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# A Single-Valued Neutrosophic Extension of the EDAS Method

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**Abstract:** This manuscript aims to propose a new extension of the EDAS method, adapted for usage with single-valued neutrosophic numbers. By using single-valued neutrosophic numbers, the EDAS method can be more efficient for solving complex problems whose solution requires assessment and prediction, because truth- and falsity-membership functions can be used for expressing the level of satisfaction and dissatisfaction about an attitude. In addition, the indeterminacy-membership function can be used to point out the reliability of the information given with truth- and falsity-membership functions. Thus, the proposed extension of the EDAS method allows the use of a smaller number of complex evaluation criteria. The suitability and applicability of the proposed approach are presented through three illustrative examples.

**Keywords:** neutrosophic set; single-valued neutrosophic set; EDAS; MCDM



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## 1. Introduction

Multicriteria decision making facilitates the evaluation of alternatives based on a set of criteria. So far, this technique has been used to solve a number of problems in various fields [1–6].

Notable advancement in solving complex decision-making problems has been made after Bellman and Zadeh [7] introduced fuzzy multiple-criteria decision making, based on fuzzy set theory [8].

In fuzzy set theory, belonging to a set is shown using the membership function $\mu(x) \in [0,1]$. Nonetheless, in some cases, it is not easy to determine the membership to the set using a single crisp number, particularly when solving complex decision-making problems. Therefore, Atanassov [9] extended fuzzy set theory by introducing nonmembership to a set $\nu(x) \in [0,1]$. In Atanassov's theory, intuitionistic sets' indeterminacy is, by default, $1 - \mu(x) - \nu(x)$.

Smarandache [10,11] further extended fuzzy sets by proposing a neutrosophic set. The neutrosophic set includes three independent membership functions, named the truth-membership $T_A(x)$, the falsity-membership $F_A(x)$ and the indeterminacy-membership $I_A(x)$ functions. Smarandache [11] and Wang et al. [12] further proposed a single-valued neutrosophic set, by modifying the conditions $T_A(x)$, $I_A(x)$ and $F_A(x) \in [0, 1]$ and $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$, which are more suitable for solving scientific and engineering problems [13].

When solving some kinds of decision-making problems, such as problems related to estimates and predictions, it is not easy to express the ratings of alternatives using crisp values, especially in cases when ratings are collected through surveys. The use of fuzzy sets, intuitionistic fuzzy sets, as well as neutrosophic fuzzy sets can significantly simplify the solving of such types of complex decision-making problems. However, the use of fuzzy sets and intuitionistic fuzzy sets has certain limitations related to the neutrosophic set theory. By using three mutually independent membership functions applied in neutrosophic set theory, the respondent involved in surveys has the possibility of easily expressing their views and preferences. The researchers recognized the potential of the neutrosophic set and involved it in the multiple-criteria decision-making process [14,15].

The Evaluation Based on Distance from Average Solution (EDAS) method was introduced by Keshavarz Ghorabaee et al. [16]. Until now, this method has been applied to solve various problems in different areas, such as: ABC inventory classification [16], facility location selection [17], supplier selection [18–20], third-party logistics provider selection [21], prioritization of sustainable development goals [22], autonomous vehicles selection [23], evaluation of e-learning materials [24], renewable energy adoption [25], safety risk assessment [26], industrial robot selection [27], and so forth.

Several extensions are also proposed for the EDAS method, such as: a fuzzy EDAS [19], an interval type-2 fuzzy extension of the EDAS method [18], a rough EDAS [20], Grey EDAS [28], intuitionistic fuzzy EDAS [29], interval-valued fuzzy EDAS [30], an extension of EDAS method in Minkowski space [23], an extension of the EDAS method under q-rung orthopair fuzzy environment [31], an extension of the EDAS method based on interval-valued complex fuzzy soft weighted arithmetic averaging (IV-CFSWAA) operator and the interval-valued complex fuzzy soft weighted geometric averaging (IV-CFSWGA) operator with interval-valued complex fuzzy soft information [32], and an extension of the EDAS equipped with trapezoidal bipolar fuzzy information [33].

Additionally, part of the EDAS extensions is based on neutrosophic environments, such as refined single-valued neutrosophic EDAS [34], trapezoidal neutrosophic EDAS [35], single-valued complex neutrosophic EDAS [36], single-valued triangular neutrosophic EDAS [37], neutrosophic EDAS [38], an extension of the EDAS method based on multivalued neutrosophic sets [39], a linguistic neutrosophic EDAS [40], the EDAS method under 2-tuple linguistic neutrosophic environment [41], interval-valued neutrosophic EDAS [22,42], interval neutrosophic [43].

