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An Extended Hierarchical Linguistic Model for Managing Integral Evaluation

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Abstract

Performance appraisal is a process used by companies in order to evaluate their employees' efficiency and productivity for planning their Human Resource policies. Traditionally this process has just been carried out by the executive staff but recently it has started to be based on opinions of different appraisers, being called integral evaluation. In such an evaluation process, the appraisers provide their opinions according to their own perceptions, knowledge and feelings regarding the evaluated employee. Such knowledge is then, vague and subjective. Consequently, its *modelling* by means of linguistic information is more flexible and suitable than a crisp *modelling*. Due to the fact that different *types of experts* could have different degree of knowledge about the evaluated employee, in this paper is proposed an integral evaluation model capable of dealing with multiple linguistic scales in a precise way by using extended linguistic hierarchies.

Keywords: Performance appraisal, integral evaluation, multiple linguistic scales, extended linguistic hierarchies

1. Introduction

Along the history, organizations and companies have been adapting to market conditions with the aim of achieving their survival and success. Nowadays, global competition affects companies and organizations and therefore, keeping competitive up in this environment is their main goal. Due to this fact, lots of managers are conscious that being competitive in this environment depends on a constant development of the Human Resources.

A main goal of the Human Resources Department is the administration of the human capital by means of measuring the relationships between the company's human capital and the financial results obtained by the company[14].

According to some authors[14], it is easy to check that most companies are symbolized by their human capital (around 80%). But, it is very difficult to measure how much human capital contributes to the company financial results. In the specialized literature it can be checked that several trends corroborate that human behaviour measurement improves companies productivity[3,11,14,23].

In a gradual way, organizations and companies have introduced different methods for evaluating their employees performance. In the literature, it can be found several definitions about what performance appraisal[3,4,8,14,28] is. Although in general, we can say that performance appraisal is a formal process to evaluate the efficiency and productivity of employees. This process takes into account the contribution that every employee carries out to fulfil companies goals during a period of time. Thus, performance appraisal process consists of estimating workers effectiveness and efficiency degree [2,7,8,15,27,28]. Despite the existence of many different evaluation methods, all of them present common problems[2,14], that are usually:

1. *Lack of objectivity*.
2. *Prejudice or Halo errors*.
3. *Indulgence and requirement*.
4. *Central tendency*.
5. *Recent behavior prejudice*.
6. *Intentional errors*.

Generally, performance appraisal process has been directly carried out by executive teams where only supervisors make decisions about employees in Human Resources policies, appearing the drawbacks pointed out previously. In order to overcome these drawbacks, corporations are adopting new methods that use information from different people (appraisers) related to the evaluated worker. So, companies and organizations have been taking into account in the evaluation process not only managers opinions but also the opinion of the evaluated employee's partners, as well as subordinates, collaborators, customers, and even the opinions of employees about themselves (see Fig. 1). This evaluation process is so-called *360-degree appraisal* or *integral evaluation*[12,14,24].

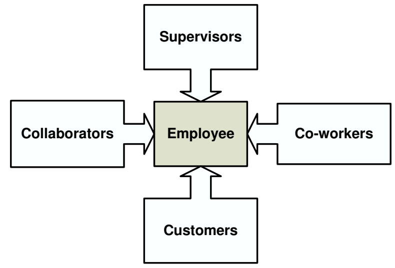

Fig. 1. Different points of view in integral evaluation

The use of this methodology allows companies to obtain information about employees' performance from different points of view, which improves the process results. Recent polls in USA estimate that 90% of Fortune 1000 firms use 360-degree appraisal or integral evaluation to evaluate their employees as McDonnell-Douglas, AT&T, Allied Signal, Dupont, Honeywell, Boeing and Intel, among others[14]. This methodology has been extensively used since the 80's, for evaluating supervisors and managers. Several 360-degree appraisal advantages over the classical system with just supervisors as appraisers are[2,12,14]:

- This method collects simultaneously information from different points of view about employees' performances. Supervisors, collaborators, customers and employees themselves take part in the evaluation process.
- Companies obtain information from different reviewers and they can appraise various dimensions of employees' performance.
- The use of different sources leaves out biased.

