Neutrosophic Sets and Systems

Volume 37 Article 14

1-1-2020

Experts' Selection for Neutrosophic Delphi Method. A Case Study of Hotel Activity

Vladimir Vega Falcón

Belkis Sánchez Martínez

Fernando Castro Sánchez

Neutrosophic Sets and Systems
{Special Issue: Impact of neutrosophy in solving the Latin American's social problems}, Vol. 37, 2020
University of New Mexico

Experts' Selection for Neutrosophic Delphi Method. A Case Study of Hotel Activity

Vladimir Vega Falcón [1], Belkis Sánchez Martínez[2], and Fernando Castro Sánchez[3]

[1] Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: ua.vladimirvega@uniandes.edu.ec
[2] Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: ua.belkissanchez@uniandes.edu.ec
[3] Universidad Regional Autónoma de Los Andes, Ecuador. E-mail: ua.fernandocastro@uniandes.edu.ec

Abstract. This investigation aims to model experts' selection for neutrosophic Delphi method. The phase of selecting experts is essential to obtain adequate results in Delphi method, thus this phase deserves a major attention. The proposed method considers the complexity of the subject, according to experts' criteria to fix the number of experts necessary to apply the neutrosophic Delphi method. Single-valued triangular neutrosophic numbers are used to measure experts' self-evaluations and the weights of expertise criteria. Neutrosophy allows us to include indeterminacy, which is typical in any decision-making problem, as well as the calculation based on linguistic terms. Hotel activity serves as a case study for illustrating the applicability of the method in a real life situation.

Keywords: Neutrosophic logic, neutrosophic Delphi method, expert selection process, intellectual capital.

1 Introduction

Among the qualitative methods, Delphi is one of the most widely used in scientific researches. This method is applied to solve many types of problems. Among them, we may find the topic identification in a research, to elaborate instruments for the analysis and collection of information, thus, it is broadly applied in social sciences [1].

Scientific literature reports that this method has been used in different fields like, economy [2], where it was introduced for the first time, as a predictive tool of technological aspects and also as a validation system for information collection tools. Its popularity can be verified in [3], where about 500 publications containing this are reckoned up to the year 1974.

Delphi method is a prospective, expert-based method [4, 5] which is defined as a systematic iterative process aimed to obtain opinions and, if possible, consensus, of a group of experts [6], considering experts those specialist who have a close relationship on the issue, sector, technology or object of investigation [6]. This methodology is appropriate to obtain information from experts based on their knowledge and their ability to analyze the consulted items. It becomes suitable especially in areas of knowledge, which are usually complex, dynamic, ambiguous and lacking of information, [4].

Delphi technique was developed in 1950 by the RAND Corporation of Santa Monica, California [7] with the goal to investigate the impact of technology in the war. The name is derived from the Oracle of Delphi, which was a popular oracle dedicated to the god Apollo in ancient Greece, inspired by its application as a prospective technique [1].

There are several ways of applying Delphi method [3], e.g., with one or two iterations depending on the degree of agreement between the panelists. During this procedure, after every round, panelists' responses are qualitatively and quantitatively analyzed. Usually they are statistically processed by using medians and confidence intervals. Delphi method aims to achieve as much as possible the consensus among the panelists. Empirically, variance of the panelists' responses for each round is used to measure consensus.

Currently, there are several variants of Delphi method rather than the classical one. Each type has its pros and cons based on the field of application [8]. The different changes of this technique have caused significant criticism, which negatively affects its reliability and validity. Selecting a Delphi method variant depends on the problem object of study. This selection depends on the algorithm's characteristics, the number of rounds, anonymity, feedback, sampling, and analysis, among other aspects, [8]. The criteria or opinions issued by experts constitute the examining aspect of the technique, which may be affected by some variables associated with the specialists involved in the research. The indicators to be considered are: years of experience, qualification, and knowledge referred to the problem to study.

This investigation aims to describe a procedure for experts' selection for neutrosophic Delphi method, which is exemplified with hotel activity. This is a real-life case applied to tourism management, specifically to measure intellectual capital in one of the hotels of Meliá Group in Cuba.