In order to enable the usage of the EDAS method for solving complex decision-making problems, a novel extension that enables usage of single-valued neutrosophic numbers is proposed in this article. Therefore, the rest of this paper is organized as follows: In Section 2, some basic definitions related to the single-valued neutrosophic set are given. In Section 3, the computational procedure of the ordinary EDAS method is presented, whereas in Section 3.1, the single-valued neutrosophic extension of the EDAS method is proposed. In Section 4, three illustrative examples are considered with the aim of explaining in detail the proposed methodology. The conclusions are presented in the final section.

## 2. Preliminaries

**Definition 1.** *Let X be the universe of discourse, with a generic element in X denoted by x. A Neutrosophic Set (NS) A in X is an object having the following form [11]:*

$$A = \{x < T_A(x), I_A(x), F_A(x) >: x \in X\}, \tag{1}$$

*where: $T_A(x)$, $I_A(x)$, and $F_A(x)$ are the truth-membership function, the indeterminacy-membership function and the falsity-membership function, respectively, $T_A(x), I_A(x), F_A(x) : X \to ]^-0, 1^+[$, $^-0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3^+$, and $]^-0, 1^+[$ denotes bounds of NS.*

**Definition 2.** *Let X be a space of points, with a generic element in X denoted by x. A Single-Valued Neutrosophic Set (SVNS) A over X is as follows [12]:*

$$A = \{x < T_A(x), I_A(x), F_A(x) > | x \in X\}, \tag{2}$$

*where: $T_A(x)$, $I_A(x)$ and $F_A(x)$ are the truth-membership function, the indeterminacy-membership function and the falsity-membership function, respectively, $T_A(x), I_A(x), F_A(x) : X \to [0,\ 1]$ and $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$.*

**Definition 3.** *A Single-Valued Neutrosophic Numbera $= \langle t_a,\ i_a, f_a \rangle$ is a special case of an SVNS on the set of real numbers $\Re$, where $t_a, i_a, f_a \in [0,1]$ and $0 \le t_a + i_a + f_a \le 3$ [12].*

**Definition 4.** *Let $x_1 = \langle t_1, i_1, f_1 \rangle$ and $x_2 = \langle t_2, i_2, f_2 \rangle$ be two SVNNs and $\lambda > 0$. The basic operations over two SVNNs are as follows:*

$$x_1 + x_2 = < t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2 >, \tag{3}$$

$$x_1 \cdot x_2 = < t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2 > . \tag{4}$$

$$\lambda x_1 = < 1 - (1 - t_1)^{\lambda}, i_1^{\lambda}, f_1^{\lambda} > . \tag{5}$$

$$x_1^{\lambda} = < t_1^{\lambda}, i_1^{\lambda}, 1 - (1 - f_1)^{\lambda} > . \tag{6}$$

**Definition 5.** *Let $x = < t_i, i_i, f_i >$ be an SVNN. The score function $s_x$ of x is as follows [44]:*

$$s_i = (1 + t_i - 2i_i - f_i)/2, \tag{7}$$

*where $s_i \in [-1, 1]$.*

**Definition 6.** *Let $a_j \le t_j, i_j, f_j > (j = 1, \ldots, n)$ be a collection of SVNSs and $W = (w_1, w_2, \ldots, w_n)^T$ e an associated weighting vector. The Single-Valued Neutrosophic Weighted Average (SVNWA) operator of $a_j$ is as follows [40]:*

$$SVNWA(a_1, a_2,\ \ldots, a_n) = \sum_{j=1}^{n} w_j a_j = \left(1 - \prod_{j=1}^{n} (1 - t_j)^{w_j}, \prod_{j=1}^{n} (i_j)^{w_j}, \prod_{j=1}^{n} (f_j)^{w_j}\right), \tag{8}$$

*where: $w_j$ is the element j of the weighting vector, $w_j \in [0, 1]$ and $\sum_{j=1}^{n} w_j = 1$.*

**Definition 7.** *Let $x = < t_i, i_i, f_i >$ be an SVNN. The reliability $r_i$ of x is as follows [45]:*

$$r_i = \begin{cases} \frac{|t_i - f_i|}{t_i + i_i + f_i} & t_i + i_i + f_i \ne 0 \\ 0 & t_i + i_i + f_i = 0 \end{cases}. \tag{9}$$

**Definition 8.** *Let D be a decision matrix, dimension m x n, whose elements are SVNNs. The overall reliability of the information contained in the decision matrix is as follows:*

$$r_d = \frac{\sum_{j=1}^{n} r_{ij}}{\sum_{i=1}^{m} \sum_{j=1}^{n} r_{ij}}. \tag{10}$$

## 3. The EDAS Method

The procedure of solving a decision-making problem with *m* alternatives and *n* criteria using the EDAS method can be presented using the following steps:

Step 1. Determine the average solution according to all criteria, as follows:

$$x_j^* = (x_1, x_2, \cdots, x_n), \tag{11}$$

with:

$$x_j^* = \frac{\sum_{i=1}^{m} x_{ij}}{m}. \tag{12}$$

where: $x_{ij}$ denotes the rating of the alternative $i$ in relation to the criterion $j$.

