Journal of Advanced Research in Applied Sciences and Engineering Technology 41, Issue 2 (2024) 139-151

SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage: https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Single-Valued Neutrosophic Sets Based Score Function and WASPAS Method for Plant Location Selection Problem

Abeer Eisa[1,*], M. Fattouh[1], A. A. ElShabshery[2]

[1] Production Engineering and Mechanical Design Department, Faculty of Engineering, Menoufia University, Shebin El Kom, Egypt
[2] High Institute for Engineering and Technology, Elmahalla Alkobra, Egypt

ARTICLE INFO

Article history:
Received 4 October 2023
Received in revised form 13 December 2023
Accepted 22 January 2024
Available online 20 March 2024

Keywords:
Neutrophication; SVNS sets; MCDM problems; VIKOR; MOORA; WASPAS; Entropy weight method; Plant location selection problem

ABSTRACT

In the context of single-valued neutrosophic sets (SVNSs), where the weights of the criteria are unknown, this work seeks to provide an integrated technique based on Entropy and Weighted Aggregate Sum Product Assessment (WASPAS) methodologies. A numerical case study (the plant site selection issue) is used to establish precise values for the criteria. We initially "fuzzify" the decision matrix before transforming it into an SVNS- decision matrix. The SVNS entropy weight technique is used to assign weights to each criterion. The scoring function is used by a tweaked version of the WASPAS algorithm to choose the optimal solution. The subject under study has also been applied to other MCDM methods, such as the more prevalent VIKOR and MOORA procedures. The SVNS-VIKOR technique has also been applied to the issue at hand. Using the same illustrative scenario, this study evaluates the strengths and weaknesses of several methods for verifying the accuracy of previously published data. The usefulness and efficiency of the used strategy are highlighted by the comparison study. When applied to real-world situations, the suggested method shines because it yields reliable findings even though the underlying data is plagued with issues such as uncertainty, imprecision, indeterminacy, and inconsistency.

1. Introduction

Location considerations have become more important in service and industrial industries as a result of long-term planning. If the incorrect site had been picked, the company may have been severely harmed by factors like political and social unrest, an unprepared workforce, a lack of raw materials, a clumsy transportation system, higher operating costs, and so on. Choosing a site for a facility that can adapt to changing needs without sacrificing performance is challenging for decision-makers. The decision-maker is tasked with finding a site for a facility that can adapt to new requirements without compromising performance. Numerous methods have been explored in the past to aid in the facility site selection process. Six potential facility sites and five evaluation criteria were taken into account by Bhattacharya *et al.,* [1]. To help with difficult plant site selection

* *Corresponding author.*
E-mail address: abeer.essa@sh-eng.menofia.edu.eg

https://doi.org/10.37934/araset.41.2.139151

decisions, Bhattacharya *et al.,* [2] devised a comprehensive approach using the MCDM technique. The case study developed by Bhattacharya *et al.,* [1] is used by Rao [3] to demonstrate the usefulness and efficacy of SAW, WPM, AHP, GTMA, TOPSIS, and modified TOPSIS as MCDM tools. Supportive nodes in military logistics networks may be identified with the use of a TOPSIS technique provided by Farahani and Asgari [4]. To solve site selection issues that include both material and immaterial considerations, Tabari *et al.,* [5] suggested a hybrid MCDM approach. It was clear that the suggested method is practical and effective by examining a numerical example and the sensitivity analysis for facility site selection problems. To discover the optimal site, Amiri *et al.,* [6] coupled TOPSIS with algorithms based on fuzzy goal programming. The authors Arora and Arora [7] developed two methods for dealing with multi-objective capacitated plant placement issues. In a recent study, Farahani *et al.,* [8] examined the state of the art in solving multi-criteria locating problems. To prove the value and efficacy of MCDM, Athawale *et al.,* [9] used the PROMETHEE II (Preference Ranking Organization technique for Enrichment Evaluation) approach based on a case study by Bhattacharya *et al.,* [1]. The majority of the aforementioned research examined and chose plant areas when the weather was cool. The most well-liked MCDM methods, however, have the inherent limitation of requiring precise measurement of the performance values and criterion weights. Inaccurate or unpredictable language evaluation might be a fatal flaw in traditional MCDM methods to plant placement problems. Evaluation data on plant site appropriateness for various subjective aspects and the respective weights of the criteria are often given verbally in the actual world. The fuzzy set theory (FST) has been used in the development of ill-defined multiple-criteria decision-making challenges to better account for the ambiguity inherent in human judgment and preference. Recently, FST has been applied to the issue of facility location choice.

