ФАКУЛТЕТ ЗА ПРИМЕЊЕНИ МЕНАЏМЕНТ ЕКОНОМИЈУ И ФИНАНСИЈЕ

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МЕЂУНАРОДНА НАУЧНО-СТРУЧНА КОНФЕРЕНЦИЈА

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ИНОВАЦИЈЕ КАО ПОКРЕТАЧ РАЗВОЈА
INNOVATION AS AN INITIATOR OF THE DEVELOPMENT

ЗБОРНИК РАДОВА СА МЕЂУНАРОДНОГ СКУПА / INTERNATIONAL CONFERENCE PROCEEDINGS

6. децембар 2018. Београд

6th December, 2018, Belgrade

Универзитет Привредна академија у Новом Саду

University Business Academy in Novi Sad

Факултет за примењени менаџмент, економију и финансије Београд

Faculty of Applied Management, Economy and Finance Belgrade

Међународна научно-стручна конференција

International Scientific & Professional Conference

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ИНОВАЦИЈЕ КАО ПОКРЕТАЧ РАЗВОЈА

„Иновативна делатност – напредак и будућност“

INNOVATION AS AN INITIATOR OF THE DEVELOPMENT

“Innovative Activities – Progress and Future”

ЗБОРНИК РАДОВА СА МЕЂУНАРОДНОГ СКУПА

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МЕФкон 2018:

„Иновације као покретач развоја“

Зборник радова са међународног скупа – *електронско издање*

**радови су објављени у изворном облику*

Belgrade, December 6th 2018

International Scientific & Professional Conference

MEFkon 2018:

“Innovation as an Initiator of the Development”

International Conference Proceedings – *digital edition*

**papers were published in the original form*

Издавач / Publisher

Факултет за примењени менаџмент, економију и финансије Београд

Faculty of Applied Management, Economy and Finance Belgrade

За издавача / For the Publisher:

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Strahinja Vidojević, Bsc

Штампа / Print

Факултет за примењени менаџмент, економију и финансије Београд

Faculty of Applied Management, Economy and Finance Belgrade

Тираж / Number of copies

100

ISBN 978-86-84531-37-9

AN APPROACH FOR ASSESSING THE RELIABILITY OF DATA CONTAINED IN A SINGLE VALUED NEUTROSOPHIC NUMBER

Florentin Smarandache[1]; Dragiša Stanujkić[2]; Darjan Karabašević[3]

Abstract

Neutrosophic sets, as the generalization of many types of sets, including classical and fuzzy sets, are becoming more and more important for solving a number of complex decision-making problems. On the other hand, the reliability of the information used to solve a problem also has an impact on the selection of the most appropriate solution. Therefore, in this paper, an approach for assessing the reliability of information contained in single valued neutrosophic numbers has been proposed. The usability of the proposed approach is considered in the case of determining customer satisfaction of users of traditional Serbian restaurants in the city of Zajecar.

Keywords: *neutrosophy, SVNN, estimating data reliability*

Introduction

In order to provide methodology for solving complex decision-making problems, Zadeh (1965) introduced fuzzy set theory. Based on the fuzzy set theory, a number of extensions of this theory was proposed.

The membership function to the set, introduced in the fuzzy set theory, in the case of solving some complex decision-making problems has not been sufficient, or its determination was difficult. Therefore, some extensions of the fuzzy set theory are proposed.

For example, Atanassov (1986) proposed intuitionistic fuzzy sets by introducing non-membership function. After that, Atanassov and Gargov, (1989) proposed the moreefficient use of the intuitionistic fuzzy set theory by introducing more flexible approach for determining boundaries of membership function, or more precisely said, they introduced the usage of intervals for determining boundaries of membership function and so they made intuitionistic fuzzy setsmore flexible and practical for solving complex decision-making problems.

The lack of non-membership function, identified in fuzzy set theory, has been successfully solved in anintuitionistic set theory. However, the lack of a measure that would show a gap between membership and non-membership functions remains present in intuitionistic set theory, where it is determined as difference between membership functions.

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Finally, Smarandache (1998) introduced the neutrosophic set as generalization the concepts of the classical sets, fuzzy sets and other fuzzy sets based theories, and so provide very flexible approach for dealing with membership, non-membership and indeterminacy functions.Smarandache(1998) and Wang*et al*. (2010) further introduced the single valued neutrosophic sets that are more suitable for solving many real-world decision-making problems.