Step 2. Calculate the positive distance from average (PDA) $d_{ij}^+$ and the negative distance from average (NDA) $d_{ij}^-$, as follows:

$$d_{ij}^+ = \begin{cases} \frac{\max(0,(x_{ij}-x_j^*))}{x_j^*}; & j \in \Omega_{\max} \\ \frac{\max(0,(x_j^*-x_{ij}))}{x_j^*}; & j \in \Omega_{\min} \end{cases}, \tag{13}$$

$$d_{ij}^- = \begin{cases} \frac{\max(0,(x_j^*-x_{ij}))}{x_j^*}; & j \in \Omega_{\max} \\ \frac{\max(0,(x_{ij}-x_j^*))}{x_j^*}; & j \in \Omega_{\min} \end{cases}, \tag{14}$$

where: $\Omega_{\max}$ and $\Omega_{\min}$ denote the set of the beneficial criteria and the nonbeneficial criteria, respectively.

Step 3. Determine the weighted sum of PDA, $Q_i^+$, and the weighted sum of NDS, $Q_i^-$, for all alternatives, as follows:

$$Q_i^+ = \sum_{j=1}^{n} w_j d_{ij}^+, \tag{15}$$

$$Q_i^- = \sum_{j=1}^{n} w_j d_{ij}^-, \tag{16}$$

where $w_j$ denotes the weight of the criterion $j$.

Step 4. Normalize the values of the weighted sum of the PDA and NDA, respectively, for all alternatives, as follows:

$$S_i^+ = \frac{Q_i^+}{\max_k Q_k^+}, \tag{17}$$

$$S_i^- = 1 - \frac{Q_i^-}{\max_k Q_k^-}, \tag{18}$$

where: $S_i^+$ and $S_i^-$ denote the normalized weighted sum of the PDA and the NDA, respectively.

Step 5. Calculate the appraisal score $S_i$ for all alternatives, as follows:

$$S_i = \frac{1}{2}(S_i^+ + S_i^-). \tag{19}$$

Step 6. Rank the alternatives according to the decreasing values of appraisal score. The alternative with the highest $S_i$ is the best choice among the candidate alternatives.

### *3.1. The Extension of the EDAS Method Adopted for the Use of Single-Valued Neutrosophic Numbers in a Group Environment*

Let us suppose a decision-making problem that include $m$ alternatives, $n$ criteria and $k$ decision makers, where ratings are given using SVNNs. Then, the computational procedure of the proposed extension of the EDAS method can be expressed concisely through the following steps:

Step 1. Construct the single-valued neutrosophic decision-making matrix for each decision maker, as follows:

$$\widetilde{X}^k = \begin{bmatrix} < t_{11}^k,\ i_{11}^k, f_{11}^k > & < t_{12}^k,\ i_{12}^k, f_{12}^k > & \cdots & < t_{1n}^k,\ i_{1n}^k, f_{1n}^k > \\ < t_{21}^k,\ i_{21}^k, f_{21}^k > & < t_{22}^k,\ i_{22}^k, f_{22}^k > & \cdots & < t_{2n}^k,\ i_{2n}^k, f_{2n}^k > \\ \vdots & \vdots & \vdots & \vdots \\ < t_{m1}^k,\ i_{m1}^k, f_{m1}^k > & < t_{m2}^k,\ i_{m2}^k, f_{m2}^k > & \cdots & < t_{mn}^k,\ i_{mn}^k, f_{mn}^k > \end{bmatrix} \tag{20}$$

whose elements $\widetilde{x}_{ij} =< t_{ij}^k,\ i_{ij}^k, f_{ij}^k >$ are SVNNs.

Step2. Construct the single-valued neutrosophic decision making using Equation (8):

$$\widetilde{X} = \begin{bmatrix} < t_{11},\ i_{11}, f_{11} > & < t_{12},\ i_{12}, f_{12} > & \cdots & < t_{1n},\ i_{1n}, f_{1n} > \\ < t_{21},\ i_{21}, f_{21} > & < t_{22},\ i_{22}, f_{22} > & \cdots & < t_{2n},\ i_{2n}, f_{2n} > \\ \vdots & \vdots & \vdots & \vdots \\ < t_{m1},\ i_{m1}, f_{m1} > & < t_{m2},\ i_{m2}, f_{m2} > & \cdots & < t_{mn},\ i_{mn}, f_{mn} > \end{bmatrix} \tag{21}$$