Four fuzzy multi-attribute group decision-making processes for assessing facility sites were presented by Kahraman *et al.,* [10]. To evaluate facility site selections using objective/subjective criteria in group decision-making situations, Chou *et al.,* [11] used fuzzy set theory, a factor rating system, and simple additive weighting (SAW) to develop a fuzzy simple additive weighting system. After determining the relative importance of each criterion using the analytic hierarchy process (AHP), Nüt and Soner [12] used a fuzzy TOPSIS method-based approach to settle the solid waste transshipment site selection issue. Despite its popularity, fuzzy set theory is not a foolproof method of accommodating the fuzziness and inaccuracy of human judgment. We've found a poorly articulated issue in facility site selection, and we've used intuitionistic fuzzy set (IFs) theory to solve it. Using the TOPSIS technique, Fatih Emre Boran [13] suggested a novel approach to fuzzy multi-criteria decision-making. S.S. Alkafaas [14] used three distinct IF approaches (IF-TOPSIS, IF-GRA, and IF-VIKOR) to analyse the case study by Bhattacharya *et al.,* [1] and determine the optimal site for the plant. Although IFSs excel in processing partial data, they are useless when confronted with the ambiguous and contradictory decision information found in the real world. If pressed for an opinion, a professional could say that they are 50% certain that a given statement is true, 70% confident that it is false, and 20% confident that they do not know. We need to come up with some new strategies since traditional FSs and IFSs won't work in this case. Smarandache [15] first proposed the concept of a Nutrosophic (NS) set, an abstraction of the FSs and IFSs, to deal with these problems. Truth-membership, indeterminacy-membership, and falsity-membership functions in the interval] are all valid representations of NS.−0, 1+ [. Fuzzy sets (FS, IFS, Pythagorean fuzzy set, interval-valued IFS) may be better able to express ambiguous, imprecise, incomplete, or inconsistent information than other methods. Wang *et al.,* [16] expanded on the ground-breaking work of Smarandache [15] and showed that NSs posed difficulties when applied to scientific and technical contexts. Because of this, the concept of SVNS was born. SVNSs, a subclass of NS, are defined by truth-membership, indeterminacy-membership, and falsity-membership functions and are thus applicable in situations involving conflicting or uncertain data. In 2016, Zhang *et al.,* [17], Abdel-Basset *et al.,* [18], Rani *et al.,* [19], Topal *et al.,* [20], and Mishra *et al.,* [21] all published similar findings. Additional resources may be found in Chaw *et al.,* To demonstrate the value of the SVN relations-based decision-making model, Chaw *et al.,* [22] suggested the most important determinant in oil prices. Zavadskas *et al.,* [23] created a Single-Valued Neutrosophic Set (WASPAS-SVNS). The primary goal of this plan was to find a suitable location for the landfill's incineration plant. Mishra *et al.,* [21] developed the comprehensive ARAS (Additive Ratio Assessment) technique to assess and rank potential sites for electric car charging infrastructure. In order to deal with the challenges of selecting a reliable third-party reverse logistic provider in an SVNS scenario, Mishra and Rani [24] developed a hybrid technique that combines the criteria significance by entering the criterion correlation (CRITIC) approach and the (CoCoSo) method. Literature reviews show that SVNSs are effective methods of dealing with uncertainty. It's well knowledge that people have difficulty making judgments because of incomplete or contradictory data. Therefore, investigation into the MCDM method for SVNSs is essential, just as it is for FSs and IFSs. MADM techniques that make use of SVNS have come a long way in recent years. The ambiguity of subjective judgments is easily represented by SVNSs, making them a useful tool for obtaining imprecise, confused, and inconsistent data, which is necessary for multi-criteria decision analysis.

The goals of this study are to:

i. explain SVNS, Entropy, and WASPAS
ii. provide illustrations of how such decision-making systems may be put into practice.

A numerical example is used to demonstrate the efficacy of the suggested strategy. Finally, by comparing the findings of the proposed technique with those of other approaches, this study validates the accuracy based on the same illustrative situation offered here. The results are outlined, along with suggestions for where the field may go from here.

The most important findings of this research are as follows: a method for accommodating the fuzziness and unpredictability of selection issues. Here are the three main points: Three techniques are used to determine the best options:

i. utilizing SVNS numbers to represent performance ratings of alternatives
ii. using the SVNS - Entropy weight approach to generate criterion weights in addressing selection problems
iii. using the SVNS - WASPAS technique. The practicality and efficiency of the suggested technique are further shown by applying it to a single real-world instance of plant location selection. This work's following portions are structured as follows. Part Two of this tutorial provides an introduction to SVN. In Section 3, we examine only one situation in which SVNSs might be advantageous. The comparison is provided in Section 4. In this last part, we present a quick overview of the article's key ideas and provide some perspectives on where it may go from here.

2. Basic Preliminaries Related to SVNSs

This part sets the stage for the rest of the research by discussing foundational ideas in SVNS theory and highlighting some recent advances in SVNS-based decision-making. The SVNS set model is a subset of the more general NS set model in which the intervals [0, 1] are used for the ranges of the three membership functions rather than the more unusual [-0, 1+]. There are several articles about making choices using the SVNS model since it is one of the most often used variants of the NS model. Many elementary concepts and set-theoretic procedures are defined once the SVNS is explicitly defined. Let's call the topic area U and the collection of things being discussed x.