Besides the problems that the traditional methodology has, it is possible to check that there is another problem common to classical and integral method. Such a problem is related to the way in which the information is expressed. Although the indicators or criteria used to evaluate employees are usually qualitative and subjective (communication ability, cooperativeness, loyalty to company, etc.), the traditional and the integral appraisal force reviewers to express their opinions by means of numerical values[3,14]. Consequently, this fact achieves a lack of accuracy in the evaluation process due to the difficulty of expressing vague and imprecise concepts in a precise way, and even more in the integral evaluation due to the fact that each reviewers' collective might have different degree of knowledge about employees.

In order to overcome the problems of the traditional methods, in this paper we propose an integral appraisal model where different groups of reviewers evaluate employees attending to different criteria and attributes, in this way our proposed model adopts the advantages of the integral method. Moreover, in order to manage the uncertainty associated with the information, we propose a flexible model where the appraisers' opinions are modelled by means of linguistic information because the use of this type of approach is more suitable and flexible for this kind of information and it has provided good results in similar situations in other fields as sensory evaluation[25,26,29,33].

In addition, and due to the fact that the different groups of reviewers may have different knowledge about the evaluated employees, we suggest a flexible framework where the different reviewers could express their opinions by means of different linguistic scales according to their knowledge and expertise. Although there are different approaches which deal with such a type of context[9,10,16,22], our proposal will make use of the extended linguistic hierarchies[13] because such a method overcomes the limitations in applicability, effectiveness and accuracy present in the other approaches and the computational model associated with it is based on a symbolic one and the results are expressed in the initial term sets used by the experts to provide their knowledge without loss of information.

The paper is organized as follows. Section 2 reviews some important concepts about linguistic information. In Section 3, we present an integral performance appraisal model with multiple linguistic scales. In Section 4 we propose an illustrative example. And finally, the contribution is concluded in Section 5.

2. Linguistic Background

Due to the fact that our proposal will deal with linguistic information, here, we shall review in short some necessary concepts about linguistic information to understand our proposal. We review briefly the fuzzy linguistic approach and how to manage multi-granular linguistic information by means of extended linguistic hierarchies.

2.1. Fuzzy linguistic approach

Many aspects of different activities in the real world cannot be assessed in a quantitative form, but rather in a qualitative one, i.e., with vague or imprecise knowledge. In that case, a better approach may be the use of linguistic assessments instead of numerical values. The fuzzy linguistic approach represents qualitative aspects as linguistic values by means of linguistic variables[31]. We have to choose appropriate linguistic descriptors for the term sets and their semantics[5]. In the linguistic approach an important parameter to be determined is the "granularity of uncertainty" that indicates the degree of discrimination given by a term set, so that the more knowledge about the variable, the more granularity that can be utilized to assess it. When different experts have different uncertainty degrees about the items, several linguistic term sets with a different granularity of uncertainty may be then necessary[9,10,17].

One possibility of generating the linguistic term set consists in directly supplying the term set by considering all the terms distributed on a scale on which a total order [31] is defined. For example, a set of seven terms S (see Fig. 2) could be:

$$S = \{s_0\text{: N (Null)}, s_1\text{: VL (Very-Low)}, s_2\text{: L (Low)}, s_3\text{: M (Medium)}, s_4\text{: H (High)}, s_5\text{: VH (Very-High)}, s_6\text{: P (Perfect)}\}$$

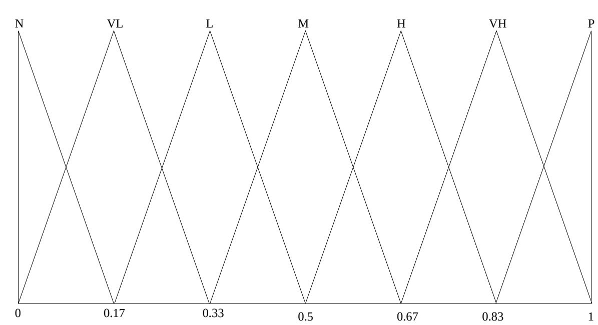

Fig. 2. A set of seven terms with its semantics

The semantics of terms is given by fuzzy numbers defined on the $[0,1]$ interval, which are usually described by membership functions.