Step 3. Determine the single-valued average solution (SVAS) $\widetilde{x}_j^*$ according to all criteria, as follows:

$$\widetilde{x}_j^* = (< t_1^*,\ i_1^*, f_1^* >, < t_2^*,\ i_2^*, f_2^* >, \cdots, < t_n^*,\ i_n^*, f_n^* >), \tag{22}$$

where:

$$t_j^* = \frac{\sum_{l=1}^m t_{ij}}{m} \tag{23}$$

$$i_j^* = \frac{\sum_{l=1}^m i_{ij}}{m}, \text{ and} \tag{24}$$

$$f_j^* = \frac{\sum_{l=1}^m f_{ij}}{m} \tag{25}$$

Step 4. Calculate a single-valued neutrosophic PDA (SVNPDA), $\widetilde{d}_{ij}^+ =< t_{ij}^+, i_{ij}^+, f_{ij}^+ >$, and a single-valued neutrosophic NDA (SVNNDA), $\widetilde{d}_{ij}^- =< t_{ij}^-, i_{ij}^-, f_{ij}^- >$, as follows:

$$\widetilde{d}_{ij}^+ =< t_{ij}^+, i_{ij}^+, f_{ij}^+ >= \begin{cases} \left\langle \frac{\max(0,(t_{ij}-t_j^*))}{x_j^*}, \frac{\max(0,(i_{ij}-i_j^*))}{x_j^*}, \frac{\max(0,(f_{ij}-f_j^*))}{x_j^*} \right\rangle & j \in \Omega_{\max} \\ \left\langle \frac{\max(0,(t_j^*-t_{ij}))}{x_j^*}, \frac{\max(0,(i_j^*-i_{ij}))}{x_j^*}, \frac{\max(0,(f_j^*-f_{ij}))}{x_j^*} \right\rangle & j \in \Omega_{\min} \end{cases} \tag{26}$$

$$\widetilde{d}_{ij}^- =< t_{ij}^-, i_{ij}^-, f_{ij}^- >= \begin{cases} \frac{\max(0,(t_j^*-t_{ij}))}{x_j^*}, \frac{\max(0,(i_j^*-i_{ij}))}{x_j^*}, \frac{\max(0,(f_j^*-f_{ij}))}{x_j^*} & j \in \Omega_{\max} \\ \frac{\max(0,(t_{ij}-t_j^*))}{x_j^*}, \frac{\max(0,(i_{ij}-i_j^*))}{x_j^*}, \frac{\max(0,(f_{ij}-f_j^*))}{x_j^*} & j \in \Omega_{\min} \end{cases} \tag{27}$$

where:

$$x_j^* = \max\left( \frac{\sum_{i=1}^m t_{ij}}{m}, \frac{\sum_{i=1}^m i_{ij}}{m}, \frac{\sum_{i=1}^m f_{ij}}{m} \right) \tag{28}$$

For a decision-making problem that includes only beneficial criteria, the SVNPDA and SVNNDA can be determined as follows:

$$\widetilde{d}_{ij}^+ =< t_{ij}^+, i_{ij}^+, f_{ij}^+ >= \left\langle \frac{\max(0,(t_{ij}-t_j^*))}{x_j^*}, \frac{\max(0,(i_{ij}-i_j^*))}{x_j^*}, \frac{\max(0,(f_{ij}-f_j^*))}{x_j^*} \right\rangle \tag{29}$$

$$\widetilde{d}_{ij}^- =< t_{ij}^-, i_{ij}^-, f_{ij}^- >= \left\langle \frac{\max(0,(t_j^*-t_{ij}))}{x_j^*}, \frac{\max(0,(i_j^*-i_{ij}))}{x_j^*}, \frac{\max(0,(f_j^*-f_{ij}))}{x_j^*} \right\rangle \tag{30}$$

Step 5. Determine the weighted sum of the SVNPDA, $\widetilde{Q}_i^+ = < t_i^+, i_i^+, f_i^+ >$, and the weighted sum of the SVNNDA, $\widetilde{Q}_i^- = < t_i^-, i_i^-, f_i^- >$, for all alternatives. Based on Equations (5) and (8) the weighted sum of the SVNPDA, $\widetilde{Q}_i^+$, and the weighted sum of the SVNNDA, $\widetilde{Q}_i^-$, can be calculated as follows:

$$\widetilde{Q}_i^+ = \sum_{j=1}^{n} w_j \widetilde{d}_{ij}^+ = \left\langle 1 - \prod_{j=1}^{n} (1 - t_{ij}^+)^{w_j}, \prod_{j=1}^{n} (i_{ij}^+)^{w_j}, \prod_{j=1}^{n} (f_{ij}^+)^{w_j} \right\rangle, \tag{31}$$

$$\widetilde{Q}_i^- = \sum_{j=1}^{n} w_j \widetilde{d}_{ij}^- = \left\langle 1 - \prod_{j=1}^{n} (1 - t_{ij}^-)^{w_j}, \prod_{j=1}^{n} (i_{ij}^-)^{w_j}, \prod_{j=1}^{n} (f_{ij}^-)^{w_j} \right\rangle. \tag{32}$$

Step 6. In order to normalize the values of the weighted sum of the single-valued neutrosophic PDA and the weighted sum of the single-valued neutrosophic NDA, these values should be transformed into crisp values. This transformation can be performed using the score function or similar approaches. After that, the following three steps remain the same as in the ordinary EDAS method.