Definition 1. A set A is SVNS if and only if it is of type A = x, (x), (x), (x): x U, where the functions T, I, F U. The membership functions 0, 1+ [represent the truth, indeterminacy, and falsehood of the element x U concerning A. Each membership function must be true if and only if 0 + x + x = 3+.

Definition 2. If for any x U, TA (x) TB (x), (x) IB (x), and (x) FB (x), then SVNS set A is included in SVNS set B. The symbol for this partnership is A B.

Definition 3. An SVNS A is an NS set whose properties include a truth-membership function TA(x), an indeterminacy-membership function IA(x), and a falsity-membership function FA(x), all of which lie outside the interval [0, 1]. Therefore, we can express this set A as

$A = \{\langle x, TA\ (x), IA\ (x), FA\ (x)\rangle : x \in U\}$.

The sum of $TA\ (x)$, (x), and (x) must fulfil the condition $0 \leq TA\ (x) + (x) + FA\ (x) \leq 3$. For an SVNS A in U, the triplet $((x), (x), (x))$ is called an SVN number.

2.1 Convert Crisp Data into SVNS Numbers (Neutrophication)

Starting points for MCDM problems are the criteria ratings and weights applied to the alternatives. Using a decision matrix, one may illustrate how an expert weighs the ith alternative in light of the jth criterion. As a result, the decision matrix may be set up as follows:

$$X = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix}$$

The reliability of findings is questioned when data is gathered from questionable sources. The following part delves into the theoretical underpinnings of the Neutrosophication technique used in this study to convert crisp data into SVNSa values. In [25], A. Elshabshery, and M. Fattouh, outline the procedures involved in Neutrosophication

Step 1: Data that is high in quality The vector normalization technique (fuzzy decision matrix) converts xij to fuzzy integers, denoted as NXij.:

$$NXij = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} (x_{ij})^2}} \quad (1)$$

Step2: Neutrosophication entails converting the crisp version of the fuzzy decision matrix (NXij) into the SVNS decision matrix, which incorporates truthiness T, indeterminacy I, and falsity F values. The neutrosophication option matrix must be calculated. Here, we may make use of the relationships between the criterion's normalized values (as measured by NXij) and the SVNS index. The correlation between NXij and SVNS values is seen in Table 1.

Table 1
Neutrosophic Conversion Terms to Rate the Importance of the Alternatives

Fuzzy Number from Eq. (1)	SVNS Numbers
1.0	(1.00, 0.00, 0.00)
0.9	(0.90, 0.10, 0.10)
0.8	(0.80, 0.15, 0.20)
0.7	(0.70, 0.25, 0.30)
0.6	(0.60, 0.35, 0.40)
0.5	(0.50, 0.50, 0.50)
0.4	(0.40, 0.65, 0.60)
0.3	(0.30, 0.75, 0.70)
0.2	(0.20, 0.85, 0.80)
0.1	(0.10, 0.90, 0.90)
0.0	(0.00, 1.00, 1.00)

Step 3: Normalize the SVNS decision matrix.

When normalizing the SVNS decision matrix, one must first use the complement set to transform the cost characteristics into benefit attributes.

In neutrosophic set theory, the complement is indicated by S^c and is defined by:

$$S^c = (F_{ij}, 1 - I_{ij}, T_{ij}) \quad (2)$$

To compare any two SVNNs, Peng and Dai (2018) [26] presented a score function for an SVNN

$$S = \frac{2 + \mathrm{Ta} - \mathrm{Ia} - \mathrm{Fa}}{3} \quad (3)$$

2.2.1 SVNS-entropy weights-based technique

Information about criteria weights is typically imprecise since real-world decision-making circumstances are complex and ambiguous. Therefore, giving pertinent traits their due importance is crucial for making a good decision. Several methods, such as the entropy approach, the maximizing deviation method, and the optimization method, are outlined by A.A. Elshabshery [27] for obtaining the unknown criteria weights in MCDM A.A. Elshabshery circumstances while working in an SVNS context. In this work, we unveil the SVNS entropy method.

2.2.1.1 SVNS -entropy weights-based technique

The core steps of this technique are shortened as follows: A.A. Elshabshery [27]

Step 1: Calculation of the Entropy Values:

Grounded on the decision matrix, the value of the entropy for each criterion is considered using Eq. (4).

$$E_j = 1\text{-}1/n \sum_{i=1}^{m} (T_{ij}(X_i) + F_{ij}(X_i))\ |2(I_{ij}(X_i)) - 1| \quad (4)$$

Where E_j is the calculated entropy value for criterion j,

Step 2: Calculation of the degree of divergence:

Using Eq. (5), we can define the degree of deviation dj of the average intrinsic information provided by the associated performance ratings on criteria Cj as:

$$d_j = (1 - E_j) \tag{5}$$

Step 3: Calculation of the criteria weights:
The criteria weights are then considered depending on the values of the entropy by Eq. (6).

