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AN INNOVATIVE APPROACH TO EVALUATION OF THE QUALITY OF WEBSITES IN THE TOURISM INDUSTRY: A NOVEL MCDM APPROACH BASED ON BIPOLAR NEUTROSOPHIC NUMBERS AND THE HAMMING DISTANCE

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ABSTRACT. ***Nowadays, the performance and business operations of organizations are closely linked to the quality of their websites compared to the competition. With growing market competition, the quality of websites becomes a significant component and is increasingly being explored and identified as the main factor of comparative advantage over the competition and the maintenance of good customer relationships. A multiple criteria decision-making approach based on the use of bipolar neutrosophic numbers and the Hamming distance is proposed in this paper. The main aim of this article is to emphasize the fact that MCDM models with a smaller number of criteria can be formed without a loss of precision by applying bipolar neutrosophic numbers. In addition to this, the three variants for ranging bipolar neutrosophic numbers based on the Hamming distance and a distance from the ideal point are proposed. The applicability of the proposed approach is considered in the case of website evaluation.***

KEYWORDS: bipolar neutrosophic set, Hamming distance, MCDM.

JEL classification: D81, C61, C44.

Introduction

The beginnings of the Internet use in tourism are considered to be the revolutionary changes that have completely transformed the tourism sector. Today, an increasing number of customers avoid traditional intermediaries when buying products and services in tourism – customers first obtain information on products and services and then buy them online.

The rapid developments of the Internet, the expansion of its availability and its integration with other technologies have led to significant changes in consumer behaviour when buying products and services in tourism (Verma, 2010).

Nowadays, the performance and business operations of organizations are closely linked to the quality of their websites compared to the competition. With growing market competition, the quality of websites becomes a significant component and is increasingly being explored and identified as the main factor of comparative advantage over the competition. Websites could be also important for maintenance of good customer relationships.

Therefore, the measuring of the quality of an organization's website is of particular importance for the organization. Based on the evaluation of the website quality, organizations may receive feedback on the segment which they need to improve in order to be ahead of the competition. The significance of the quality evaluation, especially when websites are concerned, are highlighted by Hsu *et al.*, (2018), Abbasi *et al.*, (2018), Chen *et al.*, (2017), Tian, Wang (2017), Wang *et al*. (2015), Al-Qeisi *et al*. (2014), Parasuraman *et al*. (1985) and so on.

A Multiple Criteria Evaluation (MCE), often referred to as Multiple Criteria Decision Analysis (MCDA), refers to the evaluation of alternatives in relation to several our often mutually conflicting criteria of a larger number.

Compared to Multiple Criteria Decision Making (MCDM), which is usually carried out with the aim of selecting one out of a set of available alternatives, the primary goal of the MCE is more often the ranking or determination of the relative importance of alternatives. Such an approach can be very useful in a competitive environment, especially when taking into consideration the fact that the entry of new players may affect the positions of the existing players in the market.

In the MCE, as well as in the MCDM, the selected set of evaluation criteria and their relative significance have a significant impact on the results of the evaluation. It is also known that a more accurate evaluation can be made by using a greater number of evaluation criteria. However, an increase in the number of the evaluation criteria can affect the increasing complexity of a proposed decision-making model, which can have a negative impact on the effectiveness and real usage of proposed MCE models.

Certain possibilities of forming the decision-making models based on the use of a smaller number of evaluation criteria, without losing precision, can be obtained based on the use of grey, fuzzy or neutrosophic numbers. In the decision-making models formed in such a manner, certain types of grey, fuzzy or neurotrophic numbers can be used to collect the ratings obtained from respondents.

Therefore, the rest of this article is structured as follows: in the first section, some significant elements of the neutrosophic sets theory are considered, with a special emphasis on the bipolar neutrosophic sets, whereas in the second section, certain approaches to the evaluation of websites are considered, with the aim of defining an effective set of evaluation criteria containing as small a number of evaluation criteria as possible. In Section Three, a framework for the evaluation of the quality of websites is proposed, and in Section Four, its use is illustrated with the aim to demonstrate its practical usability. Finally, conclusions are given.

1. The Basic Concepts of a Bipolar Neutrosophic Set

As is previously mentioned, Zadeh (1965) proposed fuzzy set theory and introduced the membership function.