Step 7. Normalize the values of the weighted sum of the SVNPDA and the single-valued neutrosophic SVNNDA for all alternatives, as follows:

$$S_i^+ = \frac{Q_i^+}{\max_k Q_k^+}, \tag{33}$$

$$S_i^- = 1 - \frac{Q_i^-}{\max_k Q_k^-}. \tag{34}$$

Step 8. Calculate the appraisal score $S_i$ for all alternatives, as follows:

$$S_i = \frac{1}{2}(S_i^+ + S_i^-). \tag{35}$$

Step 9. Rank the alternatives according to the decreasing values of the appraisal score. The alternative with the highest $S_i$ is the best choice among the candidate alternatives.

## 4. A Numerical Illustrations

In this section, three numerical illustrations are presented in order to indicate the applicability of the proposed approach. The first numerical illustration shows in detail the procedure for applying the neutrosophic extension of the EDAS method. The second numerical illustration shows the application of the proposed extension in the case of solving MCDM problems that contain nonbeneficial criteria, while the third numerical illustration shows the application of the proposed approach in combination with the reliability of the information contained in SVNNs.

### *4.1. The First Numerical Illustration*

In this numerical illustration, an example adopted from Biswas et al. [46] is used to demonstrate the proposed approach in detail. Suppose that a team of three IT specialists was formed to select the best tablet from four initially preselected tablets for university students. The purpose of these tablets is to make university e-learning platforms easier to use.

The preselected tablets are evaluated based on the following criteria: Features—$C_1$, Hardware—$C_2$, Display—$C_3$, Communication—$C_4$, Affordable Price—$C_5$, and Customer care—$C_6$. The ratings obtained from three IT specialists are shown in Tables 1–3.

**Table 1.** The ratings of three tablets obtained from the first of three IT specialist.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <1.0, 0.0, 0.0> | <1.0, 0.2, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.3, 0.0> | <0.8, 0.2, 0.2> | <0.9, 0.1, 0.1> |
| $A_2$ | <1.0, 0.0, 0.0> | <0.9, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.2> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.0> |
| $A_3$ | <0.9, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.7, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.7, 2.0, 2.0> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.7, 0.3, 0.3> | <0.6, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.5, 0.0, 0.2> |

**Table 2.** The ratings of three tablets obtained from the second of three IT specialist.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <0.8, 0.2, 0.2> | <1.0, 0.0, 0.1> | <0.7, 0.3, 0.2> | <0.7, 0.3, 0.2> | <1.0, 0.0, 0.0> | <0.8, 0.1, 0.1> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.2> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> | <1.0, 0.1, 0.1> |
| $A_3$ | <0.7, 0.3, 0.2> | <0.9, 0.0, 0.0> | <0.7, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.7, 0.2, 0.2> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.7, 0.3, 0.3> | <0.6, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.5, 0.1, 0.2> |

**Table 3.** The ratings of three tablets obtained from the third of three IT specialist.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <0.9, 1.0, 1.0> | <0.9, 0.0, 0.2> | <1.0, 0.0, 1.0> | <0.7, 0.3, 0.2> | <1.0, 0.0, 0.0> | <0.9, 0.0, 0.1> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.9, 0.2, 0.1> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> | <1.0, 0.1, 0.1> |
| $A_3$ | <0.6, 0.3, 0.2> | <0.9, 0.0, 0.0> | <0.5, 0.2, 0.2> | <0.5, 0.3, 0.2> | <0.9, 0.2, 0.4> | <0.7, 0.0, 0.0> |
| $A_4$ | <0.6, 0.0, 0.3> | <0.5, 0.3, 0.4> | <0.4, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.2, 0.3> | <0.7, 0.0, 0.2> |

After that, a group evaluation matrix, shown in Table 4, is calculated using Equation (8) and $w_k$ = (0.33, 0.33, 0.33), where $w_k$ denotes the importance of $k$-th IT specialist.

**Table 4.** The group evaluation matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.3, 0.0> | <1.0, 0.0, 0.0> | <0.9, 0.0, 0.1> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> |
| $A_3$ | <0.8, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.6, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.7, 0.0, 0.0> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.6, 0.3, 0.3> | <0.5, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.6, 0.0, 0.2> |

The SVNPDA and the SVNPDA, shown in Tables 5 and 6, are calculated using Equations (29) and (30).

