Neutrosophic Sets and Systems
{Special Issue:Impact of neutrosophic scientific publication in Latin American context}, Vol. 44, 2021
University of New Mexico

Managing Contradictions in Software Engineering Investigations using the Neutrosophic IADOV Method

Vladimir Vega Falcón[1], John Luis Toasa Espinoza[2], Andrés Roberto León Yacelga[3] and Luis Orlando Albarracín Zambrano[4]

[1] Universidad Regional Autónoma de los Andes (UNIANDES). Km 5 ½ vía a Baños. Ambato. Tungurahua. Ecuador
Email: ua.vladimirvega@uniandes.edu.ec
[2] Universidad Regional Autónoma de los Andes (UNIANDES). Calle Teniente Hugo Ortiz, Puyo. Pastaza. Ecuador
Email: up.johntoasa@uniandes.edu.ec
[3] Universidad Regional Autónoma de los Andes (UNIANDES). Juan de Salinas 612-500, Ibarra. Imbabura. Ecuador
Email: ui.andresleon@uniandes.edu.ec
[4] Universidad Regional Autónoma de los Andes (UNIANDES). Transversal Central, Quevedo. Los Ríos. Ecuador
Email: uq.luisalbarracin@uniandes.edu.ec

Abstract: Software Engineering is a profession of a technological nature, which takes up theories and knowledge from various sources and addresses the development of quality software at an industrial level. Software Engineering builds knowledge around these software development practices, concretized in the definition of methods, models, and operating schemes that engineers can apply in their professional activities. However, research processes in Software Engineering lack sufficient clarity, mainly due to the level of maturity reached in this discipline. This element hinders the ability of novice researchers to design their research strategies or to recognize the research of excellence. The study is focused on evaluating the consensus and acceptance of the experts on the integration of software engineering sciences and the investigations carried out with the elements that make it up through the IADOV neutrosophic study.

Keywords: Research in software engineering, research processes, IADOV neutrosophic

1 Introduction

Research in software engineering is a subject that requires permanent reflection on the part of the groups that wish to undertake its realization [1], especially even when in some areas this type of activity is not considered as a type of research strictly or is confused with any type of software development process [2].

How these methods, models, and operating diagrams that constitute the own knowledge of Software Engineering (SI) are built [3], is based on the review and formalization of heuristics arising from real experience in software processes and products [4]. This situation requires the definition of research methods that address real problems and situations in the Software Industry, which seek to identify, formalize and theorize about its best practices and its general applicability in different companies at a regional and global level [5].

Although creativity could be seen as a characteristic of research, independent of the method, it is understood that there are sciences whose research requires a high degree of creativity as opposed to observation or experimentation [6]. Such is the arts and engineering case in terms of their artistic solid component [7]. When creativity marks the research process [8], creative methods are mentioned. These methods are based on characteristics such as imagination, premonition [9], visualization, and in them, the creative intelligence of the researcher intervenes above the rational (Table 1).

Science	**Object of study**	**Scope**	**Method**
Software Engineering Sciences	Construction of new objects	Engineer	Qualitative Creative
Software Sciences	Built object	Empirical	Quantitative
Information Systems Sciences	Implementation and use of built objects	Cultural and social	Qualitative

Table 1. Main objects of study, sciences, and methods used in the discipline of SI.

For some time, differences have been observed between the knowledge generated in the academic and research fields [10], and its real application in companies [9]. In many cases, problems and situations analyzed and solved at the investigative level still do not transcend the business level [11].

One of the examples of this situation, and the need for adaptations of theory to practice, was raised by Jacobson when he established differences between method and process [12]. The method refers to the sequence of activities that allow achieving a specific development in the laboratory, this as such cannot be applied directly and without differences in all organizations [13].

Due to its relatively short existence, SI (unlike other sciences: mathematics, chemistry, social sciences, etc.) does not have a consolidated research process that allows us to recognize that it is good to research within the field [14] [1]. Most researchers in SI do not describe the research paradigm used or the standards by which the quality of the research developed is measured [15]. Although some attempts have been made to fill in this gap [13], the results achieved have not been sufficient for the research community to reach a common position [16].

Intending to raise scientific production in the SI area, researchers, especially newcomers and universities [12], require research strategies and scientific writing following what is internationally accepted so that they can raise the quality of the research carried out [17].

The main difference between science and engineering lies in their object of study; while science studies natural aspects to know "how things are", engineering tries to determine how "things should be" so that they make possible the development of new objects [18]. Science studies existing objects and phenomena while engineering focuses on how to create new objects [15].

