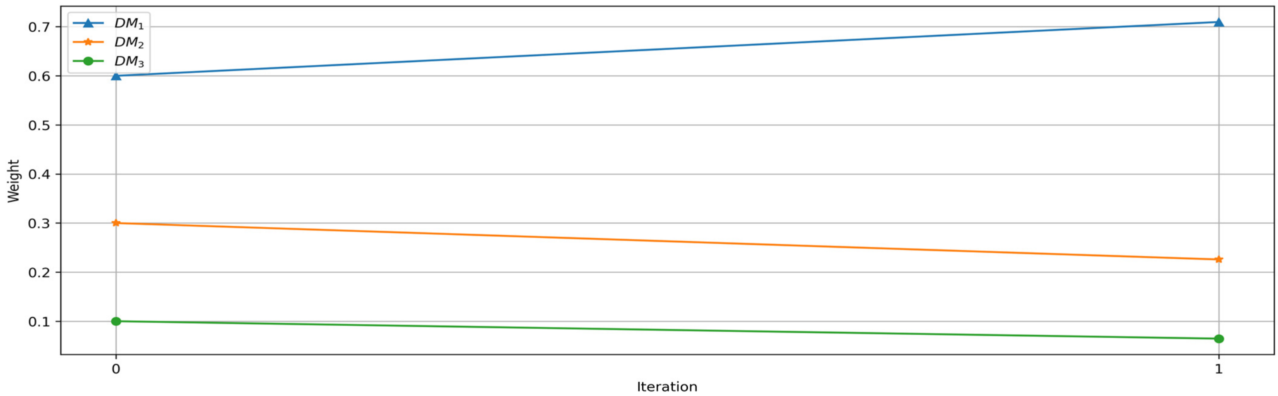

Figure 5. The order of changing the weights of experts in different iterations (the third strategy).

Furthermore, the process of changing the ranking of different alternatives based on different thresholds in both strategies is illustrated in Figures 6 and 7.

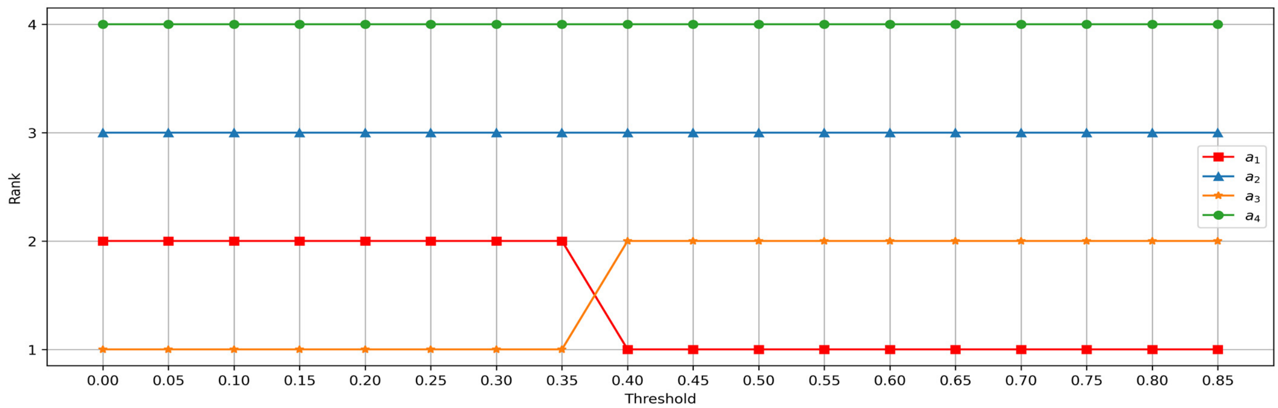

Figure 6. The order of changing the rank of alternatives based on different thresholds (the second strategy).