However, various types of fuzzy numbers, including neutrosophic numbers, are becoming more and more complex compared to crisp numbers. It is certain that the mentioned types of numbers have their advantages. However, the use of such numbers can become rather complex in the case of data collection, especially when data are collected by interviewing respondents who are not pre-prepared for the use of such numbers.

In the past period, many researchers are dedicated to the use of neutrosophic numbers for solving a number of different problems, while problems related to data collection and assessment of their reliability are marginalized.

Therefore, the rest of the manuscript is organized as follows: in Section 2, the basic elements of neutrosophic sets are considered and in Section 3, a procedure for estimating data reliabilityis proposed. Section 4 presents a new innovative procedure for evaluating alternatives whereas in Section 5 its usability is demonstrated in numerical illustration. Finally, the conclusion are given.

Preliminaries

Definition 1. *Neutrosophic set*. Let Xbe the universe of discourse, with a generic element in X denoted by x. Then, the neutrosophic set A in X is as follows(Smarandache, 1999):

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

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, $T_A, I_A, F_A : X \to]^-0,1^+[$ and $^-0 \leq T_A(\text{x})+I_A(\text{x})+U_A(\text{x}) \leq 3^+$.

Definition 2.*Single valued neutrosophic*set.Let X be the universe of discourse. The Single Valued Neutrosophic Set(SVNS) A over X is an object having the form(Smarandache, 1998, Wang *et al.* 2010):

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

where$T_A(x)$, $I_A(x)$ and $F_A(x)$ are the truth-membership function, the intermediacy-membership function and the falsity-membership function, respectively, $T_A, I_A, F_A : X \to [0,1]$ and $0 \leq T_A(\text{x})+I_A(\text{x})+U_A(\text{x}) \leq 3$.

Definition 3.*Single valued neutrosophic number*.For an SVNS A in X, the triple $< t_A, i_A, f_A >$ is called the single valued neutrosophic number (SVNN)(Smarandache, 1999).

Definition 4. *Basic operations onSVNNs*. Let $x_1 = < t_1, i_1, f_1 >$ and $x_2 = < t_2, i_2, f_2 >$ be two SVNNs and $\lambda > 0$; then, the basic operations are defined as follows:

$$x_1 + x_2 =< t_1 + t_2 - t_1 t_2, i_1 i_2, f_1 f_2 >. \quad (3)$$

$$x_1 \cdot x_2 =< t_1 t_2, i_1 + i_2 - i_1 i_2, f_1 + f_2 - f_1 f_2 >. \quad (4)$$

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

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

Definition 6.*Single valued neutrosophic average*.Let $a_i =< t_i, i_i, f_i >$ be a collection of SVNNs and $W = (w_1, w_2, ..., w_n)^T$ be an associated weighting vector. Then the Single Valued Neutrosophic Weighted Average (SVNWA)operatorof$a_j$is as follows(Smarandache, 2014):

$$SVNWA(a_1, a_2, ..., A_n) = \sum_{j=1}^{n} w_j a_j = \left(1 - \prod_{j=1}^{n}(1-t_j)^{w_j}, \prod_{j=1}^{n} i_j^{w_j}, \prod_{j=1}^{n} f_j^{w_j}\right), \quad (7)$$

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

Procedure for estimating data reliability

In this section, an approach for estimating reliability of SVNN, as well as thecollection of SVNNs, is introduced.

Definition7. *Reliability of information contained in a SVNN*. Let $x =< t, i, f >$ be a SVNN. Then, the reliability of information contained in SVNN x is as follows:

$$r_{(x)} = \frac{t-f}{1+i^{1/n}} \quad (8)$$

where: $r_{(x)} \in [-1,1]$ and $r_{(x)} \to 0$ indicates the lack of the reliability of the information contained in$x$.

Example. Let x=<0.80, 0.10, 0.30> be a SVNN. Then$r_{(x)}$is 0.45 for$n$=1. For higher values of n, such as: 2, 3, 4, 5 and 10, $r_{(x)}$ is as follows: 0.38, 0.34, 0.31 and 0.28.
It is evident that by increasing the value of parameter n the value of r decreases, which could be very successful for analyzing different decision-making scenarios.