SI has a particular characteristic in terms of its object of study which, as previously expressed, consists of the methods for software development. Initially, the methods do not exist [19, 20], “They are not natural things” and therefore cannot be studied following the paradigm of science and the engineering approach must be used to determine how “they should be” [21]. But once created, these methods become "natural" objects that can and should be analyzed following the paradigm of science. Perhaps in this particularity lies to a great extent the difficulty that the research community has had to agree on a research paradigm in IS to such an extent that this subject has become an area of research in itself [18], [19], [11], [15], [22].

Regardless of the object of study or the method used, the research process in both science and engineering can be characterized by the type of question that is sought to be answered, the results that are offered in response to those questions, and the criteria used to evaluate the results [13, 23]. The conjunction of these characteristics determines the research strategy for each particular problem [11].

To undertake the research tasks, the research groups must define a work strategy that allows combining academic work in the laboratory with real experiences of applying technology in companies in the software industry [3].

The objective of this article is to evaluate the consensus and acceptance of experts on the integration of software engineering sciences and the research carried out with the elements that comprise it; to understand the use of software engineering research through the application of the neutrosophic IADOV method, as well as its advantages [24]. IADOV method stands out for the simplicity with which it can be applied to obtain the collective evaluation of experts on the subject at hand. Neutrosophy combined with the IADOV method allows to include the indeterminacy, contradiction, and ignorance of the evaluators, therefore, the results of the evaluation are more attached to the real knowledge of the specialists.

To evaluate the level of satisfaction of the experts with the methodology used, all of them with affinity to the subject were surveyed. The groups were made up of a total of 24, 15, and 21 experts respectively.

2 Materials and methods

To apply the neutrosophic IADOV technique, experts must rely on a linguistic evaluation system that shows the expert's opinion [25-28]. This system and its neutrosophic and numerical equivalents are shown in Table 2 [25][29].

Linguistic term	**SVNN**	**Scale**
Clearly satisfied	(1,0,0)	3
More satisfied than dissatisfied	(1, 0.35, 0.35)	2.3

Undefined	I	1.5
More dissatisfied than satisfied	(0.35, 0.35, 1)	1
Clearly dissatisfied	(0; 0; 1)	0
Contradictory	(1,0,1)	2

Table 2. Evaluation system for experts. Linguistic terms are associated with their neutrosophic assessment and a score value

The term I in neutrosophy is interpreted as a unit of indeterminacy.

Another component of the method is the IADOV Logical Table, which assigns numerical values to three closed questions that are applied to the experts. If necessary, open questions can be applied in the surveys [30].

1st question	Yes			I don't know			Not		
2nd question	Yes	I don't know	Not	Yes	I don't know	Not	Yes	I don't know	Not
3rd question									
It is a consolidated research process	1	2	6	2	2	6	6	6	6
It is a partially consolidated research process	2	3	3	2	3	3	6	3	6
It does not matter to me	3	3	3	3	3	3	3	3	3
It is a less established research process than it claims to be	6	3	6	3	4	4	3	4	4
It is an unconsolidated research process	6	6	6	6	4	4	6	4	5
I do not know what to say	2	3	6	3	3	3	6	3	4

Table 3. Derivation of IADOV's Logical box

To survey the level of satisfaction of the experts, the neutrosophic IADOV technique was used. This technique is based on the use of single value neutrosophic sets (SVNS) associated with linguistic variables or its ability to increase the interpretability in the recommendation models and the use of indeterminacy [31] [32].

The definition of SVNS is:

Let X be a universe of discourse. An SVNS A over X is an object of the form.

$$A = \{[x, u_a(x), r_a(x), v_a(x)] : \in X\}\, dA = \{[x, u_a(x), r_a(x), v_a(x)] : \in X\} d \qquad (1)$$

Where:

$$u_a(x): X \rightarrow [0,1], r_a(x): X \rightarrow [0,1]\ y\ v_a(x): X \rightarrow [0,1]$$

With

$$0 \leq u_a(X), r_a(X), v_a(X) \leq 3, \forall x \in X$$

For convenience, a Single Value Neutrosophic Number (SVNS) will be expressed as $A = (a, b, c), where\ a, b, c \in [0,1]\ and\ satisfies\ 0 \leq a + b + c \leq 3$.

Aggregation operators are used for finding a SVNS that describes several sets at the same time. One of these operators is the neutrosophic weighted average (WA), which is defined as follows [30].