Expert criterion occupies a significant place between the methods of empirical research in the sciences [9-12], based on the consultation of people who have deep knowledge about the object of study. There is consent that collective judgment exceeds the insignificant sum of individual results. The available information is continually more opposed than that available to the most qualified participants [3], and of course, when working with a group of experts, one of the main underlying premises is the assumption that a large number of expert judgments are required to adequately deal with any problem. Although generally a face-to-face exchange between the members of the group would be inefficient or impossible due to the cost and time needed for all parties to meet.

In literature, there is no consensus regarding the different methods for choosing experts, such as the selection of individuals, the choice of the best method to use for a particular problem situation although in the state of the art, the method of the greatest application has been the so-called Delphi method [4]. There are other methods applicable to the solution of organizational problems, among which stand out the methods of individual aggregates, the Nominal Group technique and the Group Consensus method. The prediction capacity of the Delphi method is based on the systematic use of an intuitive judgment exposed by a group of experts. The quality of the results is mainly due to the care taken in the preparation of the questionnaire and in the election of the consulted experts.

For the authors, an expert is the individual or group of people or organizations capable of offering conclusive assessments for a particular problem. They are who make recommendations regarding their fundamental moments, with a maximum of competence. In this regard, it is important that prior to considering a work group, the principal investigator or facilitator studies experts' universe linked to the subject. They have to examine and then select the most competent experts.

Neutrosophy is the branch of philosophy related to neutralities. Neutralities are produced by a lack of information, contradictions, the unknown, inconsistencies, and so on, in human's information and knowledge. One component of decision-making is indeterminacy. Neutrosophic logic contains three elements, one of truthfulness, another of indeterminacy, and a third one of falseness. The three are independent from each other.

Using neutrosophic experts' selection for neutrosophic Delphi method guarantees to take into account the uncertainty and indeterminacy we deal with when this phase is carried out. We based our solution on the neutrosophic Delphi method introduced in [13, 14]. Here we generalize to the neutrosophic framework the first phase of the implementation of the well-known modified Delphi method, in a version elaborated by Kaufmann and Gil Aluja in [15] known as Fuzzy-Delphi. In this version, expert theory is incorporated as a valuable tool, which allows us to aggregate the opinion of several experts so that it is transformed into a single truly representative opinion of all of them, that allows to perform the measurement of intellectual capital [16]. The advantage over fuzziness is that neutrosophic framework explicitly contains indeterminacy, thus the results are more accurate than fuzzy theory[17]. We have to highlight the application of a neutrosophic Delphi method for evaluating scientific research proposals that can be read in [14].

The intellectual capital in hotel activity [18] is used as a real case study for applying the proposed neutrosophic method, due to the importance of this subject; this example illustrates well the applicability of the method.

This paper is divided into the following structure. The section of materials and methods contains the main concepts of Neutrosophy, as well as some important aspects of Delphi method. Next section is dedicated to introduce the expert selection method for the neutrosophic Delphi we propose, and to illustrate it with a case study. Finally, last section announces the conclusions of the paper.

2 Materials and Methods

This section describes the preliminaries on Delphi method in subsection 2.1, whereas the main concepts of Neutrosophy are described in subsection 2.2.

2.1 Preliminaries on Delphi method

Delphi method allows expert groups to be consulted on a wide range of possible future developments in their respective fields of action.

The main characteristics of the original Delphi method are the following:

Anonymity: There should be no physical contact between the participants, but the survey administrator can identify each participant and their responses.

Iteration: It can handle as many rounds as necessary.

Controlled feedback: the total results of the previous round are not delivered to the participants, only a selected part of the information circulates.

Statistical results: the group response can be presented statistically (mean and dispersion degree).

Delphi method has the following phases:

1. The group of experts that will design the questionnaire is formed.
2. Participants (experts and non-experts in the specific topic of the survey) are selected.
3. The questionnaire is circulated among the participants (First Round).
4. The answers are analyzed, and the necessary clarifications can be requested from the participants and a second questionnaire is prepared.
5. The second questionnaire is circulated among the participants, and they can re-evaluate their opinion in the light of the other participants´ opinions.
6. Many Rounds as necessary can be carried out until it is noticed that opinions have been consolidated.
7. Finally, the information is summarized and presented, indicating the average values and their dispersion, and it is analyzed by expert groups.