Definition 8. *Reliability of information contained in a collection of SVNNs*.Let $x_i =< t_i, i_i, f_i >$ be a collection of SVNNs. Then, the average reliability of collection $x_i$is as follows:

$$ra_{(x_i)} = \frac{1}{L}\sum_{l=1}^{L} r_{(x_i)} \quad (9)$$

where$L$ denotes the number of elements of the collection.

Example. Let $x_i$be a collection of SVNNs. The collection x_i and the values of their $r$and ra functions are accounted for in Table 1,

Table 1: *The reliability and overall reliability of the collection of SVNNs*

		r_i
x_1	<0.80, 0.10, 0.30>	0.45
x_2	<0.70, 0.10, 0.20>	0.45
x_3	<0.70, 0.10, 0.10>	0.55
	ra	0.48

Procedure for assessing the reliability of the information contained in an evaluation matrix can be precisely described by the following steps:

Step 1. Determine the reliability of data contained in each element of the evaluation matrix, using Eq. (8).

Step 2. Determine the reliability of data contained in the evaluation matrix, or its rows or columns, using Eq. (9).

A new innovative procedure for evaluating alternatives

A group multiple criteria decision-making procedure usually begins with a team of experts and / or decision-makers who will perform the evaluation. At the very beginning they define goal, or goals, that should be reached by the evaluation, define a set of evaluation criteria and identify available alternatives. By this time, they also determine the significances, often called weights, of criteria.

The remaining part of the evaluation procedure can be precisely described by the following steps:

- Evaluate alternatives in relation to the select of evaluation criteria. In this step each expert and / or decision-maker forms its individual evaluation matrix, which elements are SVNNs.
- Check the data reliability. In this step, based on the procedure for estimating data reliability, reliability of each expert and/or decision-maker is calculated. If the reliability of any evaluation matrix is under minimally acceptable level, it should be reconsidered or omitted from further calculations.
- Construct a group evaluation matrix. The group evaluation matrix is formed on the basis of evaluation matrix formed by using Eq. (8).
- Calculate the overall rating for each alternative by using Eq (9).
- Determine the ideal point.
- Determine the Hamming distance of each alternative to the ideal point.
- Rank the alternatives according to their distances to the ideal point and select the most appropriate ones. In this approach, the alternative with least distance to the ideal point is the most appropriate one.

Numerical Illustration

In this section, the usability of the proposed approach is demonstrated on the basis of a numerical illustration adopted Stanujkic et al. (2016). In this numerical illustration, three traditional restaurants were evaluated based on the following criteria:

- C_1: the interior of the building and the friendly atmosphere,
- C_2: the helpfulness and friendliness of the staff,
- C_3: the variety of traditional food and drinks,

– C_4: the quality and the taste of the food and drinks, including the manner of serving them, and
– C_5: the appropriate price for the quality of the services provided.

In order to explain the proposed approach, three completed surveys have been selected. The ratings of the evaluated alternativesobtained on the basis of the three surveys are given in Tables 2 to 4.

Table 2: *The ratings obtained from the first of three respondents expressed in the form of SVNN*

	C_1	C_2	C_3	C_4	C_5
A_1	<0.80, 0.10, 0.30>	<0.70, 0.20, 0.20>	<0.80, 0.10, 0.10>	<1.00, 0.01, 0.01>	<0.80, 0.10, 0.10>
A_2	<0.70, 0.10, 0.20>	<1.00, 0.10, 0.10>	<1.00, 0.20, 0.10>	<1.00, 0.01, 0.01>	<0.80, 0.10, 0.10>
A_3	<0.70, 0.10, 0.10>	<1.00, 0.10, 0.10>	<0.70, 0.10, 0.10>	<0.90, 0.20, 0.01>	<0.90, 0.10, 0.10>

Source: *Authors' calculation*

Table 3: *The ratings obtained from the second of three respondents expressed in the form of SVNN*

	C_1	C_2	C_3	C_4	C_5
A_1	<0.80, 0.10, 0.40>	<0.90, 0.15, 0.30>	<0.90, 0.20, 0.20>	<0.85, 0.10, 0.25>	<1.00, 0.10, 0.20>
A_2	<0.90, 0.15, 0.30>	<0.90, 0.15, 0.20>	<1.00, 0.30, 0.20>	<0.70, 0.20, 0.10>	<0.80, 0.20, 0.30>
A_3	<0.60, 0.15, 0.30>	<0.55, 0.20, 0.30>	<0.55, 0.30, 0.30>	<0.60, 0.30, 0.20>	<0.70, 0.20, 0.30>