Let the Neutrosophic Weighted Average Operator (WA) be calculated:$\{A_{1,}A_2, \ldots, A_n\} \in SVNS\ (x), where\ A_j = (a_j, b_j, c_j)(j = 1, 2, \ldots, n)$,

$$WA\ (A_{1,}A_2, \ldots, A_n) = \sum\nolimits_{i=1}^{n} [w_j\ , A_i] \qquad (2)$$

Where:

$$WA\left(w_{1},w_{2},\dots,w_{n}\right)=\sum_{i=1}^{n}\left[w_{j},A_{i}\right] is\ the\ vector\ A_{j}\ (j=1,2,\dots,n)\ such\ that\ w_{n} \in [0,1]\ y \sum w_{j}=1$$

De-neutrosophication of this set so that a single value is obtained, a scoring function is generally used [33].

Let A = (a, b, c), the scoring function S of an SVNS, based on the indeterminate degree of membership and the false membership degree, is defined by the following equation:

S (A) = 2 + a-b-c (3)

For the use of an SVNS to measure individual satisfaction, this value must be associated with a linguistic variable [25]. Therefore, the scales shown in table 2 were specified and the corresponding score was calculated using (3)

For cases in which the evaluation corresponds to indeterminacy (not defined) (I), a process was developed.

$$\lambda([a_1,a_2])=\frac{a_1+\ a_2}{2} \quad (4)$$

To calculate the Global Satisfaction Index of Respondents (GSI), the aggregation operator WA (2) was used, taking into account the scoring values and that all respondents have the same weight, so that $w_i=\frac{1}{n}$

The instrument designed for the application of the survey was a questionnaire with five questions, three of which are closed (1, 3, and 5) and two are open (2 and 4). The three closed questions were related through the "IADOV logical table", which is presented in Table 3 [31] [26].

The algorithm used for the application of the neutrosophic IADOV technique:

1. Once the questionnaire is applied, the corresponding value (from 1 to 6) for the satisfaction classification of the surveyed experts is found in the IADOV logical table of three entries. [26].
2. The linguistic variable, the SVNS, and the score according to table 2 correspond to this value.
3. The score value of each respondent is used to calculate the group satisfaction index (GSI) from the aggregation of all scores using the aggregation operator formula WA (2).
4. The GSI is interpreted from the location of the value in the graph of figure 1.

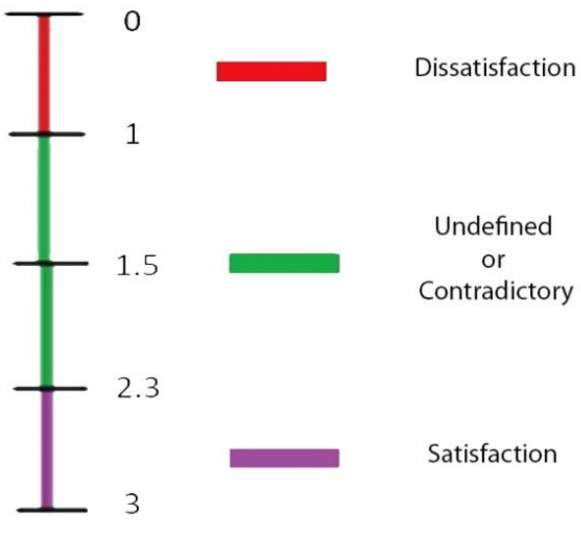

Figure 1. Scale to determine the level of satisfaction according to the scores used

The two open questions allowed to complete the assessment of the level of satisfaction of the students with the applied methodology:

1. Do you think that the integration of software engineering research will improve the proposed results in the software industry? (question 1 of the questionnaire)
2. Do you consider that the scope and guidelines of software engineering investigations should be developed? (question 4 of the questionnaire)

3. What is your judgment about the software engineering research method? (question 5 of the questionnaire)
4. How do you think you could develop this technique? (question 2 of the questionnaire)
5. How about the new science and its applications? (question 3 of the questionnaire)

3 Results

From the application of the survey to the three groups of experts, the results were obtained in terms of the individual satisfaction levels shown in Figure 2.

