Revista Cubana de Ciencias Informáticas
Vol. 12, No. 3, Julio-Septiembre, 2018
ISSN: 2227-1899 | RNPS: 2301
Pág. 47-61
http://rcci.uci.cu

Tipo de artículo: Artículo original
Temática: Inteligencia Artificial.
Recibido: 14/03/2018 | Aceptado: 04/07/2018

Application of fuzzy techniques in the evaluation of video surveillance technology suppliers

Aplicación de técnicas difusas en la evaluación de proveedores de tecnologías para VideoVigilancia

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Abstract

Supplier evaluation is considered a key element in the procurement of resources. In this stage, a characterization of suppliers is carried out, based on a documentary review, interviews and experiences acquired in similar projects, which allows managers to make decisions about the project. Some of the main difficulties presented by methods in developing supplier evaluation are associated with inadequate uncertainty modeling and the lack of a mechanism for the treatment of multiple expert preferences on various criteria, which leads to loss of time and information. The general objective of this research is the application of fuzzy techniques for the evaluation of Video Surveillance technology suppliers, based on the fuzzy hierarchical analysis process and the 2-tuple linguistic representation model to treat uncertainty in decision making, based on the management of the information provided by multiple experts in their assessments. The obtained results can be easily interpreted by evaluators, without any loss of information.

Keywords: 2-Tuple linguistic representation model, evaluation, fuzzy hierarchical analysis process, supplier management.

Resumen

La evaluación de los proveedores es considerada un elemento primordial en la adquisición de los recursos. En esta etapa se realiza una caracterización de los proveedores, a partir de una revisión documental, entrevistas, experiencias adquiridas en similares proyectos, lo que les permite a los gestores la toma de decisiones en el proyecto. Algunas de las principales dificultades que presentan los métodos para desarrollar la evaluación de proveedores, están asociadas a que realizan inadecuado modelado de la incertidumbre y no establecen ningún mecanismo para el *tratamiento de las preferencias de múltiples expertos sobre varios criterios, lo que propicia pérdida de tiempo y de información. El objetivo general de este artículo es la aplicación de técnicas difusas para la evaluación de proveedores de tecnologías para Video Vigilancia basado en el proceso de análisis jerárquico difuso y el modelo de representación lingüística 2-tupla, para dar tratamiento a la incertidumbre en la toma de decisiones, a partir del manejo de la información brindada por múltiples expertos. Se obtuvieron resultados fácilmente interpretables por los evaluadores y sin pérdida de información.*

Palabras clave: *Gestión de proveedores, evaluación, modelo de representación 2-Tuplalingüístico, proceso de análisis jerárquico difuso.*

Introduction

Supply management play a fundamental role in all types of companies. This process allows the establishment of contractual relations between the client and the provider, where the necessary resources for the production of goods and services are assured. Procurement management requires adequate purchasing management, bearing in mind that it ensures that the resources needed for the productive process are guaranteed, they have the necessary quality and delivery is made at the right time (Ortiz et al. 2015; Gu et al. 2016). In order to achieve the above-mentioned elements, it is necessary for the company to have the best supplier(s).

Supplier selection is a decision-making process marked by the complexity of the need to evaluate the different providers on the basis of quantitative and qualitative criteria, which can often conflict with each other, making it a multi-criteria decision-making problem with strategic impact, which can generate uncertainty for the experts responsible for carrying out this evaluation (Herrera et al. 2006). It also implies a decision that in some cases may be difficult in view of the diversity of products and services currently offered for a given market.

Multiple authors have addressed the issue of supplier evaluation and there has been a broad debate about the most appropriate criteria for carrying out this analysis (Ho et al. 2010; Chai, 2013; Ortiz et al. 2015). Some of the most commonly used criteria range from the capacity of the supplierin a given situation, quality, service, price and payment plans.

These criteria could generate a certain complexity in the process, since their character is, in most cases, subjective. Several of these criteria are composed of sub-criteria, which are also involved in the final decision. The supplier evaluation problem is usually organized in a hierarchical manner and analyzed by levels, for better processing of the information to be treated for each of the alternatives.

Furthermore, evaluators generally have different levels of knowledge, experience, and terms they use to express their judgments are vague and imprecise, which adds ambiguity to the process. Therefore, it is necessary to have tools that allow addressing the problem of multi-criteria decision making in a systematic and scientific manner, combined with elements of the theory of fuzzy sets, so as to deal with uncertainty in decision-making.

The development of computer applications has made resources and providers management easier and faster. It has also increased the influence of project leaders in the search for more efficient solutions. The Center for Geoinformatics and Digital Signals (GEYSED), which belongs to the software development centers network at the University of Informatics Sciences (UCI), is dedicated to the field of Digital Signal Processing and Geoinformation, which are its main research areas as well. Hence, they need to purchase the technology necessary for the deployment of the computer system in charge of video surveillance for locations in need of security and protection.

