Applying a linguistic multi-criteria decision-making model to the analysis of ICT suppliers' offers

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ABSTRACT

Tender analysis processes are everyday processes in any company, but they become even more important when the financial resources are limited. Achieving optimal and transparent tender analysis processes requires hard work from everyone involved. This paper proposes a linguistic multi-criteria decision-making model which helps decision-makers in this task by automating it. To do that, the proposal requires diverse experts to assess different criteria and establish their corresponding weights. The processing of all these input data will determine a minimum value, called *profile*, to consider an alternative as valid. Additionally, assessments of a similar (probably external) process will be taken into account, becoming a *reference* valuation. Unlike other decision-making models, the use of this last value gives an idea of the goodness of the result depending on whether the solution obtained is close to the reference value. To the best of our knowledge, there is no expert or intelligent system specifically designed to fully meet the needs of tender analysis processes. For both input and output process stages carried out in our proposal, 2-tuple linguistic labels have been used. These linguistic labels were chosen to facilitate decision-making for the staff involved in the process, as well as for being the most suitable communication way used by human beings. To validate the model, we apply it to a case study in the ICT (Information and Communications Technology) sector. In addition, we include a literature review related to applications using the 2-tuple representation, as well as a comparison of our proposal with related methods, including the results obtained by these methods for the case study presented.

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1. Introduction

ICT development is an important source of growth in the economies of modern societies. This claim is based on the works of authors such as Heeks (2008) and Gómez and Pather (2011), as well as on the reports of the International Telecommunication Union (2015) and the Organization for Economic Cooperation and Development (OECD, 2015), among others. Latin America is involved in these new technological trends and the member countries of this community make strong efforts concerning these technologies in order to improve the living standards of their societies. These efforts go through supplier selection and evaluation processes. Delays in the contracting processes mean loss of time, loss of revenues due to opportunity costs and lags in implementing products or services in addition to questioning the legitimacy of the procedures carried out.

Taking into account the importance of the ICT sector in the economy, this paper is aimed at providing an additional tool for decision-making applied to the evaluation of contractual offers in this sector.

There are reviews, such as the ones carried out by De Boer, Labro, and Morlacchi (2001) and by Bhutta (2003), where the works related to the selection of suppliers are compiled. These contributions classify over 150 works that provide a good perspective of the most used mechanisms to evaluate suppliers. Additionally, there are different approaches applied to this subject, like those based on auction theory (Klemperer, 1999; Ockenfels & Roth, 2006; Rothkopf, Pekeč, & Harstad, 1998; Wu, 2001; Xuefeng, Lu, Lihua, & Zhao, 2006), game theory (Cachon & Netessine, 2004; Camerer, 2003; Han, 2012) and the use of various algorithms and techniques to determine a winner (Behzadian, Otaghsara, Yazdani, & Ignatius, 2012; Fonseca & Fleming, 1995; Kwon, 2006; Sandholm, 2002), among many others.

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In practice, the majority of the supplier evaluation processes are held in two stages. The first one is carried out under the mode "Complies/Does not comply" (qualitative). At this stage, the information presented by the offerors is verified (as a check list). This first verification allows enabling the proposal presented by the offerors/competitors, verifying that the offer meets the requirements demanded. The second stage evaluates quantitative parameters related to the main characteristics of the offers which have met the requirements established in the first stage. In this second stage, where ratings are numerical, difficulties arise when there is more than a single expert evaluator in the process of rating the suppliers' offers, since each of them will have a different rating criterion.

This type of problems is analysed within the multi-criteria decision-making approach in works such as the ones described by Figueira, Greco, and Ehrgott (2005), Kabak, Burmaoğlu, and Kazançoğlu (2012) and Gal, Stewart, and Hanne (2013), where either quantitative or qualitative variables, or even hybrid (quantitative + qualitative) ones, are used. These problems involve various opinions representing the areas in which the company administrative management is distributed. In other words, these problems entail decision-making processes with multiple criteria/opinions, where participants are able to express different preferences over the different criteria discussed.

These approaches allow establishing the existing relation between the type of variables to be used and the nature of the information to be used to model the aspects demanded. When it comes to modeling quantitative aspects (length, power, financial interest…) the use of numerical information will be the one regularly used. However, when it comes to modeling qualitative aspects (degree of compliance, design, quality…), numerical information is usually not the right option, since these aspects are difficult to evaluate through an exact value.