**Table 5.** The SVNPDA.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <0.2, 0.0, 0.0> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.4, 0.0> | <0.1, 0.0, 0.0> | <0.1, 0.0, 0.0> |
| $A_2$ | <0.2, 0.0, 0.0> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.1, 0.0, 0.3> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> |
| $A_3$ | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> | <0.0, 0.1, 0.2> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> |
| $A_4$ | <0.0, 0.0, 0.2> | <0.0, 0.3, 0.3> | <0.0, 0.3, 0.1> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.1> |

**Table 6.** The SVNNDA.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $A_1$ | <0.0, 0.0, 0.1> | <0.0, 0.1, 0.1> | <0.0, 0.2, 0.1> | <0.0, 0.0, 0.1> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> |
| $A_2$ | <0.0, 0.0, 0.1> | <0.0, 0.1, 0.1> | <0.0, 0.2, 0.2> | <0.0, 0.1, 0.0> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.1> |
| $A_3$ | <0.1, 0.0, 0.1> | <0.0, 0.1, 0.1> | <0.2, 0.0, 0.0> | <0.1, 0.1, 0.1> | <0.1, 0.0, 0.0> | <0.1, 0.0, 0.1> |
| $A_4$ | <0.2, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.1, 0.1> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> |

The weighted sum of SVNPDA and the weighted sum of SVNNDA, shown in Table 7, are calculated using Equations (31) and (32), as well as weighting vector $w_j$ = (0.19, 0.19, 0.18, 0.16, 0.14, 0.13). Before calculating the normalized weighted sums of the SVNPDA and SVNNDA, using Equations (33) and (34), as well as appraisal score, using Equation (35), the values of the weighted sum of SVNPDA and SVNNDA are transformed into crisp values using Equation (7).

**Table 7.** Computational details and ranking order of considered tablets.

| | $\tilde{Q}_i^+$ | | $\tilde{Q}_i^-$ | | $S_i^+$ | $S_i^-$ | $S_i$ | Rank |
|---|---|---|---|---|---|---|---|---|
| | **SVNN** | **Score** | **SVNN** | **Score** | | | | |
| $A_1$ | <0.168, 0.000, 0.000> | 0.58 | <0.000, 0.000, 0.000> | 0.50 | 1.00 | 0.20 | 0.597 | 2 |
| $A_2$ | <0.170, 0.000, 0.000> | 0.59 | <0.000, 0.027, 0.000> | 0.47 | 1.00 | 0.24 | 0.620 | 1 |
| $A_3$ | <0.003, 0.000, 0.000> | 0.50 | <0.096, 0.000, 0.000> | 0.55 | 0.86 | 0.12 | 0.488 | 3 |
| $A_4$ | <0.000, 0.000, 0.000> | 0.50 | <0.245, 0.000, 0.000> | 0.62 | 0.85 | 0.00 | 0.427 | 4 |

The ranking order of considered alternatives is also shown in Table 7. As it can be seen from Table 7, the most appropriate alternative is the alternative denoted as $A_2$.

### *4.2. The Second Numerical Illustration*

The second numerical illustration shows the application of the NS extension of the EDAS method in the case of solving MCDM problems that include nonbeneficial criteria.

An example taken from Stanujkic et al. [47] was used for this illustration. In the given example, the evaluation of three comminution circuit designs (CCDs) was performed based on five criteria: Grinding efficiency—$C_1$, Economic efficiency—$C_2$, Technological reliability—$C_3$, Capital investment costs—$C_4$, and Environmental impact—$C_5$. The group decision-making matrix, as well as the types of criteria, are shown in Table 8.

**Table 8.** Group decision-making matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| **Optimization** | **Max** | **Max** | **Max** | **Min** | **Min** |
| $A_1$ | <0.9, 0.1, 0.2> | <0.7, 0.2, 0.3> | <0.9, 0.1, 0.2> | <0.9, 0.1, 0.2> | <0.9, 0.1, 0.2> |
| $A_2$ | <0.8, 0.1, 0.3> | <0.8, 0.1, 0.3> | <0.8, 0.1, 0.3> | <0.9, 0.1, 0.2> | <0.8, 0.1, 0.3> |
| $A_3$ | <1.0, 0.1, 0.3> | <0.9, 0.1, 0.2> | <0.9, 0.1, 0.2> | <0.7, 0.2, 0.5> | <0.7, 0.2, 0.3> |

Values of the SVNPDA and SVNPDA, calculated using Equations (26) and (27), are shown in Tables 9 and 10.

**Table 9.** The SVNPDA.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <0.2, 0.0, 0.0> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.4, 0.0> | <0.1, 0.0, 0.0> |
| $A_2$ | <0.2, 0.0, 0.0> | <0.1, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.1, 0.0, 0.3> | <0.1, 0.0, 0.0> |
| $A_3$ | <0.0, 0.0, 0.2> | <0.0, 0.3, 0.3> | <0.0, 0.3, 0.1> | <0.0, 0.0, 0.0> | <0.0, 0.0, 0.0> |

**Table 10.** The SVNNDA.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <0.0, 0.0, 0.1> | <0.0, 0.1, 0.1> | <0.0, 0.2, 0.1> | <0.0, 0.0, 0.1> | <0.0, 0.0, 0.0> |
| $A_2$ | <0.0, 0.0, 0.1> | <0.0, 0.1, 0.1> | <0.0, 0.2, 0.2> | <0.0, 0.1, 0.0> | <0.0, 0.0, 0.0> |
| $A_3$ | <0.2, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.0, 0.0> | <0.3, 0.1, 0.1> | <0.1, 0.0, 0.0> |

The weighted sum of SVNPDA and the weighted sum of SVNNDA are shown in Table 11. The calculation was performed using the following weighting vector $w_j$ = (0.24, 0.17, 0.24, 0.21, 0.14). The remaining part of the calculation procedure, carried out using formulas Equations (33)–(35) is also summarized in Table 11.