In focus group discussions with the development team, it was found that suppliers had not been properly evaluated. In order to carry out project management they use the XedroGespro V13.5 tool, which has a component for the suppliers management. However, this tool has not been found to be functional enough, since it allows suppliers to be added and associated with requests for projects, offers and contracts, but it does not offer the possibility of carrying out an analysis to select among a set of possible suppliers. The team members have not established the criteria by which the evaluation of the providers could be carried out and they have not defined how or who should carry out this process to guarantee the selection of the best supplier of the means they need to acquire for the good functioning of the project. These shortcomings introduce greater uncertainty and ambiguity into the proper evaluation of providers.

The purpose of this paper is to describe how the technology suppliers for a video surveillance project are selected using a method based on two fuzzy techniques to model uncertainty: the fuzzy AHP and the fuzzy 2-tuple representation model. The rest of this paper is organized as follows. Section 2 introduces the technology supplier selection method for video surveillance. Section 3 presents the application of the proposed method to a real project and Section 4 concludes the paper.

1. A method for the selection of technology suppliers for Video Surveillance

The proposed method will have two phases: the first phase will define the criteria needed to choose the best provider for which the weights are calculated using Fuzzy AHP; the second phase will include the analysis of the providers defining the evaluation framework (experts, criteria, alternatives) and the linguistic scales that will be used in the

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evaluation of the providers. Subsequently, the preferences of the evaluators are collected, for which the 2-tuple linguistic representation model is used to calculate the linguistic overall evaluation of suppliers.

1.1 Phase 1. Evaluation of criteria based on fuzzy AHP

1. - Definition of the evaluation criteria and development of the hierarchical structure: A hierarchy structure is the framework of proposed solution. It can not only be utilized to study the interaction among the elements involved in each layer but also help decision makers to explore the impact of different elements against the objective. The concepts of hierarchical structure analysis with two distinct levels; that is, criteria level and sub-criteria level, are used in this paper. The definition of criteria should be flexible and in line with the needs of the organization. The following are the criteria proposed for the research: Quality (Q), Delivery Time (DT), Cost (Co), Performance (P), Flexibility (F), Guarantee (G) and Technology (T). Figure 1 shows the sub-criteria that correspond to each criterion. To apply fuzzy AHP, the goal, criteria and sub-criteria must be structured at different levels of hierarchy.

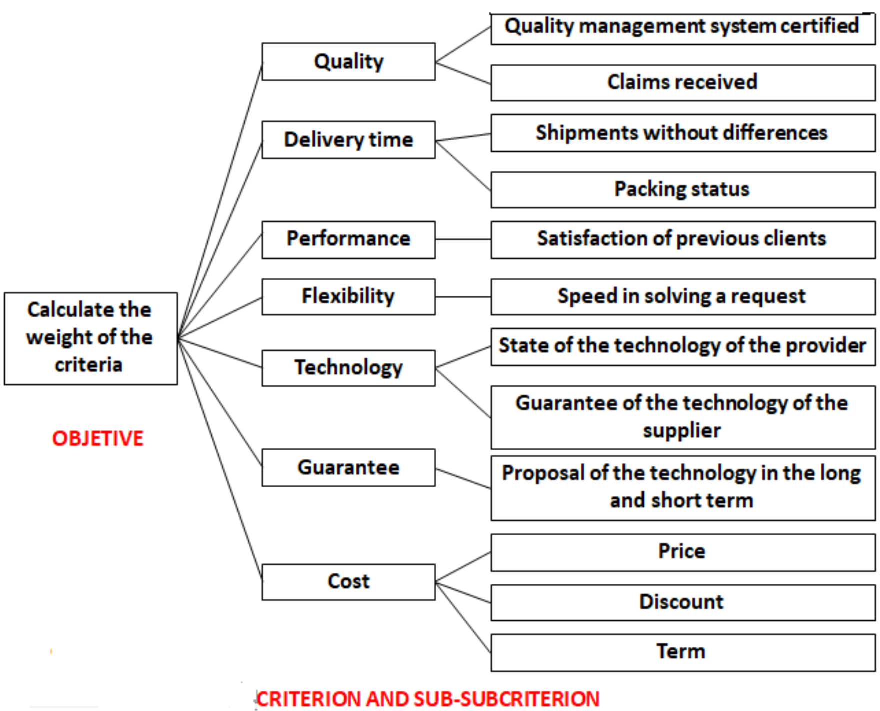

Figure 1. Hierarchical structure of the proposed criteria

2.- Selection of the fuzzy scale: It will allow the construction of the fuzzy judgment matrices. The experts' assessments will be made on the basis of the modified Saaty scale (Chiu, 1998).