There are some decision-making methods, such as TOPSIS (Behzadian et al., 2012), VIKOR (Opricovic & Tzeng, 2004), MULTIMOORA (Brauers & Zavadskas, 2012), etc., which are quantitative models. However, some proposals based on the mentioned models use linguistic labels. Some example of this are LTOPSIS (Cables, García-Cascales, & Lamata, 2012) and 2-tuple linguistic VIKOR (You, You, Liu, & Zhen, 2015), among others. These methods are focused on measuring the distance between the assessment of the criteria and both an ideal and a non-ideal appraisal. Others approaches use a hybrid methodology, in the sense that they combine several models; for example, AHP-TOPSIS-Grey (Oztaysi, 2014).

In Liao and Xu (2015), Massanet, Riera, Torrens, and Herrera-Viedma, (2014), Morente-Molinera, Pérez, Ureña, and Herrera-Viedma, (2015a), Perez-Asurmendi and Chiclana (2014) and Tapia-García, Del Moral, Martínez, and Herrera-Viedma (2012), we can find some proposals to approach the problem of establishing evaluation criteria without using quantitative (numerical) elements. These proposals are founded on the use of ratings based on natural language and which are aimed at providing a qualitative approach to these problems. They suggest applying a fuzzy linguistic modeling through the use of linguistic variables, which are variables that take values in a discrete universe of discourse, perhaps less precise than numerical values, but which better adapt to the human mindset when it comes to evaluating complex scenarios (Carrasco, Sánchez-Fernández, Muñoz-Leiva, Blasco, & Herrera-Viedma, 2015; Dutta & Guha, 2015; Morente-Molinera, Pérez, Ureña & Herrera-Viedma, 2015b; Wu, Chiclana, & Herrera-Viedma, 2015).

However, to the best of our knowledge, there is no linguistic multi-criteria decision-making model in the literature that presents a solution for the processing of qualitative ratings without information loss in the analysis of supplier' offers in the ICT sector. Our proposal intends to solve this by presenting a solution for the qualitative analysis of offers using the 2-tuple representation model (Herrera & Martínez, 2000), which allows data processing without information loss. Additionally, comparative methods that allow knowing the distance from a given alternative to a known reference are also used.

In our proposal, the process used to achieve the ordered list of alternatives includes an established *reference* value and calculates and uses a minimum value called *profile*, which determines the valid alternatives. By including these two elements, our proposal differs from other existing decision-making models in that it not only sorts the alternatives according to evaluation criteria, but it also determines how good the achieved solution is by comparing it with these referential values. Hence, our proposal offers a more reliable warranty and a high level of transparency for its application to the decision-making process carried out in any company concerning the analysis of suppliers' offers.

The rest of the article is organized as follows: Section 2 presents a literature review concerning the use of the 2-tuple representation model. Section 3 establishes the necessary theoretical foundations. Section 4 presents the proposed linguistic multi-criteria decision-making model, while Section 5 shows its application to a case study. Finally, Section 6 addresses the conclusions and future works.

2. Literature review

The 2-tuple linguistic model was developed by Herrera and Martínez, (2000). In the last 15 years, it has had a major impact, being used by many researchers to define new theoretical models and approaches, as well as to apply them in different domains, mainly in decision-making processes and decision analyses. This is due to a common activity for human beings in their daily lives making decisions in conditions of uncertainty, thus selecting the best solution from a set of different possible alternatives. There are many areas in which the 2-tuple linguistic model has been applied, but we can group them in the four following clusters, which are briefly described just below, including complementary information and references in Table 1:

- **Decision Analysis**: it uses different tools to assess all pertinent information to support the decision-making process. It is applied to many different areas, though Table 1 only shows those in which the 2-tuple linguistic model has been used, such as engineering systems, knowledge evaluation, performance appraisal, product development, and risk evaluation, among others.

- **e-Services:** these are ICT tools or systems that manage information. Some application areas belonging to this cluster in which the 2-tuple linguistic model or any of its extensions have been used are information retrieval, recommender systems, and networks.

- **Fuzzy Rule-Based Systems (FRBS):** they represent expert knowledge by means of linguistic rules containing linguistic variables. These rules, which are usually provided by experts, link the evidences with the conclusions. They have been applied to improve fuzzy models in different domains, such as control systems, association rules, classification problems, imbalanced classification problems, and subgroup discovery.

- **Multi-Criteria Decision-Making (MCDM) models**: these are widely used to deal with decision-making problems where several criteria are considered to select the best solution from a set of possible alternatives. Usually, most of these decision-making approaches have been used in quantitative contexts. However, many authors have used the 2-tuple linguistic model to define new MCDM models based on such approaches and extend them to manage qualitative information. These resulting models have been applied to different decision-making problems in diverse domains. Table 1 shows some of the most representative ones.