Definition 1. **A Fuzzy Set** (Zadeh, 1965). Let *X* be a nonempty set. Then, a fuzzy set *A* in *X* is a set of ordered pairs:

$$A = \left\{ \langle x, \mu_A(x) \rangle \middle| x \in X \right\}, \tag{1}$$

where the membership function $\mu_A^+(x)$ denotes the degree of the membership of an element *x* to the set *A*, and $\mu_A(x) \in [0,1]$.

Atanassov (1986) extended the concept of fuzzy set theory and introduced intuitionistic fuzzy sets, which are characterized by using the membership and non-membership functions.

Definition 2. **An Intuitionistic Fuzzy Set** (Atanassov, 1986). Let *X* be a nonempty set. Then, an intuitionistic fuzzy set is defined as follows:

$$A = \left\{ \langle x, \mu_A(x), \nu_A(x) \rangle \middle| x \in X \right\}, \tag{2}$$

where: $\mu_A(x)$ and $\nu_A(x)$ represent the degree of the membership and the degree of the non-membership of the element *x* to the set *A*, respectively; $\mu_A(x) \in [0,1]$ and $\nu_A(x) \in [0,1]$, where $\mu_{A(x)}$ and $\nu_{A(x)}$ satisfy the following condition $0 \le \mu_A(x) + \nu_A(x) \le 1.$

In Intuitionistic Set Theory, Atanassov (1986) also implicitly introduced the indeterminacy-membership function $\pi_A(x)$, which is defined as $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$.

Lee (2000) introduced the notion of bipolar fuzzy sets by extending the concept of fuzzy sets, where the degree of the membership is expanded from [0, 1] to [-1, 1].

Definition 3. **A Bipolar Fuzzy Set** (Lee, 2000). Let *X* be a nonempty set. Then, a bipolar fuzzy set is defined as follows:

$$A = \left\{ \langle x, \mu_A^+(x), \nu_A^-(x) \rangle \middle| x \in X \right\}, \tag{3}$$

where: the positive membership function $\mu_A^+(x)$ denotes the satisfaction degree of the element *x* to the property corresponding to a bipolar-valued fuzzy set, and the negative membership function $\nu_A^-(x)$, denotes the degree of the satisfaction degree of the element *x* to a corresponding complementary bipolar-valued fuzzy set, respectively; $\mu_A^+ : X \to [0,1]$ and $\nu_A^- : X \to [-1,0]$.

Smarandache (1999) introduced the neutrosophic sets theory, as the generalization of fuzzy sets and intuitionistic fuzzy sets.

Definition 4. **Neutrosophic Sets** (Smarandache, 1999). Let *X* be a nonempty set. Then, Neutrosophic Set (NS) *A* in *X* is defined as:

$$A = \left\{ \left\langle x, T_A(x), I_A(x), F_A(x) \right\rangle \middle| \; x \in X \right\}, \tag{4}$$

where: $T_A(x)$, $I_A(x)$ and $F_A(x)$, denote the truth-membership $T_A(x)$, the indeterminacy-membership $I_A(x)$ and the falsity-membership functions $F_A(x)$, and $T_A, I_A, F_A : X \to]^-0,1^+[$.

In contrast to intuitionistic sets, the restriction regarding to the sum of the membership functions is eliminated, so that $^-0 \le T_A(x)+I_A(x)+U_A(x) \le 3^+$.

In 2015, Deli *et al.* (2015) introduced Bipolar Neutrosophic Sets (BNS) by generalizing the concept of bipolar fuzzy sets. Deli *et al.* (2015) also defined the Score, Certainty and Accuracy functions, as well as the Bipolar Neutrosophic Weighted Average and the Bipolar Neutrosophic Weighted Geometric operators for the BNS.