**Table 11.** Computational details and ranking order of considered GCDs.

| | $\tilde{Q}_i^+$ | | $\tilde{Q}_i^-$ | | $S_i^+$ | $S_i^-$ | $S_i$ | Rank |
|---|---|---|---|---|---|---|---|---|
| | **SVNN** | **Score** | **SVNN** | **Score** | | | | |
| $A_1$ | <0.009, 0.000, 0.000> | 0.50 | <0.057, 0.000, 0.000> | 0.53 | 0.910 | 0.005 | 0.458 | 2 |
| $A_2$ | <0.000, 0.000, 0.000> | 0.50 | <0.063, 0.000, 0.000> | 0.53 | 0.902 | 0.000 | 0.451 | 3 |
| $A_3$ | <0.109, 0.000, 0.000> | 0.55 | <0.000, 0.000, 0.000> | 0.50 | 1.000 | 0.059 | 0.530 | 1 |

As can be seen from Table 11, by applying the proposed extension of the EDAS method, the following ranking order of alternatives is obtained $A_3 > A_1 > A_2$, i.e., the alternative $A_3$ is selected as the most appropriate.

A similar order of alternatives was obtained in Stanujkic et al. [45] using the Neutrosophic extension of the MULTIMOORA method, where the following order of alternatives was achieved $A_3 > A_2 > A_1$.

### 4.3. The Third Numerical Illustration

The third numerical illustration shows the use of a newly proposed approach with an approach that allows for determining the reliability of data contained in SVNNs, proposed by Stanujkic et al. [43]. Using this approach, inconsistently completed questionnaires can be identified and, if necessary, eliminated from further evaluation of alternatives.

In order to demonstrate this approach, an example was taken from Stanujkic et al. [48]. In this example, the websites of five wineries were evaluated based on the following five criteria: Content—$C_1$, Structure and Navigation—$C_2$, Visual Design—$C_3$, Interactivity—$C_4$, and Functionality—$C_5$.

The ratings obtained from the three respondents are also shown in Tables 12–14.

**Table 12.** The ratings obtained from the first of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <1.0, 0.0, 0.0> | <1.0, 0.2, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.3, 0.0> | <0.8, 0.2, 0.2> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> |
| $A_3$ | <0.9, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.7, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.7, 0.3, 0.3> | <0.6, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_5$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.2> | <1.0, 0.0, 0.0> |

**Table 13.** The ratings obtained from the second of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <0.8, 0.2, 0.2> | <1.0, 0.0, 0.0> | <0.7, 0.3, 0.1> | <0.7, 0.3, 0.2> | <1.0, 0.0, 0.0> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> |
| $A_3$ | <0.7, 0.3, 0.2> | <0.9, 0.0, 0.0> | <0.7, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.7, 0.3, 0.3> | <0.6, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_5$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.2> | <1.0, 0.0, 0.0> |

**Table 14.** The ratings obtained from the third of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <0.9, 1.0, 1.0> | <0.9, 0.0, 0.2> | <1.0, 0.0, 1.0> | <0.7, 0.3, 0.2> | <1.0, 0.0, 0.0> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> |
| $A_3$ | <0.6, 0.3, 0.2> | <0.9, 0.0, 0.0> | <0.5, 0.2, 0.3> | <0.5, 0.3, 0.3> | <0.9, 0.3, 0.4> |
| $A_4$ | <0.6, 0.0, 0.3> | <0.5, 0.3, 0.4> | <0.4, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.3, 0.3> |
| $A_5$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.2> | <1.0, 0.0, 0.0> |

The reliability of the collected information calculated using Equations (9) and (10) are shown in Tables 15–17. In this case, the lowest value of overall reliability of information was 0.61 which is why all collected questionnaires were used to evaluate alternatives.

