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A Method for Decision-Making on the Tendering procedure for the Acquisition of Goods and Services in Public Procurement

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Abstract. The legislation on public procurement in Ecuador has undergone a profound change with the issuance of the Organic Law of the National Public Procurement System and the use of tools generated by Information and Communication Technologies (ICT). The tender constitutes a contractual award procedure, provided for in this legal body. However, the selection of suppliers for certain non-standardized goods and services represents a conflict that is assumed by decision-makers in the tendering processes. This research proposes a solution to the problem posed from the development of a decision-making method on tenders for non-standard goods and services as part of the public procurement process.

Keywords: Tender, public procurement, neutrosophic numbers, multi-criteria decision making.

1. Introduction

In accordance with the provisions of Article 119 of the Political Constitution of the Republic of Ecuador, public sector entities and public officials are only empowered to do what the Law allows them. For this reason, in matters of public procurement, it is necessary that, prior to starting any process, both the object of the procurement and the legal basis that sustains it be clearly identified. In the same way, it is very important to identify the origin of the economic resources that will be used to finance the hiring; Therefore, depending on who finances the contract, certain procedures will be adopted [1-3].

In Ecuador, before the issuance of the Organic Law of the National Public Procurement System, there was a wide legislative dispersion; Public Procurement was based, fundamentally, on the Public Procurement Law and the Consulting Law. In addition to these normative bodies, the Internal Contracting Regulations were added, where the contracting entities acted without following the same pattern, nor requirements, nor preference margins, which generated that each contracting entity handled the contracting processes differently from the others, hindering the work of control bodies and citizen participation through oversight bodies and other social evaluation mechanisms[4]

Similarly, there was no single registry of suppliers at the national level, each contracting entity handled the qualification processes with which they created a database of some suppliers, which undermined the equal opportunity of participation, especially of the micro, small and medium businesses. This meant that, for each contracting process, each supplier had to gather and present again all the necessary legal documentation [5, 6].

Finally, the participation of the control bodies was prior to hiring, through the corresponding reports from the State Attorney General's Office and the State Comptroller General's Office. It was in 2008 that the Organic Law of the National Public Procurement System was issued.

Contract award procedures are varied, with a close relationship between the amount of the referential budget and the type of award regulated by the Organic Law of the National Public Procurement System. In this legal body the tender operates differently in public works contracts, where it has a leading role, and in the acquisition of goods and services, where its behavior is supplementary.

The process called bidding or tendering is based on the principles of free competition and equality, although the majority of those established in article 4 of the organic law of the national public procurement system affect this contractual award procedure. Free participation guarantees the presence of all people who are in a position to participate under equal conditions. It will allow the Public Administration to really know which is the bidder who

presents the best proposal and to choose the most suitable, complying with the implicit principle in the administrative legal system of objective selection [1][7].

Figure 1 shows the annual evolution and percentage of participation in public procurement in Ecuador.

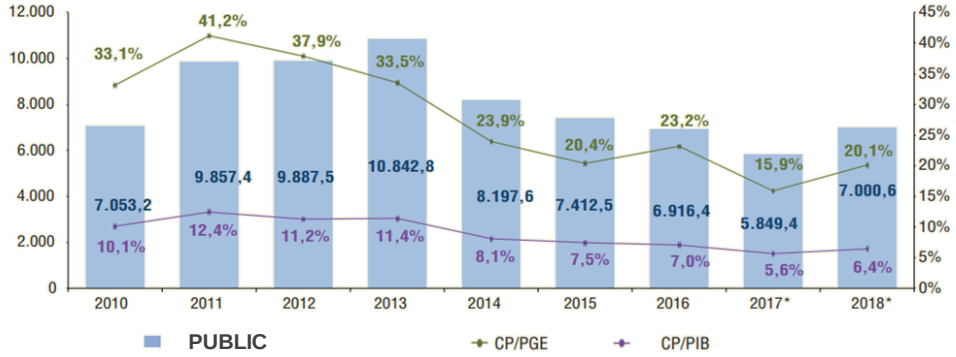

Figure 1: Annual evolution and percentage of participation in public procurement (Millions of dollars and % of representation)
Source: SERCOP - SOCE, Central Bank of Ecuador and Ministry of Finance
Produced by: SERCOP - Directorate of Public Procurement Studies

The graph displays the behavior in millions of dollars that have been invested in public procurement. However, it has had a decline in 2017 with a slight rise for 2018. Public Entities must become aware of what the expression or requirement comprises; more convenient for national and institutional interests that are not always linked or necessarily derived from the lowest price offered; but other factors of equal or perhaps greater importance in the provision, such as technical solvency, opportunity, experience and better prospects.[8]

Based on the aforementioned analysis, the objective of this research is defined as the development of a decision-making method on tendering for non-standardized goods and services as part of the public procurement process.