Definition 5. **Bipolar Neutrosophic Sets** (Deli *et al.*, 2015). Let X be a nonempty set. Then, a BNS A in X is as follows:

$$A = \left\{ \left\langle x, T_A^+(x), I_A^+(x), F_A^+(x), T_A^-(x), I_A^-(x), F_A^-(x) \right\rangle \middle| \; x \in X \right\}, \tag{5}$$

where: $T^+(x), I^+(x), F^+(x)$ denote the membership, the indeterminate membership and the falsity membership of x to the BNS A, and $T^-(x), I^-(x), F^-(x)$ denote the membership, the indeterminate membership and the falsity membership of x to a complemenry BNS; $T^+, I^+, F^+ : X \to [1,0]$ and $T^-, I^-, F^- : X \to [-1,0]$.

Deli *et al.* (2015) also introduced the Bipolar Neutrosophic Number (BNN), which can be denoted as follows $a =< t^+, i^+, f^+, t^-, i^-, f^- >$ for convenience.

Definition 6. (Deli *et al.*, 2015) Let $a_1 =< t_1^+, i_1^+, f_1^+, t_1^-, i_1^-, f_1^- >$ and $a_1 =< t_2^+, i_2^+, f_2^+, t_2^-, i_2^-, f_2^- >$ be two BNNs and $\lambda > 0$. The basic operations for these numbers are as follows:

$$a_1 + a_2 =< t_1^+ + t_2^+ - t_1^+ t_2^+, i_1^+ i_2^+, f_1^+ f_2^+, -t_1^- t_2^-, -(-i_1^+ - i_2^+ - i_1^+ i_2^+), -(-f_1^+ - f_2^+ - f_1^+ f_2^+) > \tag{6}$$

$$a_1 \cdot a_2 =< t_1^+ t_2^+, i_1^+ + i_2^+ - i_1^+ i_2^+, f_1^+ + f_2^+ - f_1^+ f_2^+, -(-t_1^- - t_2^- - t_1^- t_2^-), -i_1^- i_2^-, -f_1^- f_2^- > \tag{7}$$

$$\lambda a_1 =< 1-(1-t_1^+)^\lambda, (i_1^+)^\lambda, (f_1^+)^\lambda, -(-t_1^-)^\lambda, -(-i_1^-)^\lambda, -(1-(1-(-f_1^-))^\lambda) > \tag{8}$$

$$a_1^\lambda =< (t_1^+)^\lambda, 1-(1-i_1^+)^\lambda, 1-(1-f_1^+)^\lambda, -(1-(1-(-t_1^-))^\lambda), -(-i_1^-)^\lambda, -(-f_1^-)^\lambda > \tag{9}$$

Definition 7. (Deli *et al.*, 2015) Let $a =< t^+, i^+, f^+, t^-, i^-, f^- >$ be a BNN. The score function $s_{(a)}$ of an BNN is as follows:

$$s_{(a)} = (t^+ + 1 - i^+ + 1 - f^+ + 1 + t^- - i^- - f^+)/6. \tag{10}$$

Definition 8. (Deli *et al.*, 2015) Let $a_j =< t_j^+, i_j^+, f_j^+, t_j^-, i_j^-, f_j^- >$ be a collection of BNNs. The Bipolar Neutrosophic Weighted Average Operator (A_w) of the n dimensions is a mapping $A_w : Q_n \to Q$ as follows:

$$\begin{aligned} A_w(a_1, a_2, ..., a_n) &= \sum_{j=1}^{n} w_j a_j \\ &= \left(1 - \prod_{j=1}^{n} (1-t_j^+)^{w_j}, \prod_{j=1}^{n} (i_j^+)^{w_j}, \prod_{j=1}^{n} (f_j^+)^{w_j}, -\prod_{j=1}^{n} (-t_j^-)^{w_j}, -(1-\prod_{j=1}^{n} (1-(-i_j^-))^{w_j}), -(1-\prod_{j=1}^{n} (1-(-f_j^-))^{w_j}) \right) \end{aligned} \tag{11}$$

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 8. Let $a_1 = < t_1^+, i_1^+, f_1^+, t_1^-, i_1^-, f_1^- >$ and $a_2 = < t_2^+, i_2^+, f_2^+, t_2^-, i_2^-, f_2^- >$ be two BNNs. The Hamming distance between a_1 and a_2 is as follows:

$$d_H(a_1, a_2) = \frac{1}{6}\left(|t_1^+ - t_2^+| + |i_1^+ - i_2^+| + |f_1^+ - f_2^+| + |t_1^- - t_2^-| + |i_1^- - i_2^-| + |f_1^- - f_2^-| \right) \quad (12)$$

2. Choosing Criteria for Evaluating Websites

In a business environment, websites can have different purposes. Moreover, a website must often play multiple roles, such as: providing information to customers, acquiring and retaining new customers, and so on. In addition to the said, the fact that customers cannot be treated as homogeneous groups and that specific customer groups can have their own specific needs and requirements should not be ignored.