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \tag{6}$$

3 . An Integrated SVNS-Entropy - WASPAS Method

WASPAS is a recently developed approach for dealing with optimization issues that include multiple solutions. Zavadskas *et al.,* [28] combined elements of the weighted product model (WPM) and the weighted sum model (WSM). An SVNS-Entropy-WASPAS approach is settled to solve the MCDM issue. The new approach maintains the integrity of the WASPAS technique while extending its usefulness by using the SVNS set model. This is a summary of the SVNS-WASPAS procedure:

i. Convert crisp data into SVNS Numbers (Neutrophication) by Eq. (1) and Table 1.
ii. Normalize the SVNS decision matrix by Eq. (2).
iii. Define the weights of criteria by entropy weights-based technique Eq. (4) to Eq. (6).
iv. Calculate the score function of each SVNS number in the normalized SVNS decision matrix by Eq. (3).
v. Switch the score function matrix into a normalized matrix as follows

Maximization: $$\overline{x}_{ij} = \frac{x_{ij}}{max_i x_{ij}} \tag{7}$$

Minimization: $$\overline{x}_{ij} = \frac{min_i x_{ij}}{x_{ij}} \tag{8}$$

vi. Determine the total relative importance of the ith alternative based on the weighted sum model (WSM) by Eq. (9) where wj is the weight for the jth parameter.

$$Q_i^{(1)} = \sum_{j=1}^{n} \overline{x}_{ij} w_j \tag{9}$$

vii. Calculate the total relative weight of the ith alternative according to the WPM method, by Eq. (10)

$$Q_i^{(2)} = \prod_{j=1}^{n} \overline{x}_{ij}^{wj} \tag{10}$$

viii. Calculate the generalized conjoint aggregation criterion weighted by additive and multiplicative methods by Eq. (11)

$$Q_i = 0.5Q_i^{(1)} + 0.5Q_i^{(2)} = 0.5\sum_{j=1}^{n} \overline{x}_{ij} w_j + \prod_{j=1}^{n} \overline{x}_{ij}^{wj} \tag{11}$$

ix. Rank alternatives by assessment value

4 . Case Study Illustration

As a proof of concept for the method presented here, the authors utilize data from Bhattacharya's [1] plant placement selection issue dataset. Bhattacharya looked at the difficulty of selecting a place for a facility (plant location) by considering six options (locations) and five criteria. It's important to factor in the price of land first (C1), then the price of energy, then the price of raw materials, then the price of transportation, and lastly the price of labour (C5). They all conspire against you if you're looking for the cheapest choice. Our multi-criteria decision-making (MCDM) dilemma is shown in Table 2.

Table 2
Quantitative Information of Bhattacharya on Facility Location Selection Problem

Locations	C1	C2	C3	C4	C5
L1	3300000	2.5	142	6	214
L2	2500000	3.1	179	5.8	175
L3	5200000	3.6	138	7.8	325
L4	2500000	2.8	195	8.4	252
L5	2000000	3.2	167	6.3	155
L6	5700000	3.7	142	6	214

4.1 Solving the Case Study (Ranking Order of the Alternatives) using SVNS - WASPAS Approach

High-volume computing necessitates just showing the results, and all calculations are done in Microsoft Excel. The discrete decision matrices in Table 2 may be converted to SVNS values using the vector normalizing method described in Eq. (1). The obtained normalized decision matrix is converted to SVNS values using the mappings between normalized values and SVNS numbers provided in Table 1. Changing the cost criteria to benefit criteria using Eq. (2) may normalize the SVNS decision matrix if all criteria are of the cost type. You may see the revised SVNS decision matrix in Table 3.

Table 3
Normalized SVNS Decision Matrix

Locations	C^1	C_2	C_3	C_4	C_5
*L*1	(0.6460,0.3040,0.3540)	(0.3212,0.7288,0.6788)	(0.3580,0.6920,0.6420)	(0.6393,0.3107,0.3607)	(0.6189,0.3311,0.3811)
*L*2	(0.7318,0.2182,0.2682)	(0.3983,0.6517,0.6017)	(0.4513,0.5487,0.5487)	(0.6513,0.2987,0.3487)	(0.6884,0.2616,0.3116)
*L*3	(0.4422,0.6078,0.5578)	(0.4625,0.5375,0.5375)	(0.3479,0.7021,0.6521)	(0.5311,0.4689,0.4689)	(0.4213,0.6287,0.5787)
*L*4	(0.7318,0.2182,0.2682)	(0.3597,0.6903,0.6403)	(0.4916,0.5084,0.5084)	(0.4950,0.5050,0.5050)	(0.5513,0.3987,0.4487)
*L*5	(0.7855,0.1645,0.2145)	(0.4111,0.6389,0.5889)	(0.4210,0.6290,0.5790)	(0.6213,0.3287,0.3787)	(0.7240,0.2260,0.2760)
*L*6	(0.3886,0.6614,0.6114)	(0.4753,0.5247,0.5247)	(0.3580,0.6920,0.6420)	(0.6393,0.3107,0.3607)	(0.6189,0.3311,0.3811)