Source: *Authors' calculation*

Table 4: *The ratings obtained from the third of three respondents expressed in the form of SVNN*

	C_1	C_2	C_3	C_4	C_5
A_1	<1.00, 0.10, 0.10>	<0.90, 0.15, 0.20>	<1.00, 0.20, 0.10>	<0.80, 0.10, 0.10>	<0.90, 0.10, 0.20>
A_2	<0.80, 0.15, 0.30>	<0.90, 0.15, 0.20>	<1.00, 0.20, 0.20>	<0.70, 0.20, 0.10>	<0.80, 0.20, 0.30>
A_3	<0.60, 0.15, 0.30>	<0.55, 0.20, 0.30>	<0.55, 0.30, 0.30>	<0.60, 0.30, 0.20>	<0.70, 0.20, 0.30>

Source: *Authors' calculation*

The reliabilityof the data obtained from the first respondent are accounted for in Table 5.

Table 5: *The reliability data obtained from the first of three respondents*

	C_1	C_2	C_3	C_4	C_5	*Reliability*
A_1	0.45	0.42	0.98	0.64	0.62	0.45
A_2	0.45	0.82	0.98	0.64	0.73	0.45
A_3	0.55	0.82	0.74	0.73	0.68	0.55
Reliability	0.48	0.68	0.90	0.67	0.00	0.48
					Overall reliability	0.68

Source: *Authors' calculation*

The reliability of the data obtained from three respondents is accounted for in Table 6.

Table 6:*The reliability data obtained from three respondents*

	Reliability
E_1	0.68
E_2	0.45
E_3	0.49
Average reliability	0.54

Source: *Authors' calculation*

For the presented evaluation it was decided that the achieved level of data reliability is satisfactory, which is why it was continued with the evaluation. Contrary, in cases when the achieved level of data reliability is not satisfactory surveys with lower values of data reliability must be done again or omitted from the further calculations.

In the next step the group decision matrix is formed by using Eq. (7). The group decision matrix is shown in Table 7.

Table 7: *The group ratings of alternatives*

	C_1	C_2	C_3	C_4	C_5
w_j	0.17	0.17	0.19	0.23	0.24
A_1	<1.00, 0.10, 0.28>	<0.86, 0.17, 0.23>	<1.00, 0.17, 0.13>	<1.00, 0.07, 0.13>	<1.00, 0.10, 0.17>
A_2	<0.82, 0.13, 0.27>	<1.00, 0.13, 0.17>	<1.00, 0.23, 0.17>	<1.00, 0.14, 0.07>	<0.80, 0.17, 0.24>
A_3	<0.64, 0.13, 0.24>	<1.00, 0.17, 0.24>	<0.61, 0.24, 0.24>	<0.75, 0.27, 0.14>	<0.79, 0.17, 0.24>

Source: *Authors' calculation*

Table 6 also shows the weights of the criteria. The overall ratings of the alternatives calculated by using Eq. (7) are shown in Table 8.

Table 8: *The ranking order of alternatives*

	Overall ratings	*Distance*	*Rank*
A_1	<1.00, 0.11, 0.17>	0.00	1
A_2	<1.00, 0.16, 0.16>	0.02	2
A_3	<1.00, 0.19, 0.21>	0.04	3
Ideal point	<1.00, 0.11, 0.16>		

Source: *Authors' calculation*

Table 8 also shows the ideal point, distances of alternatives to the ideal point, as well as the ranking order of alternatives.

As it can be seen from Table 8, the best placed alternative is alternative denoted as A_1.

Conclusion

In this article, an innovative multiple criterion decision making approach for evaluating alternatives based on the use of single valued neutrosophic numbers is presented. The main advantage of this approach is the use of a procedure for estimating the reliability of the collected data, which can be especially useful when the data is collected by the survey.

Using the proposed procedure for estimating data reliability, respondents who inadequately filled out surveys can be identified and further they can be asked to fill out surveys again or their surveys can be omitted from further calculations.

As the second significant characteristic of the proposed approach is the use of Hamming distance to the ideal point for ranking alternatives.

The usability and efficiency of the proposed approach is successfully demonstrated on an example of evaluating customer satisfaction in traditional Serbian restaurants in city of Zajecar.

Finally, developing the similar procedure for estimating data reliability of bipolarneutrosophic number can be identified as a continuation of this research.

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