Therefore, designing, developing and maintaining an adequate website is not an easy task to do at all. After using a website for the very first time, many useful pieces of information about its functionality can be obtained by using the website's analytics tools, as well as visitors' comments.

Additionally, based on the Service Quality Model, i.e. the SERVQUAL Model, proposed by Parasuraman *et al.* (1998), several specialized models for the evaluation of websites were proposed, such as: WebQyal (Barnes, Vidgen 2000), SITEQUAL (Yoo, Donthu, 2001), eTailQ (Wolfinbarger, Gilly, 2001) and E-S-SERVQUAL (Parasuraman *et al.*, 2005).

The alleged models, as well as the other models developed based on them, are successfully used to evaluate numerous websites, particularly so e-commerce, e-marketing and e-banking websites.

As a significant characteristic of the above-mentioned models, it can be emphasized that they use several dimensions and sub-dimensions for determining customer satisfaction. In the MCA and/or MCDM terminology, this means that evaluation is based on the use of multiple criteria, which have their own sub-criteria.

The evaluation models based on the use of MCDM methods can also be emphasized as a significant approach to the determination of the quality of websites. For example, Sun, Lin (2009) evaluated shopping websites by used fuzzy TOPSIS method, whereas Tsai (2010) evaluated a national park website by using the ANP and VIKOR methods.

These are not isolated research studies related to the use of the MCDM methods for evaluating websites. The following can be mentioned as some of earlier studies: Lee, Kozar (2006) and Bilsel *et al.* (2006), who used the AHP and PROMETHEE II for websites ranking.

There are also a number of recent research studies, such as those by: Abdel-Basset *et al.* (2018), who used the VIKOR method and neutrosophic numbers for evaluating e-government websites; and Stanujkic *et al.* (2017), who proposed a group multiple-criteria approach for evaluating hotels' websites, based on the use of triangular intuitionistic fuzzy numbers. Stanujkic *et al.* (2016) also proposed an approach for evaluating websites quality, based on the use of single-valued neutrosophic numbers.

As has been mentioned earlier, the selected set of evaluation criteria can significantly affect the characteristics of a proposed MCA/MCDM model. Therefore, the problem of selecting an adequate set of evaluation criteria for evaluating website has been considered in many previous studies. Kapoun (1998) and Lydia (2009) can be mentioned as some of such studies.

According to Kapoun (1998), the following criteria can be used for evaluating a website: Accuracy, Authority, Objectivity, Currency, and Coverage. Kapoun's set of criteria is often used, and based on it, similar sets of criteria are proposed. For example, Lydia (2009) adds the sixth criterion, Appearance, while the CRAAP test is proposed at the California State University of Chico, which suggests the use of the following criteria: Currency, Relevance, Authority, Accuracy, and Purpose.

However, there are also studies where appropriate, or specialized, sets of criteria are proposed for the evaluation of different types of websites. For example, Chung, Law (2003) proposed the following six criteria for evaluating websites in the hotel industry: Facilities Information, Customer Contact Information, Reservation Information, Surrounding Area Information, and Website Management, and for each criterion, appropriate sub-criteria are defined. Contrary to this, Herrero, San Martin (2012) suggested that only three criteria, namely: Information, Interactivity, and Navigability should be used.

A set of criteria proposed by the Webby Awards[1], can also be listed as a significant set of criteria for evaluating websites. This set of criteria includes the following criteria: Content, Structure and Navigation, Visual Design, Interactivity, Functionality, Innovation, and Overall Experience.

As a result, there are different approaches to selecting the criteria for websites evaluation: the use of a number of criteria and sub-criteria contrary to the use of a smaller number of criteria; the use of a standard set of criteria against the use of specialized sets of criteria, etc.