Using Eq. (4) to Eq. (6), we can determine the SVNS entropy value of each criterion for the normalized SVNS decision matrix. (W1= 0.2857, W2= 0.1616, W3= 0.1617, W4= 0.1649, and W5= 0.2262) is the criterion weight vector. Eq. (3) may be used to get the score function of each SVNS number in the normalized SVNS decision matrix. Table 4 displays the results of converting the standard scoring function matrix into a normalized matrix using Eq. (7).

Table 4
Standard Score Function Matrix

Location	C1	C2	C3	C4	C5
L1	0.8262	0.6406	0.6943	0.9820	0.8582
L2	0.9331	0.8028	0.9179	1.0000	0.9519
L3	0.5306	0.9730	0.6738	0.7951	0.5463
L4	0.9331	0.7217	1.0000	0.7411	0.7668
L5	1.0000	0.8298	0.8225	0.9550	1.0000
L6	0.4637	1.0000	0.6943	0.9820	0.8582

The results of the SVNS - WASPAS approach, demonstrating the usage of Eq. (8) to Eq. (10), are shown in Table 5.

Table 5
Numerical Results of SVNS - WASPAS Approach

Location	Q1	Q2	Qi	RANK
L1	0.8079	0.8000	0.8039	4
L2	0.9250	0.9229	0.9239	2
L3	0.6724	0.6545	0.6635	6
L4	0.8406	0.8336	0.8371	3
L5	0.9365	0.9330	0.9347	1
L6	0.7624	0.7289	0.7457	5

Rank six alternatives by the decreasing values of assessment value as follows: L5>L2>L4>L1>L6>L3. Consequently, it can be concluded that L5 is the optimal alternative for the selection.

Different MCDM strategies, including the traditional (crisp) VIKOR and MOORA techniques combined with the Shanon entropy method for weight assignment, have been used in the studied situation to draw comparisons. Using the SVNS-VIKOR technique, the issue under consideration has also been resolved. Only the final numbers are shown because of the extensive computations required.

4.2 Ranking the Facility Location Selection Problem using the Crisp VIKOR and MOORA Methods

The procedure for using the VIKOR and MOORA methods for ranking alternatives is described in M. Fattouh and Abeer Eisa [29] and applied in this work. The weights of the considered criteria are determined using the Shanon Entropy Method as C_1= 0.5349, C_2= 0.0619, C_3 =0.0542, C_4 =0.0887, and C_5=.0.2602. The Values of group utility Si, the individual regret Value R_i , compromise value $\mathrm{Q_i}$ and the rank for each alternative is calculated (VIKOR method). The composite score with the resulting rank for each alternative is calculated MOORA method). The results are shown in Tables 6 and 7).

Table 6
Values of Si, Ri, and Qi for all Alternatives (VIKOR) Method

Locations	Si	Ri	Qi	RANK
L1	0.2974	0.1880	0.2895	3
L2	0.1820	0.0723	0.0979	2
L3	0.8500	0.4627	0.9275	6
L4	0.3792	0.1485	0.3036	4
L5	0.0882	0.0361	0.0000	1
L6	0.6454	0.5349	0.8658	5

Table 7
Composite Score with Their Resulting Rank (MOORA method)

Locations	BC	NBC	Zi	RANK
L1	0.000	0.3627	-.3627	4
L2	0.000	0.3067	-.3067	2
L3	0.000	0.5428	-.5428	6
L4	0.000	0.3573	-.3573	3
L5	0.000	0.2704	-.2704	1
L6	0.000	0.4866	-.4866	5

4.3 Ranking of the Alternatives Based on SVNS –VIKOR

In this study, we implement the SVNS-VIKOR approach for assessing alternatives by the guidelines laid forth by A.A. Elshabshery [27].

The SVNS-VIKOR method determines the three most important values for each option (the group utility value Si, the individual regret value Ri, and the compromise value Qi). Table 8 shows that Si, Ri, and Qi for choice Ai may be determined using the Hamming distance, Xj+, Xj-, the weight vector of the evaluation criteria, and the NSVNS decision matrix.

Table 8
Values of Si, Ri, and Qi for all Alternatives (SVNS-VIKOR Method)

Locations	Si	Ri	Qi	RANK
L1	0.4879	0.1616	0.4388	4
L2	0.1889	0.0887	0.0018	1
L3	0.7807	0.2501	0.9099	6
L4	0.4419	0.1649	0.4083	3
L5	0.1932	0.0880	0.0036	2
L6	0.5194	0.2857	0.7792	5

It is clear from Table 8 that L2 is better than L5, L4, L1, and L6. In this situation, L3 (with the lowest Qi value) is preferable to L6 (with the highest Qi value). The Table 8 Qi ranking result has been verified twice to ensure its accuracy. Qi, L2= L5 >L4 >L1 > L6 > L3 since both L2 and L5 are just partial solutions. Table 9 displays the research designs used in these investigations.