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3.- Construction of fuzzy judgment matrices: the judgment matrices are constructed based on the hierarchy constructed in step one and using the selected fuzzy scale, and by comparing the elements at given levels in the hierarchical representation to estimate their relative importance in relation to the higher level element. To do this, the team uses the triangular numbers to express their preferences between the different criteria with respect to the goal (Table 1) and this same procedure is repeated for the sub-criteria.

Table 1**.** Matrix for comparison among research criteria

Criteria	Q	DT	Co	P	F	G	T
Q	(1,1,1)	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}
DT	$1/a_{12}$	(1,1,1)	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}
Co	$1/a_{13}$	$1/a_{23}$	(1,1,1)	a_{34}	a_{35}	a_{36}	a_{37}
P	$1/a_{14}$	$1/a_{24}$	$1/a_{34}$	(1,1,1)	a_{45}	a_{46}	a_{47}
F	$1/a_{15}$	$1/a_{25}$	$1/a_{35}$	$1/a_{45}$	(1,1,1)	a_{56}	a_{57}
G	$1/a_{16}$	$1/a_{26}$	$1/a_{36}$	$1/a_{46}$	$1/a_{56}$	(1,1,1)	a_{67}
T	$1/a_{17}$	$1/a_{27}$	$1/a_{37}$	$1/a_{47}$	$1/a_{57}$	$1/a_{67}$	(1,1,1)

4.- Calculation of weights of criteria and sub-criteria: It is recommended to use the methodology proposed by (Chang, 1996) in its extended method of analysis to calculate the weight of the criteria and the local weight of the sub-criteria.

$$m_{g_i}^1, m_{g_i}^2, \dots, m_{g_i}^m, i = 1,2,3 \dots n$$

Where all $m_{g_i}^j, j = 1,2,3 \dots m$ are fuzzy triangular numbers.

To calculate the weight of the criteria, Chang proposes the following equation:

$$S_i = \sum\nolimits_i^n m_{g_i}^j \otimes \left[\sum\nolimits_{i=1}^n \sum\nolimits_{j=1}^m m_{g_i}^j\right]^{-1} \quad \textbf{(I)}$$

Where the operator $\otimes$ denotes the extended multiplication of two fuzzy numbers.

To obtain the extended analysis values for each element of the paired comparison matrix$\sum_{j=1}^m m_{g_i}^j$, the basic addition of fuzzy numbers is applied as shown below:

$$\sum\nolimits_{j=1}^m m_{g_i}^j = \left(\sum\nolimits_{j=1}^m l_j, \sum\nolimits_{j=1}^m m_j, \sum\nolimits_{j=1}^m u_j\right) \textbf{(II)}$$

While to get$\left[\sum_{i=1}^n \sum_{j=1}^m m_{g_i}^j\right]$itwould be:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} m_{g_i}^{j} = \left(\sum_{i=1}^{n} l_j, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_j\right) \textbf{(III)}$$

Then$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} m_{g_i}^{j}\right]^{-1}$can be obtained as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} m_{g_i}^{j} = \left(\frac{1}{\sum_{i=1}^{n} u_j}, \frac{1}{\sum_{i=1}^{n} m_j}, \frac{1}{\sum_{i=1}^{n} l_j}\right) \textbf{(IV)}$$

To compare the values of m, it is taken into account that, for example, to determine the degree to which$m_2 \geq m_1$it is defined that$V(m_2 \geq m_1) = sup_{y \geq x}\left[min\left(m_1(x), m_2(y)\right)\right]$can also be expressed as follows:

$$V(m_2 \geq m_1) = hgt(m_2 \cap \geq m_1) = m_2(d) = \begin{cases} 1 \ if \ m_2 \geq m_1 \\ 0 \ if \ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{Inothercase} \end{cases} \quad \textbf{(VI)}$$

To carry out the comparison of $m_1$and $m_2$it is necessary to have the values of $V(m_2 \geq m_1)$ and $V(m_1 \geq m_2)$.

The degree of possibility for a convex fuzzy number to be greater than a convex fuzzy$k$, $m_i(i = 1,2, \dots, k)$ can be defined as:

$$V(m \geq m_1, m_2, \dots, m_k) = V[(m \geq m_1)y(m \geq m_2) \dots (m \geq m_k)] = minV(m \geq m_i), i = 1,2, \dots, k \textbf{(VII)}$$

So it is assumed that the weights are calculated as follows:

$d'(A_i) = minV(S_i \geq S_k)$ for $k = 1,2, \dots, n; k \neq i$ there for the weight vector is given by:

$W' = \left(d'(A_1), d'(A_2), \dots, d'(A_n)\right)$where $A_i(1,2, \dots, n)$ are the n elements. **(VIII)**

After the weight vector is obtained, it must be normalized. Being a vector of natural non-fuzzy numbers, this normalized vector is represented as:

$$W = \left(d(A_1), d(A_2), \dots, d(A_n)\right) \textbf{(IX)}$$

The local weight of the sub-criteria is calculated following the same procedure described in the previous section.