Table 1 summarizes the main variants of Delphi method, classified by their purpose, from the point of view of experts' participation and methodologies.

Delphi variant	Purpose	Experts participation	Methodology
Classical	To collect opinions and seek consensus.	Experts are selected based on the objectives of the research.	The elaborated instrument is sent by regular mail during the development of each planned round. In the first round, a qualitative analysis is carried out, the rest of rounds are concluded with a quantitative type analysis.
Modified	The purpose depends on the research, e.g., to predict and to seek group consensus.	Experts are selected based on the objectives of the research.	The elaborated instrument is sent by regular mail during the development of the first three rounds. The pre-selected articles in the specialized literature on the subject should be analyzed in both, their theoretical and practical content.
Decision	To make decisions and forecast.	Decision makers, with high hierarchical position/expertise.	From the elaborated instrument, experts' decisions are issued, and this result is sent by regular or electronic mail, after the rounds of application of the method.
Policy	To generate contrasting views on policy and possible solutions.	Policy makers qualified to suggest different alternatives.	The elaborated instrument is sent by email and it is analyzed in group meetings during the different rounds necessary to apply the method.
Real time	To elicit opinion and seek consensus in real time rather than postal.	Experts are selected based on the research goals and are available in the assigned time.	The elaborated instrument is analyzed according to the answers received on the same date and place. The first qualitative round is opened, and the rest of the rounds are concluded with their quantitative analysis.
Online	The purpose depends on the research, e.g., to predict and to seek group consensus.	Experts are selected based on the objectives of the research.	In the elaborated instrument, the conduct of the participants is reviewed via online contact, by means of chat rooms or web forms. The first round is opened in its qualitative analysis and the rest of them are concluded in its quantitative analysis.

Table 1: .List of Delphi variants and their purposes. Source: adapted from [8].

Some advantages of Delphi method are:

• It allows obtaining information on points of view in very broad or very specific topics.
• The analysis horizon can be varied.
• It allows the participation of a large number of people, without chaos.

Some disadvantages of Delphi method are:

• It has a high cost due to the amount of people and resources it requires.
• Its execution time can be quite long, from the formulation period to obtain the final results.
• It requires massive participation for the results to have statistical significance. However, the group must have a high degree of correspondence with the topics to be covered in the exercise.
• A critical part of the method is the questions in the questionnaire.

2.2 Main concepts of Neutrosophy

Definition 1: [19-23] The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsehood-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-0, 1^+[$, and $^-0 \leq \inf T_A(x) + \inf I_A(x) +$

$\inf F_A(x) \le \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \le 3^+$.

Notice that according to Definition 1, $T_A(x), I_A(x), F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x), I_A(x), F_A(x)$ can be subintervals of $[0, 1]$.

Definition 2: ([19-23]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{< x;\ T_A(x), I_A(x), F_A(x) > : x \in U\}$, where $T_A: U \to [0,1]$, $I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$.

The *Single-Valued Neutrosophic number* (SVNN) [24] is expressed by $N = (t, i, f)$, such that $0 \le t, i, f \le 1$ and $0 \le t + i + f \le 3$.

Definition 3: [19-23] The *single-valued triangular neutrosophic number* $\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on ℝ, whose truth, indeterminacy and falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \le a_3 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \le a_3 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \le a_3 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0, 1]$, $a_1, a_2, a_3 \in \mathbb{R}$ and $a_1 \le a_2 \le a_3$.

Definition 4: [19-23] Given $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued triangular neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: $\tilde{a}^{-1} = \langle (a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \ne 0$.
4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$

5. Division of two triangular neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 > 0 \textit{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \textit{ and } b_3 > 0 \\ \langle \left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$

6. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 > 0 \textit{ and } b_3 > 0 \\ \langle (a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 > 0 \\ \langle (a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_3 < 0 \textit{ and } b_3 < 0 \end{cases}$$

Where, ∧ is a t-norm and ∨ is a t-conorm.