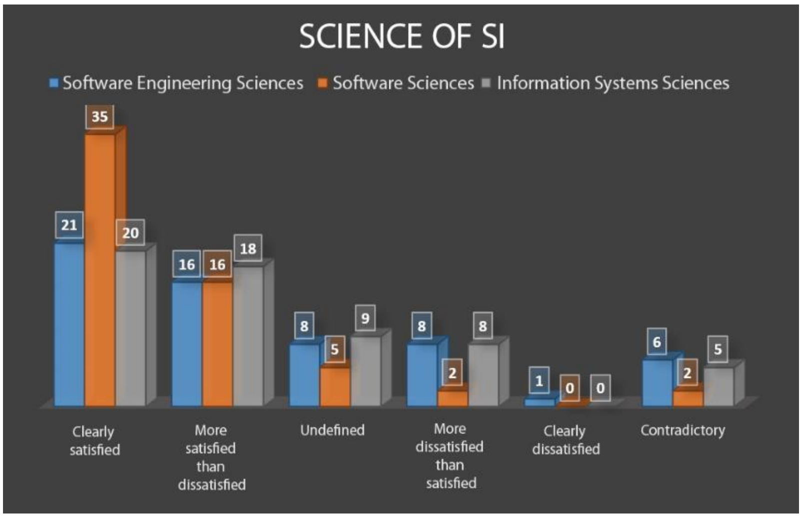

Figure 2: Individual satisfaction levels by group

Positive satisfaction levels can be seen in the sciences of the SI, with a predominance of the Software Sciences in all three groups. However, experts are observed with dissatisfaction especially in the integration of research of Software Sciences and the Information Systems Sciences. Indeterminate and contradictory positions were also found, although scarce.

The calculations of the GSI according to the frequency of observation and the indices of individual satisfaction of the designed categories and their corresponding scores are shown in tables 4, 5, and 6, for each group respectively.

Linguistic term	**SVNU**	**Punctuation** (S)	**Frequency** (F)	**F * S**	**(F * S) / n**
Clearly satisfied	(1,0,0)	3	21	63	1.05
More satisfied than dissatisfied	(1, 0.35, 0.35)	2.3	16	36.8	0.61
Undefined	I	1.5	8	12	0.20
More dissatisfied than satisfied	(0.35, 0.35, 1)	1	8	8	0.13
Clearly dissatisfied	(0; 0; 1)	0	1	0	0.00
Contradictory	(1,0,1)	2	6	12	0.20
Group Satisfaction Index					2.20

Table 4: Calculation of the Group Satisfaction Index (ISG) of the Software Engineering Sciences group

Linguistic term	**SVNU**	**Punctuation (S)**	**Frequency (F)**	**F * S**	**(F * S) / n**
Clearly satisfied	(1,0,0)	3	35	105	1.75

More satisfied than dissatisfied	(1, 0.35, 0.35)	2.5	16	40	0.67
Undefined	I	1.5	5	7.5	0.13
More dissatisfied than satisfied	(0.35, 0.35, 1)	1	2	2	0.03
Clearly dissatisfied	(0; 0; 1)	0	0	0	0.00
Contradictory	(1,0,1)	2	2	4	0.07
Group Satisfaction Index					2.64

Table 5: Calculation of the Group Satisfaction Index (GSI) of the Software Sciences group

Linguistic term	**SVNU**	**Punctuation (S)**	**Frequency (F)**	**F * S**	**(F * S) / n**
Clearly satisfied	(1,0,0)	3	20	60	1.00
More satisfied than dissatisfied	(1, 0.35, 0.35)	2.5	18	4.5	0.75
Undefined	I	1.5	9	13.5	0.23
More dissatisfied than satisfied	(0.35, 0.35, 1)	1	8	8	0.13
Clearly dissatisfied	(0; 0; 1)	0	0	0	0.00
Contradictory	(1,0,1)	2	5	10	0.17
Group Satisfaction Index					2.27

Table 6: Calculation of the Group Satisfaction Index (GSI) of the Information Systems Sciences (IS) group

Of the three groups, only the GSI from the Software Sciences group is greater than 2.30, so it is established that the experts agree on the integration of software engineering research as a consolidated investigation process of the SI.

For the Software Engineering Sciences and SI Sciences groups, there is a level of indeterminacy or contradiction among the experts on the interrelation and research of the SI Sciences.

These results obtained from the satisfaction of the experts about the Software Sciences with the IADOV technique were reaffirmed with the answers of the experts to the open questions. Among the most frequent opinions stand out the contradictions of the SI sciences as a consolidated research process, for Software Sciences, but they can help the current researchers' analysis and serve as a guide for the improvement of their research strategies by providing elements of comparison with the research strategies developed in similar studies.

It is noteworthy that there is a long way to go to lay the foundations of this new Science of SI. This requires, in turn, an adapted Philosophy of Science [34], a Philosophy of Software Engineering, to be built through close collaboration between Software Engineers and Philosophers of Science.