1.2 Phase 2. Evaluation of suppliers based on the fuzzy 2-tuple linguistic model

1.- Definition of the evaluation framework: The evaluation of suppliers should be carried out based on a set of criteria$C = \{\mathbf{c}_k | \mathbf{k} \in (\mathbf{c_1}, \dots, \mathbf{c_h})\}$, a set of suppliers (alternatives) $A = \{\mathbf{a_j} | \mathbf{j} \in (\mathbf{a_1}, \dots, \mathbf{a_n})\}$and a set of experts $E = \{\mathbf{e}_i | \mathbf{i} \in (\mathbf{e_1}, \dots, \mathbf{e_m})\}$**,** that are defined at the beginning of the evaluation. Itis important to consider the weight or importance of each criterion for which the weight vector is $\mathbf{W^c} = (\mathbf{w_1^c}, \dots, \mathbf{w_h^c})$ that can be calculated in phase 1 or can be defined according to the evaluator will be used. In order for evaluators to be able to express their perception and knowledge easily, it is necessary for them to use an appropriate set of linguistic descriptors, the cardinality of which must correspond to (Miller, 1956). The assessment information is provided using the linguistic term set in Table 2.

Table 2. Syntax and semantic of a linguistic set of seven terms

Term	Label	Fuzzy number
s_0	Null (N)	(0,0, 0.16)
s_1	Very Low (VL)	(0, 0.16, 0.33)
s_2	Low (L)	(0.16, 0.33, 0.5)
s_3	Medium (M)	(0.33, 0.5, 0.66)
s_4	High (H)	(0.5, 0.66, 0.83)
s_5	Very High (VH)	(0.66, 0.83,1)
s_6	Excellent (E)	(0.83, 1,1)

2. Compilation of experts' preferences: The collection of the experts' evaluations is based on the definitions made in the evaluation framework. Each $\mathbf{e_i}$expert will be able to express its considerations, using the utility vector $\mathbf{X} = \mathbf{x_1^{k1}}, \dots, \mathbf{x_j^{ki}}$, where $\mathbf{x_j^{ki}}$ represents his/her preference over the $\mathbf{a_j}$ supplier according to the $\mathbf{c_k}$criterion.

3.- Transformation of experts'preferencesinto 2-tuple linguistic values: For each assessment $\boldsymbol{s_t \epsilon S}$the transformation is carried out assuming that $\boldsymbol{a} = \mathbf{0}$, leaving the 2-tuple linguisticas $(\boldsymbol{s_t}, \mathbf{0})$. Applying this rule, the new 2-tuple linguistic matrices will have the form $\left(\tilde{\mathrm{X}}\right)_{n\times h} = \left(\tilde{\mathrm{x}}_{\mathrm{j}}^{\mathrm{ki}}\right)_{n\times h}$, $\tilde{\mathrm{x}}_{\mathrm{j}}^{\mathrm{ki}} = \tilde{s}_{\mathrm{j}}^{\mathrm{ki}} = (s, 0)_{\mathrm{j}}^{\mathrm{ki}}$.

Remark: Since the calculation of the collective evaluation for each supplier can be seen as a multi-step aggregation process using 2-tuple linguistic aggregation operators. In (Martínez et al. 2015) many of the basic 2-tuple linguistic aggregation operators can be revised and one of the most used in literature are the following:

Assume thatX={(s_1,α_1),…,(s_m,α_m)}is a set of 2-tuple linguistic values, and W=(w_1,…,w_m) the weighting vector such that $\sum_{i=1}^{m} w_i = 1$ the weighted averaging aggregation operator associated with W is the function$2TWM\colon \tilde{S}^m \longrightarrow \tilde{S}$defined as:

$$2TWM(X) = \Delta\left(\sum_{i=1}^{m} w_i\, \Delta^{-1}(s_i, \alpha_i)\right) \quad \textbf{(X)}$$

When$W = \left\{\frac{1}{m}, \frac{1}{m}, \dots, \frac{1}{m}\right\}$, the 2TWM operator reduces to the 2-tuple arithmetic mean (2TAM) operator:

$$2TAM(X) = \Delta\left(\frac{1}{m}\sum_{i=1}^{n} \Delta^{-1}(s_i, \alpha_i)\right) \quad \textbf{(XI)}$$

The selection of the operators in next steps 4 and 5 will depend on the intended outcome.