Let $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ be a single valued triangular neutrosophic number, then,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (4)$$

$$\mathbf{A}(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (5)$$

They are called the score and accuracy degrees of $\tilde{a}$, respectively.

Let $\{\widetilde{A}_1, \widetilde{A}_2, \cdots, \widetilde{A}_n\}$ be a set of n SVTNNs, where $\widetilde{A}_j = \langle (a_j, b_j, c_j); \alpha_{\tilde{a}_j}, \beta_{\tilde{a}_j}, \gamma_{\tilde{a}_j} \rangle$ (j = 1, 2, …, n), then the *weighted mean of the SVTNNs* is calculated with the following Equation:

$$\widetilde{A} = \sum_{j=1}^{n} \lambda_j \widetilde{A}_j \quad (6)$$

Where λ_j is the weight of A_j, $\lambda_j \in [0, 1]$ and $\sum_{j=1}^{n} \lambda_j = 1$.

Two scales of measurement used in the method are summarized in Tables 2 and 3, see [14].

Linguistic terms	SVTNN
Extremely unimportant (EU)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Not very important (NVI)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Not important (NI)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium (M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
Important (I)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Very important (VI)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Extremely important (EI)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 2. Importance weight as linguistic variables and their associated SVTNN. Source: [14].

Linguistic term	SVTNN
Very low (VL)	$\langle (0,0,1); 0.00, 1.00, 1.00 \rangle$
Medium low (ML)	$\langle (0,1,3); 0.17, 0.85, 0.83 \rangle$
Low (L)	$\langle (1,3,5); 0.33, 0.75, 0.67 \rangle$
Medium(M)	$\langle (3,5,7); 0.50, 0.50, 0.50 \rangle$
High (H)	$\langle (5,7,9); 0.67, 0.25, 0.33 \rangle$
Medium high (MH)	$\langle (7,9,10); 0.83, 0.15, 0.17 \rangle$
Very high (VH)	$\langle (9,10,10); 1.00, 0.00, 0.00 \rangle$

Table 3: Linguistic terms for evaluations associated with SVTNN. Source: [14].

3 Results

In this paper, the proposed procedure is exposed in detail. The *Competence Coefficient* (K) determines the experts' competence, which can be calculated by different procedures according to [25], such as the ones listed below:

- Based on the *Knowledge Coefficient* (Kc) and the *Coefficient of Argumentation* (Ka) in this procedure, the experts' competence is determined by the competence coefficient (K), to measure their level of knowledge about the problem and with the sources that allow us to argue these criteria (Ka), [26].
- From the *Coefficient of Theoretical Knowledge* and the *Coefficient of Practical Knowledge*.

In the procedure for the selection of experts, we considered three fundamental stages as described in Table 4:

Stages	Subject content
Stage 1: Preparation of experts' list	In the elaboration of the experts' list, a study is carried out on their quality and their workplace is also considered, as well as their real possibility of collaboration. Internal experts (belonging to the organization) and external experts (belonging to academic or business institutions) may be included in the list.
Stage 2: To fix the number of experts	With respect to this stage, the number of experts should be less or equal to (nα), where α is a numeric value included in the interval [0.1, 1], while parameter n represents the number of elements to measure in the study. According to the proposition that appears in [16] α is defined by the principal investigator, however in this paper we propose to aggregate expert's opinion for obtaining α, despite the other way is not rejected. After defining n, it is multiplied by the selected α, resulting in the number of experts to choose.
Stage 3: Experts issue their consent to participate in the investigation	During this stage, official invitation is sent to explain the pursued goal and what the work consists of; they have to fill the questionnaire about personal data and the competence they have. Once the response is obtained, the final experts' list is determined, after which the specialists are informed about their inclusion in the experts' opinion.

Table 4: .Structure of the proposed procedure for experts' selection. Source: The authors.

Considering the subject of study, it is important to judge the complexity of the knowledge with regard to the research problem, as shown in Table 5.

Very complex or not sufficiently-known topic	Moderately complex or sufficiently known topic	Simple or well-known topic
$\alpha \in [0.1, 0.4)$	$\alpha \in [0.4, 0.7)$	$\alpha \in [0.7, 1]$

Table 5: .Values of α classified according to the subject complexity. Source: The authors.