**Table 15.** The reliability of information obtained from the first of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | *Reliability* |
|---|---|---|---|---|---|---|
| $A_1$ | 1.00 | 0.83 | 1.00 | 0.70 | 0.50 | 0.81 |
| $A_2$ | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 0.90 |
| $A_3$ | 1.00 | 1.00 | 0.33 | 1.00 | 1.00 | 0.87 |
| $A_4$ | 0.40 | 0.31 | 0.33 | 1.00 | 1.00 | 0.61 |
| $A_5$ | 1.00 | 1.00 | 1.00 | 0.56 | 1.00 | 0.91 |
| | | | | Overall reliability | | 0.82 |

**Table 16.** The reliability of information obtained from the second of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | *Reliability* |
|---|---|---|---|---|---|---|
| $A_1$ | 0.50 | 1.00 | 0.55 | 0.42 | 1.00 | 0.69 |
| $A_2$ | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 0.90 |
| $A_3$ | 0.42 | 1.00 | 0.33 | 1.00 | 1.00 | 0.75 |
| $A_4$ | 0.40 | 0.31 | 0.33 | 1.00 | 1.00 | 0.61 |
| $A_5$ | 1.00 | 1.00 | 1.00 | 0.56 | 1.00 | 0.91 |
| | | | | Overall reliability | | 0.77 |

**Table 17.** The reliability of information obtained from the third of three respondents.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | *Reliability* |
|---|---|---|---|---|---|---|
| $A_1$ | 0.03 | 0.64 | 0.00 | 0.42 | 1.00 | 0.42 |
| $A_2$ | 1.00 | 1.00 | 1.00 | 0.50 | 1.00 | 0.90 |
| $A_3$ | 0.36 | 1.00 | 0.20 | 0.18 | 0.31 | 0.41 |
| $A_4$ | 0.33 | 0.08 | 0.20 | 1.00 | 0.40 | 0.40 |
| $A_5$ | 1.00 | 1.00 | 1.00 | 0.56 | 1.00 | 0.91 |
| | | | | Overall reliability | | 0.61 |

The group decision-making matrix formed on the basis of the ratings from Tables 12–14 is shown in Table 18, while the calculation details are summarized in Table 19, using the following weight vector $w_j$ = (0.22, 0.20, 0.25, 0.18, 0.16).

**Table 18.** The group decision-making matrix.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.3, 0.0> | <1.0, 0.0, 0.0> |
| $A_2$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.6, 0.0, 0.2> | <1.0, 0.0, 0.0> |
| $A_3$ | <0.8, 0.0, 0.0> | <0.9, 0.0, 0.0> | <0.6, 0.2, 0.3> | <0.5, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_4$ | <0.7, 0.0, 0.3> | <0.6, 0.3, 0.3> | <0.5, 0.4, 0.2> | <0.4, 0.0, 0.0> | <0.9, 0.0, 0.0> |
| $A_5$ | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <1.0, 0.0, 0.0> | <0.7, 0.0, 0.2> | <1.0, 0.0, 0.0> |

**Table 19.** Computational details and ranking order of considered websites.

| | $\tilde{Q}_i^+$ | | $\tilde{Q}_i^-$ | | $S_i^+$ | $S_i^-$ | $S_i$ | Rank |
|---|---|---|---|---|---|---|---|---|
| | **SVNN** | **Score** | **SVNN** | **Score** | | | | |
| $A_1$ | <0.141, 0.000, 0.000> | 0.57 | <0.000, 0.000, 0.000> | 0.50 | 1.00 | 0.21 | 0.61 | 3 |
| $A_2$ | <0.110, 0.000, 0.000> | 0.56 | <0.000, 0.006, 0.000> | 0.47 | 0.97 | 0.26 | 0.62 | 2 |
| $A_3$ | <0.000, 0.000, 0.000> | 0.50 | <0.125, 0.000, 0.000> | 0.56 | 0.88 | 0.11 | 0.49 | 4 |
| $A_4$ | <0.000, 0.000, 0.000> | 0.50 | <0.269, 0.000, 0.000> | 0.63 | 0.88 | 0.00 | 0.44 | 5 |
| $A_5$ | <0.141, 0.000, 0.000> | 0.57 | <0.000, 0.006, 0.000> | 0.47 | 1.00 | 0.26 | 0.63 | 1 |

From Table 15 it can be seen that the following order of ranking of alternatives was achieved $A_5 > A_2 > A_1 > A_3 > A_4$, which is similar to the order of alternatives $A_5 = A_2 > A_1 > A_3 > A_4$ given in Stanujkic et al. [48].

## 5. Conclusions

A novel extension of the EDAS method based on the use of single-valued neutrosophic numbers is proposed in this article. Single-valued neutrosophic numbers enable simultaneous use of truth- and falsity-membership functions, and thus enable expressing the level of satisfaction and the level of dissatisfaction about an attitude. At the same time, using the indeterminacy-membership function, decision makers can express their confidence about already-given satisfaction and dissatisfaction levels.

The evaluation process using the ordinary EDAS method can be considered as simple and easy to understand. Therefore, the primary objective of the development of this extension was the formation of an easy-to-use and easily understandable extension of the EDAS method. By integrating the benefits that can be obtained by using single-valued neutrosophic numbers and simple-to-use and understandable computational procedures of the EDAS method, the proposed extension can be successfully used for solving complex decision-making problems, while the evaluation procedure remains easily understood for decision makers who are not familiar with neutrosophy and multiple-criteria decision making.

Finally, the usability and efficiency of the proposed extension is demonstrated on an example of tablet evaluation.

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