4.-Calculation of the collective value for each criterion: In this step, preferences provided by experts are aggregated together, obtaining collective valuations from individual valuations, that is to say, the collective value of each criterion can be obtained for each supplier by aggregating the preferences of all the experts. Matrices $(\bar{X})_{n\times h} = (\bar{x}_j^k)$ are obtained based on:$(\bar{X})_{n\times h} = 2TAM(\tilde{x}_j^{ki})$.

5-. Calculation of the collective value for each supplier: Once the evaluations issued on each criterion have been aggregated, the overall value of the preferences for each supplier is then calculated. Matrices $(\bar{\bar{\mathbf{X}}})_{\boldsymbol{n}} = (\bar{\bar{\mathbf{x}}}_j)$ are generated based on:$(\bar{\bar{\mathbf{X}}})_{\boldsymbol{n}} = 2TWM(\bar{\mathbf{x}}_j^k)$.

6-. Obtaining the ordered list of suppliers: Once the overall evaluation is obtained for each supplier, by comparing the $\bar{\bar{\mathbf{x}}}_j$2-tuple linguistic values, we can determine the ranking order of all suppliers and select the best one from the initial set of feasible alternatives. The rules of comparison for 2-tuple linguistic values were introduced in (Herrera and Martínez, 2000).

Figure 2 summarize the inputs, outputs and the 2-tuple linguistic computing tool to be applied in each step.

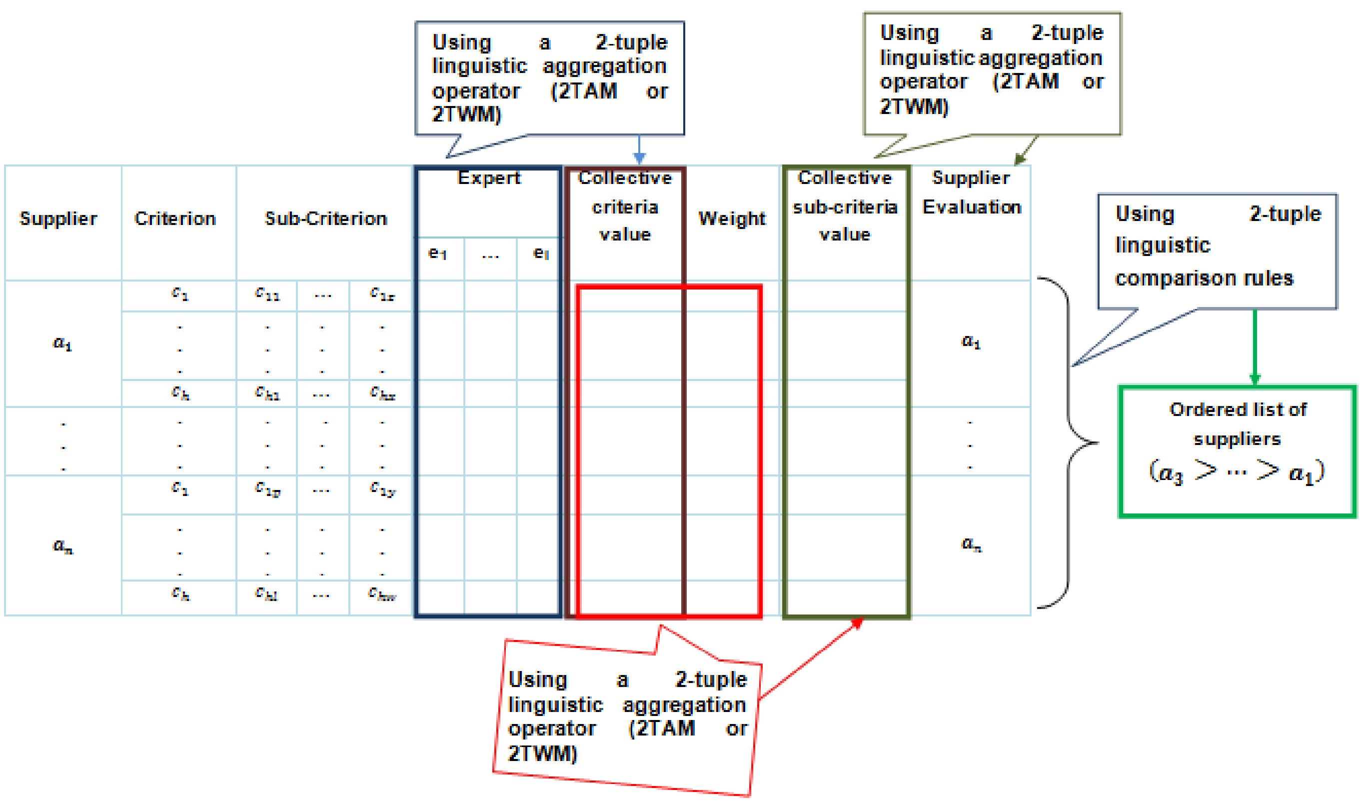

Figure 2. Summary for the supplier evaluation phase based on the fuzzy 2-tuple linguistic model