5 . Comparative Analysis

Several articles examine the similarities and differences between the different MCDM methods. The question, "Which is the best approach for a given problem?" is vital. Whether or if there is variation in results across MCDM methods is a related and very serious topic. One of the primary objectives of this work was to compare and contrast the results found from the MCDM methods used in this work with the published results based on the similar illustrative example presented in this paper, to validate the accuracy and then highlight the advantages of some methods over others. Previous research by Rao [3] and Athawale *et al.,* [9] employing a wide range of clear decision-making procedures (WPM, GTMA, SAW, AHP, TOPSIS, MTOPSIS, and PROMETHE II) has already addressed the same facility site selection problem investigated here. Using the AHP method, they determined that C1 = 0.3439, C2 = 0.0544, C3 = 0.3439, C4 = 0.1289, and C5 = 0.1289 were the most important factors to take into account. S.S. Alkafaas [14] employed three different intuitionistic fuzzy techniques (IF-TOPSIS, IF-GRA, and IF-VIKOR) to solve an identical case study. C1=.4174, C2=.0748, C3=.0.1204, C4=.0.1410, and C5=0.2464 are the derived relative weights for the five criteria, determined using the intuitionistic fuzzy entropy weight technique. The ranks from this research and those from the academic literature are listed in Table 9.

Table 9
Comparative Review of the Obtained Results and Past Researchers

	Method	Locations	Best	Worst
Rao [3]	WPM	L5> L2> L1> L4> L6> L3	L5	L3
	GTMA	L5> L2 >L1> L4> L6> L3	L5	L3
	SAW	L5> L2> L1> L4> L6> L3	L5	L3
	AHP	L5> L2 >L1> L4> L6 >L3	L5	L3
	TOPSIS	L5 >L2 >L1 > L4> L3> L6	L5	L6
	M.TOPSIS	L5> L2> L1> L4> L6> L3	L5	L3
Athawale *et al.,* [9]	PROMETHE II	L5 >L2 >L1> L3> L4> L6	L5	L6
S.S Alkafaas [14]	IF TOPSIS	L5> L2 >L4> L1 L6 L3	L5	L3
	IF VIKOR	L5 > L2 >L1> L4 >L6 >L3	L5	L3
	IF GRA	L5 >L2 >L1 >L4> L6 >L3	L5	L3
Present Work	Crisp- VIKOR	L5> L2> L1> L4 >L3 >L6	L5	L6
	Crisp-MOORA	L5> L2 >L4> L1 >L6> L3	L5	L3
	SVNS-VIKOR	L2 >L5> L4> L1> L6> L3	L2	L3
	SVNS-WASPAS	L5>L2>L4>L1>L6>L3	L5	L3

Table 9 and Figure 1 demonstrate that the results obtained using the suggested approaches used in this investigation are consistent with the results testified in the literature. Not much has changed in the rankings, especially between the best and worst choices.