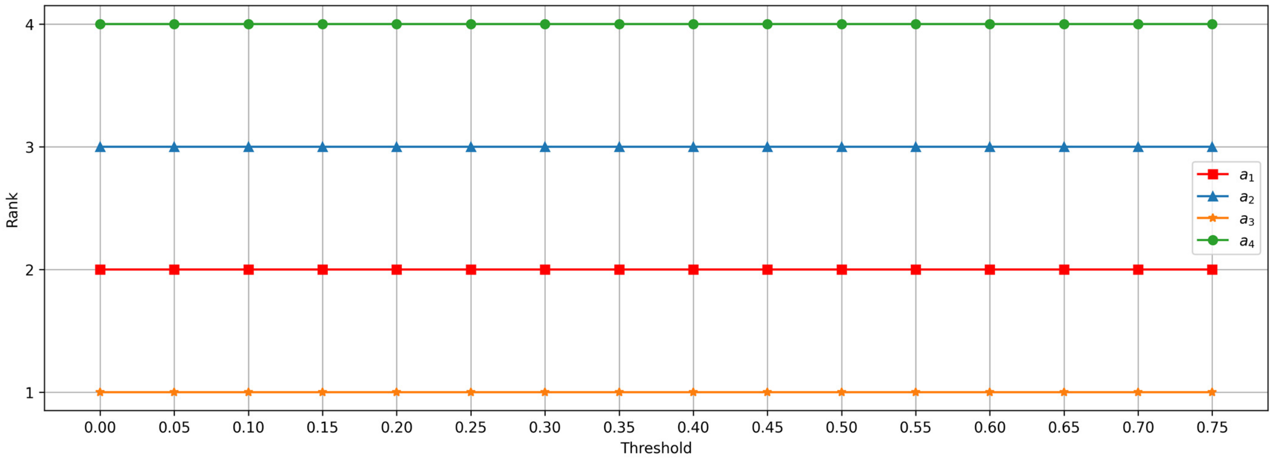

Figure 7. The order of changing the rank of alternatives based on different thresholds (the third strategy).

Although the ranking of the first and the third alternatives has been changed in $-TH = 0.375$ in the method implemented based on score function S, the priority of the alternatives in the process implemented based on score function N remains unchanged for all thresholds. This result indicates the stability of this strategy compared to other techniques.

The analyses carried out in this research show that the preferences of the decision maker can directly affect the final result. This preference can exist from the beginning or be created in the decision-making process. So that, as a given amount is added to the importance of one decision maker, the same amount is reduced from the preference of other decision makers. Adopting a suitable threshold and score function are other factors that must be considered. Despite shortcomings in score function N in the ranking of neutrosophic triplets in certain cases discussed by Nafei et al. in [29], the results obtained in this research indicate that the use of score function N reduces the computational complexity. So, the introduced algorithm using score function N reaches the final order after only one iteration.

Meanwhile, the introduced algorithm based on the score function AZ needs six repetitions to reach the final result. This point indicates that the character of the data plays an essential role in the autocratic algorithm. In such a way, we can use score functions in an alternative form. So, if a simple score function can classify the data, then an algorithm can be implemented based on the same simple score function. Therefore, we can avoid complexity in the implementation of an algorithm. In this respect, the more complex score function can be used when the data cannot be classified with the more straightforward score function.

5. Conclusions

This study proposes a neutrosophic autocratic MAGDM approach for addressing construction material SS challenges. Neutrosophic triplets are employed to indicate the evaluation values of alternatives over characteristics. Designers can cope with inconsistent, imprecise, and vague values using neutrosophic triplets. Considering the superiority of the autocratic method in selection using only a few decision makers, this strategy excels at managing commercial and administrative concerns when there are a small number of specialist decision makers. The suggested method recalculates the decision-maker weights until their group consensus degree is higher than or equal to a predetermined threshold value.

Incorporating a variety of score functions into the autocratic procedure and evaluating their impact on the final result constitutes one of the essential objectives of this research. In order to investigate the effects of different score functions on the decision-making process, the autocratic algorithm is reimplemented based on three score functions AZ, S, and N.

The proposed algorithm achieved the final order by using all three functions separately. According to the proven preferences of score function AZ, against other existing score functions, the autocratic algorithm implemented based on this function was also expected to show better performance. However, the obtained results indicated that this score function increases the complexity of the algorithm process. Using a more straightforward score function, such as N, despite having some shortcomings, reduced the algorithm's computational complexity. The collected findings demonstrate that input data features significantly impact decision making. In this regard, it is crucial to use a practical score function if it is impossible to distinguish two pairs of numbers from one another due to factors such as chance or the proximity of the numbers. Selecting an ideal score function increases computational complexity, but the primary objective of the decision-making process is to get an optimal conclusion. In circumstances where a simple score function may readily separate the data, due to the features of the data, this is the case. These findings need the introduction of an intelligent scoring mechanism based on artificial intelligence, which might be considered for future research. So, in the first stage, the data can be analyzed. Then the best score function can be chosen based on the properties of these data so that the decision algorithm adopts the minor computing complexity by offering the best ranking.

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