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2. Application of the proposed method in the technology supplier selection for Xilema Suria

Xilema Suria is a professional platform for the management of video surveillance in any environment in need of security and protection. With a high degree of scalability and adaptability it represents the ideal support in the protection of people, buildings, offices, public establishments and other assets. Structured in six subsystems that interact with each other, the system described is capable of operating on IP cameras of any known manufacturer and allows real-time and delayed monitoring of each action performed. The project team needs to select a company to provide the necessary cameras for the deployment of the application. Mobotix (a_1), Vivotek (a_2), Axis Comunications (a_3) and Visiotech (a_4), meet the essential requirements for software installation and our model will be used to select the right provider.

In the following, we employ the proposed method to aidthe Xilema Suria project to select the most suitable technology supplier. The solution process and the computation resultsare summarized as follows:

2.1 Phase 1. Evaluation of criteria based on fuzzy AHP

1. - Definition of the evaluation criteria and development of the hierarchical structure: Based on an interview with the project leader, where the needs of the project were analyzed, it was determined that it was not necessary to take into account the evaluation based on the 7 criteria defined in the main method. Those chosen are represented in the hierarchical structure with their respective sub-criteria in Figure 3.

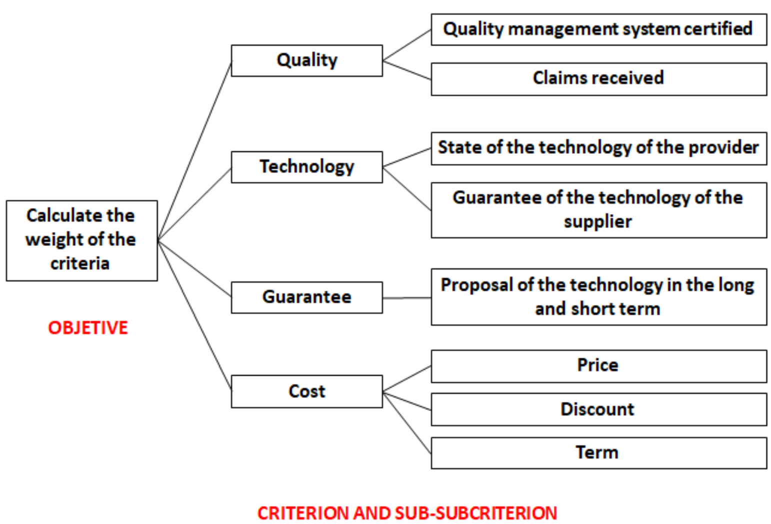

Figure 3. Hierarchical structure of criteria considered for Xilema Suria supplier selection

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2.-Selection of the fuzzy scale: The construction of the matrices of fuzzy judgment will be done from the valuations of the experts taking into account the modified Saaty scale (Chiu, 1998).

3.- Construction of fuzzy judgment matrices: The criteria issued by the project leader, considered as the expert to carry out this evaluation, is presented in Table 3, the matrices of fuzzy judgment must be constructed from the paired comparison of the selected criteria and sub-criteria.

Table 3. Criteria comparison matrix

	Quality	Cost	Technology	Guaranty
Quality	(1,1,1)	(1,1,2)	(2,3,4)	(2,3,4)
Cost	(1/2,1,1)	(1,1,1)	(8,9,9)	(6,7,8)
Technology	(1/4,1/3,1/2)	(1/9,1/9,1/8)	(1,1,1)	(2,3,4)
Guarantee	(1/4,1/3,1/2)	(1/8,1/7,1/6)	(1/4,1/3,1/2)	(1,1,1)

4.- Calculation of weights of criteria and sub-criteria: Once the matrices of fuzzy judgment have been carried out from the paired comparison of the criteria and sub-criteria selected by the project leader, the corresponding weight of each criterion and sub-criterion is calculated. Table 4 shows the values.

Table 4.Weight of the criteria and sub-criteria.