The algorithm we propose is detailed below:

1. To create the experts' list, experts are asked about their expertise as follows:

1.1 Each expert evaluates its knowledge on the subject in the scale VL, ML, L, M, H, MH, and VH. Their corresponding SVTNN in Table 3 are converted into crisp values using Formula 5, let us call them NK_{Ci} for i = 1, 2,…, N.

1.2 Each expert evaluates questions in the table below in form of VL, ML, L, M, H, MH, and VH with weights measured in form of EU, NVI, NI, M, I, VI, and EI. The weights are assigned by the moderator, converted into crisp values using formula 5, and finally normalized. We called them w_i.

Source of argumentation	Evaluation	Weight
Technical analysis that you have carried out during your professional life	$\tilde{A}_{1i}$	w_1
Your experience in this subject	$\tilde{A}_{2i}$	w_2
Your work with national authors	$\tilde{A}_{3i}$	w_3
Your work with foreign authors	$\tilde{A}_{4i}$	w_4
Your intuition	$\tilde{A}_{5i}$	w_5

Table 5. Aspects to assess.

This table containing the aspects to assess was inspired by the one used in [27, 28].

The SVTNNs associated with the evaluations are aggregated through formula 6, like $\tilde{A}_i = \sum_{j=1}^{5} w_j\tilde{A}_{ji}$ for i = 1, 2,…, N.

$\tilde{A}_i$s are converted into crisp values using formula 5, let us call them NK_{ai}.

Finally, for each potential expert i =1,2,…, N calculate $NK_i = \frac{NK_{Ci}+NK_{ai}}{2}$.

2. Corresponding to Stage 2 of Table 4, potential experts express their evaluations on the complexity of the subject using the linguistic scale in VL, ML, L, M, H, MH, and VH of Table 3. Let us denote them by $E_1, E_2, \dots, E_N$ and their evaluations by $v_1, v_2, \dots, v_N$.

Next, $v_1, v_2, \dots, v_N$ are converted into crisp values using Equation 5 denoted by $\bar{v}_1, \bar{v}_2, \dots, \bar{v}_N$ and they are normalized dividing by 10.875, which is the crisp value associated with 'Very High'. Then, $\alpha_i = \max\left(1 - \frac{\bar{v}_i}{10.875}, 0.1\right)$, i = 1, 2,…, N.

Finally, $\alpha = \frac{\sum_{i=1}^{N}\alpha_i}{N}$, and its linguistic interpretation can be seen in Table 5, in form of either "Very complex or not sufficiently-known topic", "Moderately complex or sufficiently known topic" or "Simple or well-known topic". Additionally, n is also fixed.

To finish this stage, the number of experts is established as m = nα.

3 The obtained values NK_i are sorted in descending order. The first m experts corresponding to this order are selected for evaluating in Delphi method. It is recommendable to choose in the previous set experts who satisfy $NK_i \geq 7.2188$, where this threshold corresponds to the crisp value associated with 'High' after applying formula 5.

Example

In this example, the previous algorithm is applied to a real case, corresponding to experts´ selection in certain hotel of the Meliá Group, located in the touristic destination Varadero, in Cuba, to measure the Intellectual Capital.

The moderator establishes the importance of each of the five aspects as it is summarized in Table 6:

Source of argumentation	Linguistic weight	Crisp weight	Relative weights
Technical analysis that you have carried out during your professional life	VI	9.2625	0.22424
Your experience in this subject	EI	10.875	0.26328
Your work with national authors	M	4.6875	0.11348
Your work with foreign authors	I	7.2188	0.17476
Your intuition	VI	9.2625	0.22424

Table 6: Moderator's linguistic evaluation on the importance of each aspect, its crisp corresponding value and the normalized values.

Table 6 contains the crisp value associated with the evaluations, after applying formula 5 and the normalization of these values in the rightmost column.

Thirteen experts for being potentially selected were self-evaluated as it is summarized in Table 7.