The choice of an appropriate set of evaluation selection criteria is very important for the successful solving of each MCA/MCDM problem. The use of a larger number of criteria usually leads to the formation of more precise models; on the one hand, a larger number of criteria can be less desirable if certain data should be collected through a survey.

In contrast to the said, a smaller number of criteria can be much more efficient when certain data should be collected through a survey, on the one hand, whereas on the other, the usage of a smaller number of criteria may require the use of significantly more complex criteria.

Neutrosophic numbers, particularly bipolar neutrosophic numbers, contain more information than crisp numbers, or fuzzy numbers, for which reason their application can be very beneficial when a small number of evaluation criteria are used.

Therefore, in this approach, the following three criteria are selected out of the set proposed by the Webby Awards: Structure and Navigation, Content and Visual Design.

3. The Alternative Procedure for Ranking Alternatives Based on the Hamming Distance

Deli *et al.* (2015) proposed a MCDM approach to the selection of the best alternative based on the use of the score, certainty and accuracy functions, as well the A_w and G_w operators.

In this paper, an approach based on the use of the Hamming distance is proposed. The detailed step-by-step procedure of the proposed approach can be described through the

[1] http://webbyawards.com/judging-criteria/

following steps:

Step 1. ***Identify available alternatives and select a set of evaluation criteria*****.** In this step, a team of experts identifies a set of available alternatives and defines the criteria for their evaluation.

Step 2. ***Determine the relative importance of evaluation criteria*****.** In the literature, many techniques are proposed for determining the weights of criteria, such as pair-wise comparisons (Saaty, 1980), SWARA (Kersuliene *et al.,* 2010), the Best-Worst Method (Rezaei, 2015), R-SWARA (Zavadskas *et al.,* 2018) and PIPRECIA (Stanujkic *et al.*, 2017). In this approach, any of the mentioned techniques can be used for determining the weights of the criteria.

Step 3. ***Construct a bipolar neutrosophic decision-making matrix,*** and do it for each decision-maker. In this step, each decision-maker forms his/her evaluation matrix, in which matrix alternatives are evaluated by using BNNs. As a result of these activities, each decision-maker forms his/her evaluation matrix, whose elements are BNNs.

The specificity of the BNSs is used in this step to perform a two-phase evaluation of the alternatives in relation to each criterion, where satisfaction is measured in the first phase and dissatisfaction in the second.

By using such an approach, respondents are enabled to carry out a sufficiently precise evaluation based on a smaller number of evaluation criteria.

Step 4. ***Construct a group bipolar neutrosophic decision-making matrix*****.** The integration of the individual evaluation matrices into a group decision-making matrix can be carried out by using an aggregation operator. In this approach, the use of the A_w aggregation operator is proposed for aggregating individual evaluation matrices into a group decision-making matrix.

After this step, the most appropriate alternative can be determined in several ways. As one of the most commonly used approaches, the approach based on the use of the score function can be specified. In such an approach, the value of the score function of each of the considered alternatives could be determined by applying Eq. (10). After that, the alternative with the highest value of the score function is the most acceptable one.

In addition to this, an increasing use of fuzzy sets theory, as well as its previously mentioned extensions, has had a significant impact on proposing the numerous extensions of the TOPSIS and VIKOR methods, as well as the extensions of the other MCDM methods. As a result, some other approaches are often proposed, out of which the approaches based on the distance from the ideal point can be especially emphasized. Therefore, as an alternative to applying the score function for ranking alternatives, the three variants of the distance-based approaches are considered in the remaining part of the paper, where all of the three variants are based on the Hamming distance.

The first variant. In the first of the three proposed variants, the ideal point is formed as follows: $a^+ = <1, 0, 0, 0, 0, 1>$. After that, the Hamming distances of the alternatives to the ideal point are determined by applying Eq. (12).

In this approach, the alternative with the smallest Hamming distance is the most preferable one.

The second variant. In the second variant, the ideal point is determined much more realistically, i.e. in the following manner:

$$a^+ = < \max_i t_{ij}^+, \min_i i_{ij}^+, \min_i f_{ij}^+, \max_i t_{ij}^-, \max_i i_{ij}^-, \min_i f_{ij}^- > \quad (13)$$

After that, similarly as in the first variant, the Hamming distance is determined for each alternative, and the best alternative is that with the smallest distance from the ideal point.