This article is divided into a section that contains the fundamental concepts of Neutrosophy, section 3 introduces the method that we will apply to solve the problem. Section 4 solves a real problem with the proposed method. The article ends with the conclusions.

2 Preliminaries

This section introduces the main theories used for research development. Specifically, the modeling of uncertainty with the use of neutrosophic numbers is described.

There are various scenarios in which people have to make decisions. A decision-making process can become insufficient when analyzing highly complex problems, especially those problems where the solution can affect many other people. Due to the above, it should be analyzed through discussions and exchange of ideas and opinions among experts, who, due to their experience and knowledge, can help structure the problem and evaluate possible solutions. Figure 2 shows a general diagram of a decision-making process.

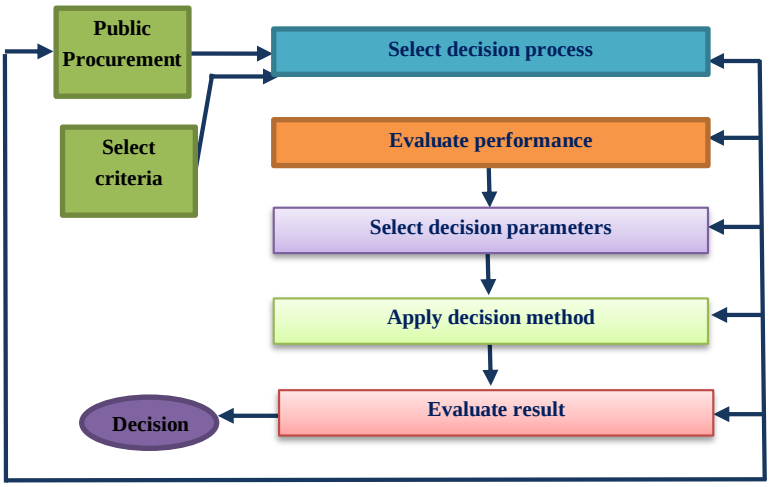

Figure 2: General diagram of a decision-making process.

The decision process requires a comparison between the alternatives that can be chosen in the face of a certain present dilemma. In the first place, it is necessary to separate a decision problem into the elements that compose it

for subsequent comparison between them; in this way, decision-making involves taking measurements that allow the application of comparison criteria to establish preferences between them.
Below, we describe the concepts of Neutrosophy that are used in this paper.

Neutrosophy emerged from the movement known as Paradoxism [9] The use of neutrosophic sets allows, in addition, the inclusion of membership functions of truth and falsehood, also membership functions of indeterminacy. This indeterminacy is used because there are contradictions, ignorance, inconsistencies, among other causes with respect to knowledge [10-12]

In the context of multi-criteria methods, neutrosophic numbers are introduced in order to represent the indeterminacy [13, 14]. It constitutes the bases of mathematical theories that generalize classical and fuzzy theories such as neutrosophic sets and neutrosophic logic.[15]. A neutrosophic number (N) is represented as follows [16, 17]:

Let $N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation is a mapping of a group of propositional formulas a *N*, that is, for each p sentence we have

$$v(p) = (T, I, F) \quad (1)$$

Where:
T: represents the truth value,
I: represents the indeterminacy value,
F: represents the falsehood value.

3 Neutrosophic method for decision-making on the tendering of services

The section presents the structure of the method's operation to make decisions about the tendering of services. Operation is guided by a three activity workflow. The method bases its operation on a neutrosophic environment to model the uncertainty.[18, 19]

It is based on a linguistic decision analysis scheme that can address criteria of different nature and provide results in a neutrosophic environment. Figure 2 shows the fundamental activities of the proposed method[20-22].