Conclusions

Based on the results obtained, we reached the following conclusions:

- In this study, knowledge in SI establishes three scientific domains related to this discipline. These domains are called: SI Sciences when the object of study does not exist except in the mind of the researcher and the research process consists precisely in the creation of the same method. Software Sciences, when the object of study is any object previously created in a research process in the Sciences of the SI [14, 15]; Information Systems Sciences if the object of study focuses on the process of implementation and use of the aforementioned objects. Given the object of study of Software Engineering Sciences, it has been concluded that the research methods that are best adapted to this type of problem are qualitative and creative.

- The application of the neutrosophic IADOV technique allows experts to represent indeterminacy as part of their knowledge and complementary evaluations, based on the linguistic terms presented in the questionnaire. It is an instrument of great value for the study of satisfaction - dissatisfaction of the experts when evaluating the investigations of Software Engineering Sciences. However, a more in-depth study of Software Engineering research would allow integration with its counterparts.

- The results obtained can help the current researchers' analysis and serve as a guide for the improvement of their SI research strategies by providing elements of comparison with the research strategies developed in similar studies.

References

[1] R. B. Standler. (2002). *Creativity in Science and Engineering*. Available: http://www.rbs0.com/create.htm

[2] J. Aracil, . *Máquinas, sistemas y modelos. Un ensayo sobre sistemática*, TECNOS, S.A ed. Madrid, 1986.

[3] K. B. A. (1996) Evaluating software engineering methods and tool, ACM SIGSOFT Software Engineering Note. 11-15.

[4] M. Bunge, *La Investigación Científica*, Ariel ed. S.A. Barcelona, 1976.

[5] M. Bunge, *Epistemología*, Ariel S.A ed. Barcelona, 1985.

[6] R. Pressman, *Software Engineering: a practicioner's approach", McGrawHill, USA*, 1998.

[7] S. L. Pfleeger, *Software Engineering: theory and practice",* , second edition, Prentice-Hall ed. USA, 2001.

[8] C. Seaman and R. Conradi, "Qualitative Methods in Software Engineering Research," presented at the Conferencia ISERN, 2000.

[9] D. Khazanchi and B. E. Munkvold, *Is Information Systems a Science? En: Information Systems- The Next Generation*, 1998.

[10] D. G. Gregg, U. R. Kulkarni, and A. S. Vinzé. (2001) Understanding the Philosophical Underpinnings of Software Engineering Research in Information Systems. *Information Systems Frontiers, 3:2*. 169-183.

[11] V. Basili. (1993) The experimental paradigm in software engineering en Rombach, D., Basili, V., Selby, R. Experimental Software Engineering Issues: Critical Assessment and Future Directives. Proceedings of Dagstuhl-Workshop. *Springer-Verlag*.

[12] I. Jacobson, "Object Oriented Software Engineering: A Use Case Driven approach.Addison-Wesley," 1992.

[13] M. Shaw, "Writing Good Software Engineering Research Papers," presented at the Minitutorial. Internacional Conference on Software Engineering, ICSE 2003, 2003.

[14] F. J. Galan and J. M. Cañete. (2002). *¿Qué se entiende en España por Investigación en Ingeniería de Software? En MIFISIS 2002. I Workshop sobre Métodos de Investigación y Fundamentos Filosóficos en Ingeniería del Software y Sistemas de Información.Universidad Rey Juan Carlos*. Available: http://kybele.escet.urjc.es/MIFISIS/Articulos/Art09.pdf

[15] J. Chavarriaga. (2003) La Ingeniería de Software como profesión tecnológica: Implicaciones en la investigación. Métodos de Investigación y Fundamentos Filosóficos en Ingeniería del Software y Sistemas de Información. *Madrid: Universidad Rey Juan Carlos*. 162 -178.

[16] J. Rodríguez, A. Muñoz, and H. José, "La Buena Administración en la Contratación Pública: Mención Especial a la Fase de Ejecución del Contrato.," *Revista del gabinete jurídico de Castilla - La mancha*, vol. 1 (1), pp. 35-62, 2019.

[17] D. Parnas. (1998) Successful Software Engineering Research". . *Software Engineering Notes*. 64-68.