Criterion	Weight	Sub-criteria	Local weight
Quality	0.342	SGCC	0.5
		RR	0.5
Cost	0.342	D	0.854
		P	0.146
		PP	0
Technology	0.300	ET	0.5
		GT	0.5
Guarantee	0.016	PGCLP	1

2.2. Phase 2. Evaluation of suppliers based on the fuzzy 2-tuple linguistic model

Table 5 summarizes steps 2 to 5 of the Phase 2. Preferences provided by experts are collected and transformed into 2-tuple linguistic values (columns 4-6). The collective value for each criterion is calculated using the 2TAM aggregation operator (column 7). The collective value of each sub-criterion is calculated using the 2TWM aggregation operator (columns 7-8) and, finally, the overall evaluation for each supplier is calculated using the 2TAM aggregation operator (column 9).

Table 5. Calculation of the overall value of preferences for each assessor.

Supplier	Criterion	Sub-criterion	Expert			Collective criteria value	Collective sub-criteria value	Supplier Evaluation
			e_1	e_2	e_3			

a_1	c_1	c_{11}	$(S_5,0)$	$(S_5,0)$	$(S_5,0)$	$(S_3,0)$	$(S_1,-0.14)$	$(S_4,0.12)$
		c_{12}	$(S_0,0)$	$(S_1,0)$	$(S_1,0)$		$(S_0,0.17)$	
	c_2	c_{21}	$(S_3,0)$	$(S_3,0)$	$(S_3,0)$	$(S_5,0)$	$(S_0,0.15)$	
		c_{22}	$(S_2,0)$	$(S_5,0)$	$(S_5,0)$		$(S_0,0)$	
		c_{23}	$(S_3,0)$	$(S_5,0)$	$(S_5,0)$		$(S_1,0.46)$	
	c_3	c_{31}	$(S_6,0)$	$(S_6,0)$	$(S_6,0)$	$(S_6,0)$	$(S_1,-0.1)$	
		c_{32}	$(S_6,0)$	$(S_5,0)$	$(S_6,0)$		$(S_1,-0.1)$	
	c_4	c_{41}	$(S_5,0)$	$(S_4,0)$	$(S_4,0)$	$(S_4,0)$	$(S_0,0.06)$	
a_2	c_1	c_{11}	$(S_6,0)$	$(S_5,0)$	$(S_5,0)$	$(S_4,-0.5)$	$(S_1,-0.14)$	$(S_3,0.1)$
		c_{12}	$(S_1,0)$	$(S_2,0)$	$(S_2,0)$		$(S_0,0.34)$	
	c_2	c_{21}	$(S_5,0)$	$(S_3,0)$	$(S_3,0)$	$(S_3,-0.5)$	$(S_0,0.15)$	
		c_{22}	$(S_4,0)$	$(S_5,0)$	$(S_5,0)$		$(S_0,0)$	
		c_{23}	$(S_1,0)$	$(S_1,0)$	$(S_2,0)$		$(S_0,0.29)$	
	c_3	c_{31}	$(S_6,0)$	$(S_6,0)$	$(S_5,0)$	$(S_6,-0.5)$	$(S_1,-0.1)$	
		c_{32}	$(S_5,0)$	$(S_5,0)$	$(S_5,0)$		$(S_1,-0.25)$	
	c_4	c_{41}	$(S_3,0)$	$(S_4,0)$	$(S_4,0)$	$(S_4,0)$	$(S_0,0.06)$	
a_3	c_1	c_{11}	$(S_5,0)$	$(S_4,0)$	$(S_4,0)$	$(S_2,0)$	$(S_1,-0.32)$	$(S_3,0.06)$
		c_{12}	$(S_0,0)$	$(S_0,0)$	$(S_2,0)$		$(S_0,0)$	
	c_2	c_{21}	$(S_4,0)$	$(S_3,0)$	$(S_3,0)$	$(S_3,0)$	$(S_0,0.15)$	
		c_{22}	$(S_4,0)$	$(S_5,0)$	$(S_3,0)$		$(S_0,0)$	
		c_{23}	$(S_3,0)$	$(S_2,0)$	$(S_3,0)$		$(S_0,-0.12)$	
	c_3	c_{31}	$(S_5,0)$	$(S_5,0)$	$(S_3,0)$	$(S_5,0)$	$(S_1,-0.25)$	
		c_{32}	$(S_5,0)$	$(S_5,0)$	$(S_3,0)$		$(S_1,-0.25)$	
	c_4	c_{41}	$(S_3,0)$	$(S_4,0)$	$(S_4,0)$	$(S_4,0)$	$(S_0,0.06)$	
a_4	c_1	c_{11}	$(S_5,0)$	$(S_4,0)$	$(S_4,0)$	$(S_3,0)$	$(S_1,-0.32)$	$(S_3,-0.12)$
		c_{12}	$(S_2,0)$	$(S_2,0)$	$(S_0,0)$		$(S_0,0.34)$	
	c_2	c_{21}	$(S_3,0)$	$(S_3,0)$	$(S_3,0)$	$(S_3,0)$	$(S_0,0.15)$	
		c_{22}	$(S_2,0)$	$(S_5,0)$	$(S_3,0)$		$(S_0,0)$	
		c_{23}	$(S_3,0)$	$(S_0,0)$	$(S_3,0)$		$(S_1,-0.12)$	
	c_3	c_{31}	$(S_5,0)$	$(S_5,0)$	$(S_3,0)$	$(S_5,-0.5)$	$(S_1,-0.25)$	
		c_{32}	$(S_4,0)$	$(S_5,0)$	$(S_3,0)$		$(S_1,-0.4)$	
	c_4	c_{41}	$(S_4,0)$	$(S_3,0)$	$(S_4,0)$	$(S_4,0)$	$(S_0,0.06)$	