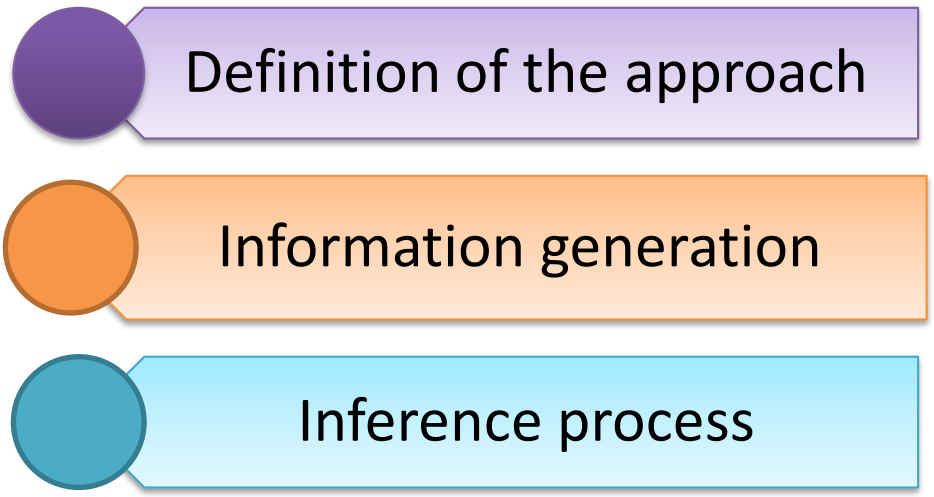

Figure 3: Representation of the method.

The method is designed to support the workflow and to determine and support decision-making on the tender for services. It consists of the following activities: definition of the approach, generation of information and processing and inference. The different stages of the method are described below:

1. Definition of the approach

At this stage, the evaluation framework is defined to specify the decision-making structure for the tender for services. The framework is modeled from the following elements [23-25]:

- $E = \{e_1, \cdots, e_n\}, (n \geq 2)$ is a group of experts.
- $TI = \{ti_1, \cdots, ti_m\}, (m \geq 2)$ it is a set of service providers.
- $C = \{c_1, \cdots, c_l\}, \ (l \geq 2)$ It is a set of criteria that characterize the services.

A heterogeneous information framework is used. For each expert, a different numerical or linguistic domain can be used to evaluate each criterion, taking into account its nature in a neutrosophic environment. From the modeling of the elements that define the approach, the information is generated.

In this article, we will use the linguistic scale summarized in Table 1.

Linguistic term	SVN numbers
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good (G)	(0.70,0.25,0.30)
Fairly good (FG)	(0.60,0.35,0.40)
Average (A)	(0.50,0.50,0.50)
Moderately bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1. Linguistic terms used.

2. Generation of information

By defining the framework, the knowledge of the group of experts is obtained. For each expert i, their preferences are provided through the use of utility vectors. The utility vector is expressed by

$$P_k^i = \{p_{k1}^i, p_{k2}^i, \cdots, p_{kl}^i\}$$

Where: P_k^i represents the preference given to the criteria c_k (k = 1,…, l) over the service providers r_j (j = 1,…, m) expressed by the expert e_i.

In the stage, the information necessary for the processing of the inferences is obtained, from the set of data obtained by consulting the experts, the processing and interpretation of the information is carried out in order to obtain the recommendations on the decision-making in the service tendering process,[26].

3. Processing and evaluation

The processing stage and evaluation is in charge of, based on the framework established with the set of data obtained, carrying out the collective linguistic evaluation that is interpretable for making decisions about the tendering of services. For this the information is unified and aggregated,[27, 28].

The aggregation is done as follows:

Given a vector of weights for each criterion $W = (w_1, w_2, \dots, w_l)$, which satisfies $w_k \in [0,1]$, such that $\sum_{k=1}^{l} w_k = 1$.

The result for each service provider is calculated with the following formula:

$$R_j = \frac{\sum_{k=1}^{l} w_k \left(\sum_{i=1}^{n} p_{kj}^i\right)}{n} \quad (2)$$

A process of sorting alternatives that are prioritized to deal with heterogeneous information and offer linguistic results is carried out [29, 30].

The results are sorted by provider using formula 3.

$$s(\tilde{a}) = \frac{1}{3}(2 + \mathrm{T} - \mathrm{I} - \mathrm{F}) \quad (3)$$

For a neutrosophic number $\tilde{a} = (\mathrm{T}, \mathrm{I}, \mathrm{F})$

4 Implementation of the neutrosophic method for decision making on the tendering of services

This section describes the operation of the proposed method for which a case study applied to a service organization for the electrical maintenance of facilities was carried out. The objective was to determine the decision-making on service providers that carry out the tender. The example illustrates the applicability of the method.

Activity 1: Assessment framework

For the present case study, a framework composed of:

$E = \{e_1, e_2, e_3\}$, which represent the 3 experts who participated in the process.