Expert	Knowledge	$\tilde{A}_1$	$\tilde{A}_2$	$\tilde{A}_3$	$\tilde{A}_4$	$\tilde{A}_5$
E_1	L	H	H	L	L	MH
E_2	L	H	H	L	L	MH
E_3	L	H	H	L	L	MH
E_4	L	H	H	L	L	MH
E_5	M	M	M	M	M	M
E_6	M	L	L	H	H	L
E_7	M	H	H	L	L	H
E_8	M	H	H	L	L	H
E_9	M	VL	VL	MH	MH	VL
E_{10}	M	L	L	H	H	L
E_{11}	M	M	M	M	M	M
E_{12}	M	M	M	M	M	M
E_{13}	M	M	M	M	M	M

Table 7. Measure of expertise for every potential expert obtained by self-evaluation.

Table 7 contains the linguistic evaluations of the 13 experts according to the linguistic scale in Table 3.

Table 8 summarizes the aggregation of $\tilde{A}_j$s for each expert according to the scalar weights calculated in Table 6, as well as their corresponding SVTNN.

Expert	Knowledge	$\tilde{A}$
E_1	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_2	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_3	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_4	$\langle(1,3,5);0.33,0.75,0.67\rangle$	$\langle(4.30,6.30,\ 8.07);0.33,0.75,0.67\rangle$
E_5	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_6	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(1.44,2.73,4.73);0.33,0.75,0.67\rangle$
E_7	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3.85,5.85,7.85);0.33,0.75,0.67\rangle$
E_8	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3.85,5.85,7.85);0.33,0.75,0.67\rangle$
E_9	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(2.02,2.59,3.59);0.00,1.00,1.00\rangle$
E_{10}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(1.44,2.73,4.73);0.33,0.75,0.67\rangle$
E_{11}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_{12}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$
E_{13}	$\langle(3,5,7);0.50,0.50,0.50\rangle$	$\langle(3,5,7);0.50,0.50,0.50\rangle$

Table 8. SVTNN values of knowledge and $\tilde{A}$s for each expert.

Finally, Table 9 contains the crisp values associated with knowledge and $\tilde{A}$s for each expert, as well as NKs indexes and their ranking.

Expert	Knowledge	$\tilde{A}_i$	NK_i	Ranking
E_1	2.5312	5.2509	3.8910	7
E_2	2.5312	5.2509	3.8910	7
E_3	2.5312	5.2509	3.8910	7
E_4	2.5312	5.2509	3.8910	7
E_5	4.6875	4.6875	4.6875	3
E_6	4.6875	2.5031	3.5953	11
E_7	4.6875	4.9359	4.8117	1
E_8	4.6875	4.9359	4.8117	1
E_9	4.6875	2.0500	3.3687	13
E_{10}	4.6875	2.5031	3.5953	11
E_{11}	4.6875	4.6875	4.6875	3
E_{12}	4.6875	4.6875	4.6875	3
E_{13}	4.6875	4.6875	4.6875	3

Table 9. Crisp values of knowledge and $\tilde{A}$s for each expert, and their NKs indexes and ranking.

Finally, to select the number of experts, we have to calculate α. We ask every expert how he/she evaluates the complexity of the subject "Intellectual Capital" in hotel business, and their responses are given in Table 10.

Expert	Complexity
E_1	H
E_2	H
E_3	MH
E_4	H
E_5	H
E_6	MH
E_7	H
E_8	H
E_9	MH
E_{10}	M
E_{11}	H
E_{12}	MH
E_{13}	H

Table 10: Evaluation of subject complexity by each expert.

Thus, according to Table 10, we have $\alpha = 0.29628$, which is classified as a "Very complex or not sufficiently-known topic". Twenty-five is the number of elements to measure in the context of Intellectual Capital for this hotel.

Thus, the number of experts to select is $m = 25x0.29628 = 7.4070 \approx 7$. Therefore, the selected experts are E_7, E_8, E_5, E_{11}, E_{12}, E_{13}, and E_1. The selection of E_1 among the set of experts $\{E_1, E_2, E_3, E_4\}$ with equal NK was based on an additional criteria assessed by the moderator.