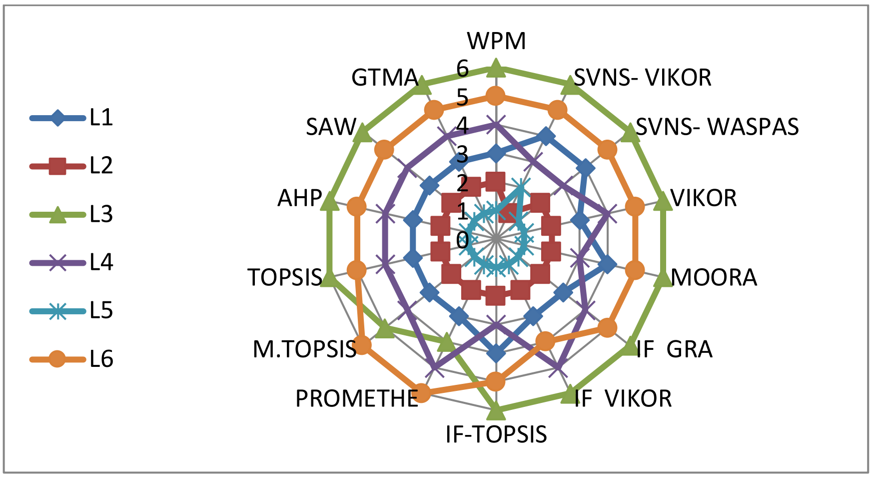

Fig. 1. The Graphical Comparisons Among Different MCDM Methods

Alternative L6 is superior to alternatives L5 and L3 in all circumstances, except for the TOPSIS approach created by Rao [3] and the Crisp-VIKOR method completed in this study. Most of the assessed methods agree on the top two alternatives, L5 and L2, except for the SVNS-VIKOR technique, which ranks alternative L2 higher than alternative L5. Thus, the comparison verifies that alternatives L5 and L2 continue to be the best candidates across all MCDM techniques (crisp, IF, and SVNS), and across all weights of the criteria (traditional, IF, and SVNS). Alterations that do not alter the optimum option are less important since it is not the definitive goal of the decision-making framework. The findings demonstrate that the rankings are affected for future ranking purposes by the weight criterion, but the original ranking is unaffected. MOORA is one such method that requires little computation. However, one strategy is shown to be superior to another learned strategy. Starting with the positive ideal solution (PIS), one method finds a solution that is as near to the PIS as possible, while the other finds a solution that is as distant from the PIS and the NIS as feasible.

6. Conclusions

When it comes to finding the optimal site for a new facility, we use cutting-edge MCDM techniques that need just concise descriptions of the criterion values. The same example is used to illustrate how the decision matrix is fuzzified and then converted into an SVNS- decision matrix, and the outcomes of the current methodologies used in this work are compared to the available findings to verify their accuracy. The score function is crucial to the success of SVNSs-MCDM approaches. When applied to crisp and SVNS data, MCDM approaches are more adaptable and sustainable while still yielding accurate rankings. The findings show that the strategies used are practicable, effective, and equitable. When dealing with real-world issues, SVNSs may be effective due to the absence of trustworthy data. Given the benefits of SVNSs, we offer and apply two SVNS strategies (SVNS-WASPAS and SVNS-VIKOR) to one of the MCDM issues.

How to improve certain current MCDM approaches might be the subject of future debate and in-depth research, taking into account the varying needs of real-world applications.

Acknowledgement
This research was not funded by any grant.

References

[1] Bhattacharya, A., B. Sarkar, and S. K. Mukherjee. "Selection of plant location through an MCDM methodology." *Industrial Engineering Journal (India)* 32 (2003): 15-20.

[2] Bhattacharya, A., B. Sarkar, and S. K. Mukherjee. "A new method for plant location selection: a holistic approach." *International Journal of Industrial Engineering: Theory, Applications and Practice* 11, no. 4 (2004): 330-338.

[3] Rao, R. Venkata. *Decision making in the manufacturing environment: using graph theory and fuzzy multiple attribute decision making methods*. Vol. 2. London: Springer, 2007.

[4] Farahani, Reza Zanjirani, and Nasrin Asgari. "Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study." *European Journal of Operational Research* 176, no. 3 (2007): 1839-1858. https://doi.org/10.1016/j.ejor.2005.10.039

[5] Tabari, Mojtaba, Amin Kaboli, Mir-Bahador Aryanezhad, Kamran Shahanaghi, and Ali Siadat. "A new method for location selection: a hybrid analysis." *Applied Mathematics and Computation* 206, no. 2 (2008): 598-606. https://doi.org/10.1016/j.amc.2008.05.111

[6] Amiri, M., A. Kazemi, J. S. Sadaghiani, A. Yaghoubi, and H. Mashatzade. "Developing and solving a new model for the location problems: Fuzzy-goal programming approach." *Journal of applied sciences* 9, no. 7 (2009): 1344-1349. https://doi.org/10.3923/jas.2009.1344.1349

[7] Arora, Sudha, and S. R. Arora. "Multiobjective capacitated plant location problem." *International Journal of Operational Research* 7, no. 4 (2010): 487-505. https://doi.org/10.1504/IJOR.2010.032423