[18] E. Marcos. (2002). *Investigación en Ingeniería de Software vs. Desarrollo de Software en MIFISIS 2002. I Workshop sobre Métodos de Investigación y Fundamentos Filosóficos en Ingeniería del Software y Sistemas de Información. Universidad Rey Juan Carlos*. Available: http://kybele.escet.urjc.es/MIFISIS/Articulos/Art11.pdf

[19] A. Finkelstein and J. Kramer. (2002). *Software Engineering: a roadmap en Finkelstein, A. (editor) Proceedings of the Conference on The Future of Software Engineering. ACM Press*. Available: http://www.softwaresystems.org/front.html

[20] P. Dewayne, A. Porter, and L. Votta. (2002). *Empirical Studies of Software Engineering: A roadmap. en Finkelstein, A. (editor) Proceedings of the Conference on The Future of Software Engineering. ACM Press*. Available: http://www.softwaresystems.org/front.html

[21] F. J. Campos. (2002). *Reingeniería de la Metodología en MIFISIS 2002. En MIFISIS 2002. I Workshop sobre Métodos de Investigación y Fundamentos Filosóficos en Ingeniería del Software y Sistemas de Información*. Available: http://kybele.escet.urjc.es/MIFISIS/Articulos/Art10.pdf

[22] R. L. Glass, Vessey, I. y and V. Ramesh. (2001) Research in software engineering: an analysis of the literature. En: Information and Software Technology Ed. *Elsevier Science B.V. N.44*. 169-183.

[23] SWEBOK. (2001). *Guide to the Software Engineering Body of Knowledge. IEEE Computer Society y ACM Software Engineering Coordinating Committee,* . Available: http://www.swebok.org/

[24] R. B. Johnson, K. Booch. G. Cook, W. Gabriel, R. Wirfs-Brock, R. *How to get a Paper Accepted at OOPSLA. Panel. OOPSLA'93*. Available: . http://www.acm.org/sigs/sigplan/oopsla/oopsla96/how93.html

[25] M. Leyva Vázquez and F. Smarandache, *Neutrosofía: Nuevos avances en el tratamiento de la incertidumbre*. Bruselas: Pons, 2018.

[26] N. Batista, N. Valcárcel, M. Leyva-Vázquez, and F. Smarandache. (2018) Validation of the pedagogical strategy for the formation of the competence entrepreneurship in high education through the use of neutrosophic logic and IADOV technique. Vol. 22. *Neutrosophic Sets and Systems*.

[27] D. Andrade Santamaría, J. W. Soxo Andachi, and O. F. Silva Montoya, "Method for Evaluating the Principle of Interculturality in the Custodial Sentence using the Iadov Technique," *Neutrosophic Sets and Systems,* vol. 37, pp. 125-131, 2020.

[28] C. F. R. Squilanda, J. A. E. Diaz, and S. B. G. Gallegos, "Validation of a Reform Project forArticle 223 of The Ecuadorian Civil Code Through the Use Of Iadov Techniques and Neutrosophic Logic," *Neutrosophic Sets and Systems,* vol. 37, pp. 302-307, 2020.

[29] J. L. Salmeron and F. Smarandache, "Redesigning Decision Matrix Method with an indeterminacy-based inference process. Multispace and Multistructure. ," *Neutrosophic Transdisciplinarity (100 Collected Papers of Sciences),* vol. 4, p. 151, 2010.

[30] M. A. Andino-Herrera, Cuenca-Díaz, H. Paronyan, and V. Murillo. (2019) Use of the neutrosophic IADOV technique to diagnosethe real state of citizen participation and social control, exercised by young people in Ecuador. *Neutrosophic Sets and Systems, 26*. 169-173.

[31] L. Guerrero Morales, R. W. Proenza Ventura, and A. H. González. (2019) Iadov Neutrosofico para medir la satisfacción de los docentes con la aplicación del Solver de Excel en la programación lineal. . *Neutrosophic Computing and Machine Learning, Vol. 5*. 14-25.

[32] M. G. M. E.-h. Abdel-Basset, A.; Smarandachec, F., *A novel model for evaluation Hospital medical care systems based on plithogenic sets," vol. 100,*: Artif Intell Med, 2019.

[33] A. S. W. Alfredo-Cacpata, Gil-Betancourt, N. J. Enríquez-Guanga, and K. T. Castillo-Núñez. (2019) Validation of the proof reversal on the inexistence of untimely dismissal by using neutrosophic IADOV technique. *Neutrosophic Sets and Systems, 26(Special Issue: Social Neutrosophy in Latin America), 45-51*.

[34] R. Glass. (1994). *The Software Research Crisis, IEEE Software*. Available: http://csdl.computer.org/comp/mags/so/1994/06/s6042abs.htm

Received: February 17, 2021. Accepted: April 23, 2021