Conclusion

This paper has the objective of proposing a new experts' selection method for neutrosophic Delphi technique. This method considers experts self-evaluation and the weights assigned to each criteria by the moderator. Single-valued triangular neutrosophic numbers are used for the model. The advantages of the new method are (1) simplicity, (2) it considers indeterminacy, (3) the calculus is made on linguistic terms, and (4) it allows ranking each expert according to their self-evaluations. The indexes are inspired by the well-known K_C and K_a for experts' selection. However, because of those indexes are generalized to the neutrosophic framework, they are more adequate to use due to the aforementioned advantages. Finally, we illustrate the applicability of the method with a real-life example to measure Intellectual Capital in a hotel activity.

References

1. Cabero, J. and A. Infante, *Application of Delphi Method especially in comunication and education (Empleo del Método Delphi y su empleo en la investigación en comunicación y educación)(In Spanish).* Revista Electrónica de Tecnología Educativa, 2014. **48**: p. 1–16.

2. Baines, T.S. and V.G. Shi *A Delphi study to explore the adoption of servitization in UK companies. Production Planning & Control*. 2015.
3. Linstone, H.A. and M. Turoff *The Delphi Method Techniques and Applications*. 2002. 5-12.
4. Ortega, F., *Delphi method, prospective in Social Sciences througth the analysis of a practical case (El método Delphi, prospectiva en Ciencias Sociales a través del análisis de un caso práctico)(In Spanish)*. Revista Escuela de Administración de Negocios, 2008(64): p. 31-54.
5. Guerrón, S.X. and Y.N. Almeida Montenegro, *Use of the Iadov method to measure the implementation of a program for sexual abuse prevention in Ecuador.* Neutrosophic Sets and Systems, 2019. **26**(1): p. 18.
6. Landeta, J., *Current validity of the Delphi method in social sciences.* Technological Forecasting & Social Change, 2005. **73**(5): p. 467-482.
7. White, C., M. Turoff, and B. Van-de-Walle. *A dynamic Delphi process utilizing a modified Thurstone scaling method.Collaborative Judgment in Emergency Response*. in *4th Annual Information Systems on Crisis and Response Management, ISCRAM*. 2007. Delft, Netherlands.
8. Alaloul, W., M. Liew, and N. Zawawi, *Delphi technique procedures: A new perspective in construction management research.* Applied Mechanics and Materials, 2015. **80**(2): p. 661-667.
9. Rodríguez, M.D.O., C.A.M. León, C.D.N. Rivera, C.M.B.R. Cueva, and C.J.E. Ricardo, *HERRAMIENTAS Y BUENAS PRACTICAS DE APOYO A LA ESCRITURA DE TESIS Y ARTICULOS CIENTIFICOS*. 2019: Infinite Study.
10. Ricardo, P.D.J.E. and P.D.J.E. Ricardo, *Importancia de la investigación jurídica para la formación de los profesionales del Derecho.* Dilemas Contemporáneos: Educación, Política y Valores.
11. Carballido, R.M., H. Paronyan, M.A. Matos, and A.L. Santillán Molina, *Neutrosofic statistics applied to demonstrate the importance of humanistic and higher education components in students of legal careers.* Neutrosophic Sets and Systems, 2019. **26**(1): p. 26.
12. Gómez, G.Á. and J.E. Ricardo, *Método para medir la formación de competencias pedagógicas mediante números neutrosóficos de valor único.* Neutrosophic Computing and Machine Learning, , 2020. **11**: p. 38-44.
13. Batista-Hernandez, N., M.B. Ruilova-Cueva, B.N. Mazacón, L.K. de-Mora, J. Alipio-Sobeni, A.V. Palma-Villegas, and J.I. Escobar-Jara, *Prospective analysis of public management scenarios modeled by the Fuzzy Delphi method.* Neutrosophic Sets and Systems, 2019. **26**: p. 114-119.