The third variant. Unlike the previous two variants, the third variant is based on the use of the well-known approach proposed in the TOPSIS method, i.e. the determination of the distances of the alternatives from the ideal and the anti-ideal points, and the determination of the relative closeness C_i of each such alternative, as follows:

$$c_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{14}$$

In the proposed approach, d_i^+ and d_i^- denote the Hamming distance of the alternative *i* from the ideal and the anti-deal points, respectively, the ideal point being determined as in the previous variant, and the anti-ideal point being determined as follows:

$$a^+ = < \min_i t_{ij}^+, \max_i i_{ij}^+, \max_i f_{ij}^+, \min_i t_{ij}^-, \min_i i_{ij}^-, \max_i f_{ij}^- > \tag{15}$$

Finally, the most acceptable alternative based on the third variant is the alternative that has the highest C_i.

4. A Numerical Illustration

In this numerical illustration, the proposed approach is used to evaluate the websites of the four regional tourism organizations, at the following web addresses:

- http://tookladovo.rs,
- http://www.toom.rs,
- http://tobor.rs, and
- http://toon.org.rs.

The evaluation was made in order to compare the quality of the website of one of the mentioned tourism organizations in relation to the others, whereby the respondents were not awarded with the main goal of the evaluation in advance. For the same reason, the order of the alternatives in the remaining segment of the numerical example is not identical with the appearance of the aforementioned alternatives.

In order to create the conditions for conducting this study, several potential respondents were introduced by applying bipolar intuitionist sets and the SWARA method.

For the purpose of this consideration, the responses obtained from the three selected respondents are chosen. The opinions related to the weights of the criteria, the weights of criteria and the ratings obtained from the first of the three respondents are presented in *Table 1* and *Table 2*.

Table 1. The opinions and the weights of the criteria obtained from the first of the three respondents

Criteria		s_j	k_j	q_j	w_j
Structure and Navigation	C_1		1.00	1.00	0.30
Content	C_2	1.20	0.80	1.25	0.37
Visual Design	C_3	0.90	1.10	1.14	0.34
			2.90	3.39	

Source: own calculations.

Table 2. The ratings obtained from the first of the three respondents

	C_1	C_2	C_3
w_j	0.30	0.37	0.34
A_1	<0.7, 0.2, 0.3, -0.3, 0, 0>	<0.7, 0, 0.1, -0.2, 0, 0>	<0.7, 0.1, 0, -0.3, 0, 0>
A_2	<0.7, 0, 0.2, -0.2, 0, -0.1>	<0.6, 0, 0.1, -0.3, 0, 0>	<0.4, 0, 0.2, -0.2, 0, 0>
A_3	<0.6, 0, 0, -0.7, 0, 0>	<0.7, 0, 0, -0.4, 0, 0>	<0.4, 0, 0.2, -0.2, 0, 0>
A_4	<0.9, 0, 0, -0.7, 0, 0>	<0.3, 0.2, 0, -0.1, 0, 0>	<0.6, 0, 0, 0, 0, 0>

Source: own calculations.

The opinions obtained from the three surveys, as well as the appropriate weights, are accounted for in *Table 3*.

Table 3. The opinions and the weights of criteria obtained from the three respondents

	E_1		E_1		E_1	
	s_j	w_j	s_j	w_j	s_j	w_j
C_1		0.30		0.34		0.38
C_2	1.20	0.37	1.00	0.34	1.10	0.34
C_3	0.90	0.34	0.90	0.31	1.20	0.28

Source: own calculations.

The group criteria weights calculated as the average value of the criteria weight from Table 3 are shown in *Table 4*.

Table 4. The group criteria weights

	w_j
C_1	0.34
C_2	0.35
C_3	0.31

Source: own calculations.

The ratings of the alternatives expressed in terms of the BNNs obtained from the second and the third respondents are given in *Table 5* and *Table 6*.