Which carry out the evaluation:

$Ps = \{Ps_1, Ps_2, Ps_3\}$, from 3 Service Providers

From the valuation of the

$C = \{c_1, \cdots, c_6\}$ which make up the 6 evaluation criteria.

Table 2 shows the criteria used.

Not	Criterion	Description
1	Certifications	The organization has international certifications to carry out the activity
2	Establishment time	Time that the organization has been established in the national market
3	Attention time	That the provider can solve the problems in a time not exceeding 2 hours
4	Compliance with standards	That the planned actions are carried out according to the regulations provided by the national standardization organization
5	Recognition	Visibility of the organization in the national marking
6	Solvency	Possibility of the organization to guarantee the resolution of problems with the provider's own resources.

Table 2: Criteria used for the selection of suppliers for the electrical maintenance of facilities.

Each expert could provide the information numerically or linguistically, taking into account the nature of the criteria. A common linguistic domain is chosen to verbalize the results that are expressed in Figure 3.

For the numerical values, the following linguistic scale will be used with neutrosophic single-valued numbers proposed in Table 4.

Activity 2: Generation of information

From the information obtained about the service providers, they are stored for further processing. The evaluation framework is presented in Table 3. The evaluation scales used is the one that appears in Table 1.

	e_1			e_2			e_3		
	Ps_1	Ps_2	Ps_3	Ps_1	Ps_2	Ps_3	Ps_1	Ps_2	Ps_3
c_1	(0.60,0.35, 0.40)	(0.70,0.25, 0.30)	(0.9, 0.1, 0.1)	(0.30,0.75, 0.70)	(0.50,0.50, 0.50)	(0.8,0.15, 0.20)	(0.60,0.35, 0.40)	(0.60,0.35,0. 40)	(0.50,0.50,0. 50)
c_2	(0.60,0.35, 0.40)	(0.9, 0.1, 0.1)	(0.60,0.35, 0.40)	(0.9, 0.1, 0.1)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.70,0.25,0. 30)	(0.9, 0.1, 0.1)
c_3	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.8,0.15, 0.20)	(0.70,0.25, 0.30)	(0.30,0.75, 0.70)	(0.60,0.35,0. 40)	(0.8, 0.1, 0.3)	(0.50,0.50,0. 50)
c_4	(0.9, 0.1, 0.1)	(0.8, 0.1, 0.3)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.70,0.25,0. 30)	(0.8,0.15,0.2 0)
c_5	(0.60,0.35, 0.40)	(0.70,0.25, 0.30)	(0.9, 0.1, 0.1)	(0.30,0.75, 0.70)	(0.50,0.50, 0.50)	(0.8, 0.1, 0.2)	(0.60,0.35,0. 40)	(0.60,0.35,0. 40)	(0.50,0.50,0. 50)
c_6	(0.9, 0.1, 0.1)	(0.60,0.35, 0.40)	(0.60,0.35, 0.40)	(0.50,0.50, 0.50)	(0.8, 0.1, 0.3)	(0.50,0.50, 0.50)	(0.9, 0.1, 0.1)	(0.50,0.50,0. 50)	(0.30,0.75,0. 70)

Table 3. Presentation of the results for the three providers, the three experts and the six criteria.

The weighting vector is used.$W = (0.38, 0.27, 0.11, 0.05, 0.08, 0.11)$

The results obtained were those shown in Table 4:

Provider	Results	Score
Ps1	$\langle 0.64200, 0.34033, 0.35800 \rangle$	0.64789
Ps2	$\langle 0.64300, 0.32283, 0.36600 \rangle$	0.65139
Ps3	$\langle 0.69867, 0.28800, 0.30133 \rangle$	0.70311

Table 4: Collective evaluation for supplier.

Table 4 summarizes the results of applying Formula 1 in the example, in addition to the score obtained from applying the Equation.

Finally, all the collective evaluations are ordered and a ranking is established among the service providers in order to identify the best calculated scoring alternatives. Therefore, in the case study, the classification of service providers was recommended as follows: $Ps_1 \prec Ps_2 \prec Ps_3$. Consequently, association with the third-party provider is recommended.

Conclusions

Based on the development of the proposed research, a system was obtained to support decision-making in the contract award procedure for the procurement of non-standardized goods and services. The implementation of the proposed system is based on neutrosophic methods to model uncertainty. With the application of the system proposed in the case study, it was possible to demonstrate the applicability of the decision support methodology for the tendering of non-standardized goods and services. Although the proposed case study presents a favorable practical application, the implementation of other multi-criteria decision-making methods is recommended in the decision-making process to compare the results obtained.

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