14. Smarandache, F., J. Estupiñán-Ricardo, E. González-Caballero, M.Y. Leyva-Vázquez, and N. Batista-Hernández, *Delphi method for evaluating scientific research proposals in a neutrosophic environment.* Neutrosophic Sets and Systems, 2020. **34**: p. 204-213.
15. Kaufmann, A. and J.V.E.M. Gil-Aluja, *Special techniques for experts' management (Técnicas especiales para la gestión de expertos)(In Spanish)*. 1993, Vigo: Editorial Milladoiro.
16. Vega Falcón, V. and D. Rivero-Díaz, *Model of measurement of intangible assets (Modelo de medición de Activos Intangibles)(In Spanish).* Revista Científica ECOCIENCIA, 2018. **5**(3): p. 1-32.
17. Ortega, R.G., M.L. Vazquez, J.A. Sganderla Figueiredo, and A. Guijarro-Rodriguez, *Sinos river basin social-environmental prospective assessment of water quality management using fuzzy cognitive maps and neutrosophic AHP-TOPSIS.* Neutrosophic Sets and Systems, 2018. **23**(1): p. 13.
18. Vega Falcón, V., M. del Roció Alarcón Quinapanta, M.M. Yancha Villacís, and J. Estupiñán Ricardo, *Medición del capital intelectual: Caso hotelero.* Dilemas Contemporáneos: Educación, Política y Valores, 2019. **7**.
19. Biswas, P., S. Pramanik, and B.C. Giri, *Aggregation of triangular fuzzy neutrosophic set information and its application to multi-attribute decision making.* Neutrosophic Sets and Systems, 2016. **12**: p. 20-40.
20. Abdel-Aal, S.I., M.A. Abd-Ellatif, and M. Monir-Hassan, *Two Ranking Methods of Single Valued Triangular Neutrosophic Numbers to Rank and Evaluate Information Systems Quality.* Neutrosophic Sets and Systems, 2018. **19**: p. 132-141.
21. Mullai, M. and R. Surya, *Neutrosophic Inventory Backorder Problem Using Triangular Neutrosophic Numbers.* Neutrosophic Sets and Systems, 2020. **31**: p. 148-155.
22. Pal, S. and A. Chakraborty, *Triangular Neutrosophic Based Production Reliability Model of Deteriorating Item with Ramp Type Demand under Shortages and Time Discounting.* Neutrosophic Sets and Systems, 2020. **35**: p. 347-367.
23. Saha, A., I. Deli, and S. Broumi, *HESITANT Triangular Neutrosophic Numbers and Their Applications to MADM.* Neutrosophic Sets and Systems, 2020. **35**: p. 269-298.
24. Saleh Al-Subhi, S.H., I.P. Pupo, R.G. Vacacela, and P.Y. Pinero Perez, *A New Neutrosophic Cognitive Map with Neutrosophic Sets on Connections: Application in Project Management.* Neutrosophic Sets and Systems, 2018. **22**(1): p. 6.
25. Cuétara S., L. *Metodological procedures to elaboration of the marketing plan in hotel organizations. Contributions from the regional development ingeneering (Procedimiento metodológico para la elaboración del plan de marketing*

en organizaciones hoteleras. Aportes de la Ingeniería para el Desarrollo Regional)(In Spanish). in *I Congreso Internacional de Ingenierías 2017*. 2017.

26. Cruz-Ramírez, M. and M.C. Martínez-Cepena, *Refining a Tool for the Selection of Experts in Educational Research (Perfeccionamiento de un instrumento para la selección de expertos en las investigaciones educativas)(In Spanish).* Revista electrónica de investigación educativa, 2012. **14**(2).
27. Muzaurieta, D., *Model of a fuzzy expert system decision making for selecting risked charges in the General Customs of the Republic (Modelo de un sistema experto fuzzy para la toma de decisiones en la selección de cargas de riesgo en la Aduana General de la República)(In spanish)*. 2007, Technical University of Havana: Havana.
28. González-Caballero, E., D. Muzaurieta-Ladrón-de-Guevara, and R.A. Espín-Andrade, *Fuzzy mathematical model for charges selection with possible economic fraud in the general customs of the republic of Cuba (Modelo matemático difuso para la selección de cargas con posible fraude económico en la aduana general de la república de Cuba)(In Spanish).* Revista Ingeniería Industrial, 2008. **29**(1): p. 48-51.

Received: March 21, 2020. Accepted: July 25, 2020