Table 5. The ratings obtained from the second respondent

	C_1	C_2	C_3
A_1	<0.7, 0.2, 0.3, -0.3, 0, 0>	<0.7, 0, 0.1, -0.2, 0, 0>	<0.7, 0.1, 0, -0.3, 0, 0>
A_2	<0.7, 0, 0.2, -0.2, 0, -0.1>	<0.6, 0, 0.1, -0.3, 0, 0>	<0.4, 0, 0.2, -0.2, 0, 0>
A_3	<0.6, 0, 0, -0.7, 0, 0>	<0.7, 0, 0, -0.4, 0, 0>	<0.4, 0, 0.2, -0.2, 0, 0>
A_4	<0.9, 0, 0, -0.7, 0, 0>	<0.3, 0.2, 0, -0.1, 0, 0>	<0.6, 0, 0, 0, 0, 0>

Source: own calculations.

Table 6. The ratings obtained from the third respondent

	C_1	C_2	C_3
A_1	<0.7, 0.2, 0.3, -0.3, 0, 0>	<0.9, 0, 0, 0, 0, 0>	<0.5, 0, 0.1, -0.2, 0, 0>
A_2	<0.7, 0, 0.2, -0.2, 0, -0.1>	<0.9, 0, 0.3, -0.1, 0, 0>	<0.5, 0, 0, -0.3, 0, 0>
A_3	<0.6, 0, 0, -0.7, 0, 0>	<0.9, 0, 0.2, -0.5, 0, -0.3>	<0.5, 0, 0, -0.7, 0, -0.2>
A_4	<0.9, 0, 0, -0.7, 0, 0>	<0.3, 0.2, 0, 0, 0, 0>	<0.5, 0, 0, 0, 0, 0>

Source: own calculations.

The group ratings calculated by applying Eq. (11) are accounted for in *Table 7*. In this calculation, the following weights are assigned to the respondents: w_{E1}=0.35, w_{E2}=0.33, and w_{E3}=0.32.

Table 7. The group ratings

	C_1	C_2	C_3
A_1	<0.7, 0.2, 0.3, -0.3, 0, 0>	<0.79, 0, 0, 0, 0, 0>	<0.65, 0, 0, -0.26, 0, 0>
A_2	<0.7, 0, 0.2, -0.2, 0, -0.85>	<0.74, 0, 0.14, -0.21, 0, 0>	<0.43, 0, 0, -0.23, 0, 0>
A_3	<0.6, 0, 0, -0.7, 0, 0>	<0.79, 0, 0, -0.43, 0, -0.68>	<0.43, 0, 0, -0.3, 0, -0.6>
A_4	<0.9, 0, 0, -0.7, 0, 0>	<0.3, 0.2, 0, 0, 0, 0>	<0.57,0,0,0,0,0>

Source: own calculations.

The overall ratings calculated by applying Eq. (11), as well as the ranking order of the alternatives, are presented in *Table 8*.

Table 8. The overall ratings, the score and the ranking order of the considered alternatives

	Overall ratings	S_i	Rank
A_1	<0.72, 0, 0, 0, 0, 0>	3.72	3
A_2	<0.65, 0, 0, -0.21, 0, -0.95>	4.39	1
A_3	<0.64, 0, 0, -0.45, 0, -0.98>	4.17	2
A_4	<0.69, 0, 0, 0, 0, 0>	3.69	4

Source: own calculations.

As can be seen from *Table 8*, the most acceptable alternative based on the Score Function is the alternative denoted as A_2.

The results achieved by using the Hamming distance and the three proposed variants are considered in the rest of this section. The results obtained by using the first of the three considered variants are demonstrated in *Table 9*.

Table 9. The overall ratings, the Hamming distances and the ranking order of the considered alternatives

	Overall ratings	d_H	Rank
a^+	<1, 0, 0, 0, 0, 0>		
A_1	<0.72, 0, 0, 0, 0, 0>	0.21	3
A_2	<0.65, 0, 0, -0.21, 0, -0.95>	0.10	1
A_3	<0.64, 0, 0, -0.45, 0, -0.98>	0.14	2
A_4	<0.69, 0, 0, 0, 0, 0>	0.22	4

Source: own calculations.

As can be seen from *Table 9*, the ranking orders obtained by using the Score Function and the first of the three proposed variants based on the Hamming distance are identical.

The results obtained by using the second of the three considered variants are shown in *Table 10*.