Since $(S_4,0.12) > (S_3,0.06) > (S_3,0.01) > (S_3,-0.12)$, the final order of suppliers $(a_1,a_3,a_2,a_4)$and the best one is Mobotix(a_1) with the highest global 2-tuple linguistic supplier evaluation.

2.3 Results analysis

It is interesting to contrast our results with others obtained with different methods. To discuss our approach we propose to solve the problem using two additional approaches:

- The Fuzzy AHP in the total solution (Chang, 1996). That is, to use fuzzy AHP with the concepts of hierarchical structure analysis with three distinct levels; that is, criteria level, sub-criteria level and suppliers level.
- The technique for order preference by similarity to ideal solution (TOPSIS) (Hwang and Yoon, 1981). TOPSIS was originally introduced for solving decision making problems with numerical inputs. Its basic principle is that the best alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. For determining a collective evaluation for each supplier, considering importance weights for criteria, fuzzy assessments are aggregated by means of arithmetical operations over fuzzy. Then we calculate a closeness coefficient based on the distances to the positive ideal solution and the negative ideal solution. So, these closeness coefficients allow to obtain a ranking of alternatives, but they lack interpretation, rather than the order.

Table 6 summarizes the outputs for the three methods. It is easy to see that the optimal order for these three potential suppliers are similar, and the supplier $\boldsymbol{a_1}$ is the most desirable supplier. The proposed method is not only simple and easy to understand but also reduces the loss of the original data information by using the 2-tuple linguistic model.

After applying the three methods to the same data set, the results of our approach were considered as better for the experts. The other approaches do not provide interpretability in the collective result for each supplier, further than the order. This is a significant feature in supplier evaluation processes when experts' and stakeholders' interpretability requirements are beyond a simple ranking of suppliers in order to understand the rating process and the obtained results. In these situations, our approach based on fuzzy AHP and fuzzy 2-tuple linguistic model, provides desirable characteristics because its results are close to human natural language and provide interpretability and understandability. Moreover, they were more confident on our results because they could deduce the result just by reading the label and the symbolic translation.

Table 6. Obtained results with the three approaches.

Fuzzy AHP			**TOPSIS**		**Proposed method**	
Alternative	**Crisp Evaluation**	**Ranking**	**Closeness Coefficient**	**Ranking**	**Linguistic Evaluation**	**Ranking**
$\boldsymbol{a_1}$	45%	1	0.92	1	$(S_4, 0.12)$	1
$\boldsymbol{a_3}$	30%	2	0.58	2	$(S_3, 0.06)$	2
$\boldsymbol{a_2}$	13%	3	0.33	3	$(S_3, 0.01)$	3
$\boldsymbol{a_4}$	12%	4	0.33	3	$(S_3, -0.12)$	4

To calculate the ranking of the TOPSIS method and the proposed method, the experimental calculation application Flintstones was used (Estrella et al. 2014). In the case of fuzzy AHP, a spreadsheet was used.

Conclusions

The supplier evaluation and selection problem involves a multiplicity of complex considerations. Moreover, some evaluation criteria faced an ambiguous and uncertain nature. Hence, the evaluation of supplier selection is usually confronted with fuzzy decision-making models. In the light of this, this paper developed a hybrid fuzzy multi criteria decision making approach to solve the problem of supplier selection for video surveillance projects. It applies in the first phase the fuzzy AHP to obtain the criteria weights in the hierarchical structure. It also uses the fuzzy 2-tuple linguistic model in the second phase to calculate the overall evaluation of each supplier.

The results are not only very simple and easy to understand but also reduces the loss of the original data information byusing the fuzzy 2-tuple linguistic model.

The proposed method is illustrated with its application to the technology supplier selection problem for Xilema Suria, a real video surveillance project developed at UCI. This selection problem is one of the possible applications; it is expected that the method proposed in this paper can be applied to many fields such as risk analysis, project evaluation, renewable energy system selection and location selection.

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