[8] Farahani, Reza Zanjirani, Maryam SteadieSeifi, and Nasrin Asgari. "Multiple criteria facility location problems: A survey." *Applied mathematical modelling* 34, no. 7 (2010): 1689-1709. https://doi.org/10.1016/j.apm.2009.10.005
[9] Athawale, Vijay Manikrao, Prasenjit Chatterjee, and Shankar Chakraborty. "Decision making for facility location selection using PROMETHEE II method." *International Journal of Industrial and Systems Engineering 1* 11, no. 1-2 (2012): 16-30. https://doi.org/10.1504/IJISE.2012.046652
[10] Kahraman, Cengiz, Da Ruan, and Ibrahim Doğan. "Fuzzy group decision-making for facility location selection." *Information sciences* 157 (2003): 135-153. https://doi.org/10.1016/S0020-0255(03)00183-X
[11] Chou, Shuo-Yan, Yao-Hui Chang, and Chun-Ying Shen. "A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes." *European Journal of Operational Research* 189, no. 1 (2008): 132-145. https://doi.org/10.1016/j.ejor.2007.05.006
[12] Önüt, Semih, and Selin Soner. "Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment." *Waste management* 28, no. 9 (2008): 1552-1559. https://doi.org/10.1016/j.wasman.2007.05.019
[13] Boran, Fatih Emre. "An integrated intuitionistic fuzzy multi criteria decision making method for facility location selection." *Mathematical and Computational Applications* 16, no. 2 (2011): 487-496. https://doi.org/10.3390/mca16020487
[14] S.S. Alkafaas. "Comparative Analysis of Some Multi-Criteria Decision-Making Methods in Intuitionistic Fuzzy Environment." *Master of Science in Production Engineering, Production Eng. & Mechanical Design Department Faculty of Engineering -Menoufia University, Egypt* (2020).
[15] Smarandache, Florentin. "A unifying field in Logics: Neutrosophic Logic." In *Philosophy*, pp. 1-141. American Research Press, 1999.
[16] Wang, Haibin, Florentin Smarandache, Yanqing Zhang, and Rajshekhar Sunderraman. "Single valued neutrosophic sets." *Infinite study* 12 (2010).
[17] Zhang, Hong-yu, Pu Ji, Jian-qiang Wang, and Xiao-hong Chen. "A neutrosophic normal cloud and its application in decision-making." *Cognitive Computation* 8 (2016): 649-669. https://doi.org/10.1007/s12559-016-9394-8
[18] Abdel-Basset, Mohamed, Mai Mohamed, Yongquan Zhou, and Ibrahim Hezam. "Multi-criteria group decision making based on neutrosophic analytic hierarchy process." *Journal of Intelligent & Fuzzy Systems* 33, no. 6 (2017): 4055-4066. https://doi.org/10.3233/JIFS-17981
[19] Rani, Pratibha, Jabir Ali, Raghunathan Krishankumar, Arunodaya Raj Mishra, Fausto Cavallaro, and Kattur S. Ravichandran. "An integrated single-valued neutrosophic combined compromise solution methodology for renewable energy resource selection problem." *Energies* 14, no. 15 (2021): 4594. https://doi.org/10.3390/en14154594
[20] Topal, Selcuk, Ahmet Cevik, and Florentin Smarandache. "A new group decision making method with distributed indeterminacy form under neutrosophic environment: an introduction to neutrosophic social choice theory." *IEEE Access* 8 (2020): 42000-42009. https://doi.org/10.1109/ACCESS.2020.2976872
[21] Mishra, Arunodaya Raj, and Pratibha Rani. "Assessment of sustainable third party reverse logistic provider using the single-valued neutrosophic combined compromise solution framework." *Cleaner and Responsible Consumption* 2 (2021): 100011. https://doi.org/10.1016/j.clrc.2021.100011
[22] Chaw, Yenling, Lazim Abdullah, and Mahmod Othman. "Single-valued neutrosophic relations and their application to factors affecting oil prices." *CAAI Transactions on Intelligence Technology* 5, no. 2 (2020): 115-120. https://doi.org/10.1049/trit.2020.0004
[23] Kazimieras Zavadskas, Edmundas, Romualdas Baušys, and Marius Lazauskas. "Sustainable assessment of alternative sites for the construction of a waste incineration plant by applying WASPAS method with single-valued neutrosophic set." *Sustainability* 7, no. 12 (2015): 15923-15936. https://doi.org/10.3390/su71215792
[24] Mishra, Arunodaya Raj, Pratibha Rani, and Abhijit Saha. "Single-valued neutrosophic similarity measure-based additive ratio assessment framework for optimal site selection of electric vehicle charging station." *International journal of intelligent systems* 36, no. 10 (2021): 5573-5604. https://doi.org/10.1002/int.22523
[25] Elshabshery, A., and M. Fattouh. "On some Information Measures of Single–Valued Neutrosophic Sets and their Applications in MCDM Problems." *Int. J. Eng. Res. Technol* 10 (2021): 406-415.
[26] Peng, Xindong, and Jingguo Dai. "Approaches to single-valued neutrosophic MADM based on MABAC, TOPSIS and new similarity measure with score function." *Neural Computing and Applications* 29 (2018): 939-954. https://doi.org/10.1007/s00521-016-2607-y
[27] A. A. Elshabshery. "Combining Multiple Criteria Decision-Making Methods and Single Valued Neutrosophic Sets for Solving Alternatives Ranking Problem." *Master of Science in Production Engineering, Production Eng. & Mechanical Design Department Faculty of Engineering -Menoufia University, Egypt* (2021).
[28] Zavadskas, Edmundas Kazimieras, Zenonas Turskis, Jurgita Antucheviciene, and Algimantas Zakarevicius. "Optimization of weighted aggregated sum product assessment." *Elektronika ir elektrotechnika* 122, no. 6 (2012): 3-6. https://doi.org/10.5755/j01.eee.122.6.1810

[29] Eisa, Abeer, and Mohamed Fattouh. "The Significance of Weighting in Multicriteria Decision-Making Methods: A Case Study on Robot Selection." *ERJ. Engineering Research Journal* 46, no. 3 (2023): 339-352.