Table 10. The ranking of the alternatives based on the second of the three proposed variants

	Overall ratings	d_H	Rank
a^+	<0.72, 0, 0, 0, 0, -0.98>		
A_1	<0.72, 0, 0, 0, 0, 0>	0.16	3
A_2	<0.65, 0, 0, -0.21, 0, -0.95>	0.05	1
A_3	<0.64, 0, 0, -0.45, 0, -0.98>	0.09	2
A_4	<0.69, 0, 0, 0, 0, 0>	0.17	4

Source: own calculations.

As can be seen from *Table 10*, the ranking orders obtained by using the second variant of the three proposed variants based on the Hamming distance is the same as in the previously considered cases. However, we should be careful because Stanujkic (2013) indicates that, in some cases, the ideal point may have an effect on the ranking order of alternatives.

Ultimately, the results obtained by applying the third proposed variant are shown in *Table 11*.

Table 11. The ranking of the alternatives based on the third of the three proposed variants

	Overall ratings	d_i^+	d_i^- -	C_i	Rank
a^+	<0.72, 0, 0, 0, 0, -0.98>				
a^-	<0.64, 0, 0, -0.45, 0, 0>				
A_1	<0.72, 0, 0, 0, 0, 0>	0.16	0.09	0.35	3
A_2	<0.65, 0, 0, -0.21, 0, -0.95>	0.05	0.20	0.79	1
A_3	<0.64, 0, 0, -0.45, 0, -0.98>	0.09	0.16	0.65	2
A_4	<0.69, 0, 0, 0, 0, 0>	0.17	0.08	0.33	4

Source: own calculations.

The results shown in *Table 11* also confirm the fact that the ranking results obtained by using the third variant based on the Hamming distance are identical with the results obtained by using the procedure for ranking BNNs, proposed by Deli *et al.* (2015).

Conclusion

Bipolar neutrosophic numbers contain more information than the other types of fuzzy or crisp numbers. In addition, these numbers can be used to carry out a two-phase evaluation of the alternative in relation to the selected criteria, where satisfaction is measured in the first phase and dissatisfaction in the second.

By applying such an approach, respondents are enabled to perform a sufficiently precise evaluation, based on a smaller number of criteria.

However, it should be emphasized that the use of bipolar neutrosophic numbers is not so simple in the case of pre-unmanaged subjects.

This paper also proposes a group multiple criteria approach based on the Hamming distance application. The numerical illustration shows that the application of this approach generates the same ranking results as is the case with the application of the Score, which confirms the applicability of the proposed approach.

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NAUJAS POŽIŪRIS Į VERTYBINĮ TURIZMO SEKTORIAUS SVETAINIŲ VERTINIMĄ: BIPOLINIAIS NEUTROSOFINIAIS SKAIČIAIS IR HEMINGO ATSTUMU GRINDŽIAMAS NAUJAS KOMBINUOTAS DAUGIAKRITERINIŲ SPRENDIMŲ PRIĖMIMO METODAS

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SANTRAUKA

Šiandienos organizacijų darbas ir jų veikla yra glaudžiai susijusi su jų svetainių kokybe dėl konkurencijos. Augant konkurencijai rinkoje, interneto svetainių kokybė tampa svarbia dedamąja bei vis dažniau tiriama ir nurodoma kaip pagrindinis santykinio pranašumo prieš konkurentus ir gerų klientų santykių palaikymo veiksnys. Šiame straipsnyje siūlomas daugiakriterinis sprendimų priėmimo metodas (angl. MCDM), pagrįstas bipolinių neutrosofinių skaičių ir Hemingo atstumo taikymu. Straipsnio tikslas yra pabrėžti tai, kad mažesnius kriterijus turintys MCDM modeliai gali būti sudaromi taikant priešingus neutrosofinius skaičius ir dėl to nenukenčia tikslumas. Be to, siūlomi trys variantai, skirti bipolinių neutrosofinių skaičių skaičiavimams pagal Hemingo atstumą ir atstumą nuo idealaus taško. Siūlomo metodo taikomumas apžvelgiamas vertinant svetainę.

REIKŠMINIAI ŽODŽIAI: bipolinė neutrosofinė aibė, Hemingo atstumas, bendras, MCDM.