In this paper, we shall use triangular membership functions as semantics of the linguistic terms whose representation is defined by three parameters (a,b,c), where b indicates the point in which the membership value is 1, with a and c indicating the left and right limits of the definition domain of the membership function[6].

2.2. Managing multi-granular linguistic information with extended linguistic hierarchies

Multi-expert decision-making problems, that deal with linguistic information expressed in different scales, are defined within a multi-granular linguistic framework. In order to manage such a type of framework different approaches have been published[9,10,13,16,21,22].
In this paper and in order to manage multi-granular linguistic information, we are going to use the approach proposed by Espinilla, Liu and Martínez[13], the *Extended Linguistic Hierarchies* (ELH), because ELH provides experts a total flexibility to model the linguistic information and it keeps accuracy in processes of computing with words.

An ELH is a set of linguistic terms sets, where each level is a linguistic term set with different granularity from the remaining levels of the ELH. Each level belongs to an ELH is denoted as $\mathbf{l}(\mathbf{t},\mathbf{n}(\mathbf{t}))$, being t the level of the ELH and $n(t)$ the granularity of the linguistic term set of the level t.

In order to build an ELH it is necessary to follow the *extended hierarchical rules*[13]. Following these rules, an ELH is built as:

- a finite number of the levels $l(t,n(t))$ with $t = 1,...,m,$ that defines the multi-granular linguistic context,
- a final level $l(t',n(t'))$, $t' = m+1$ and with the following granularity is added:

$$n(t') = \big(L.C.M(n(1)-1,...,n(m)-1)\big)+1 \quad (1)$$

being $L.C.M$ the *Least Common Multiple*.

In this way, given an ELH, $S^{n(t)}$ denotes the linguistic term set of ELH corresponding to the level t of ELH with a granularity of uncertainty of $n(t)$

$$S^{n(t)} = \{s_0^{n(t)},...,s_{n(t)-1}^{n(t)}\}.$$

Moreover, the use of linguistic information implies processes of "*computing with words*" (CW). In order to accomplish such processes when we are dealing with ELH, in [13] was proposed a computational model based on linguistic 2-tuples[18] to accomplish the proceses of CW with multi-granular linguistic information in a precise way. Such a model consists of a three-step process showed in Fig. 3, that consists of:

- Unification phase. The multi-granular linguistic information is expressed in only one linguistic term set that for ELH is always $S^{n(t')}$ (for further details see [13]).
- Computation process. Once the information is expressed in only one expression domain $S^{n(t')}$, the computations are carried out by using the linguistic 2-tuple model[18].
- Expressing results. In this step the results can be transformed into any level of the ELH in a precise way to improve the understanding of the results.

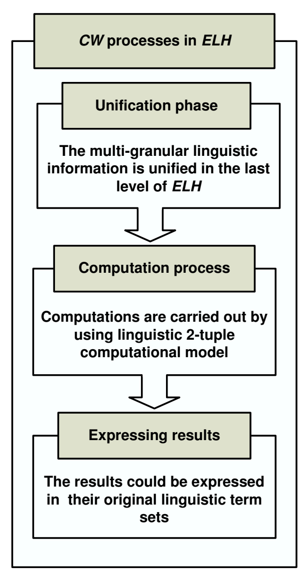

Fig. 3. *Computing with words* processes in *ELH*

Following, we introduce very briefly some necessary concepts to understand and carry out the processes of CW dealing with multi-granular linguistic information assessed in an ELH.

The 2-tuple linguistic model was introduced in [18] for improving the accuracy and flexibility of the processes of CW[20]. This model represents the linguistic information by a pair of values, (s,α), so-called 2-tuple, where s is a linguistic term and α is a numerical value that represents a symbolic translation. This model introduced a transformation functions between linguistic values and numbers in the interval of granularity $[0,g]$ to facilitate computations.

Definition 1. Let $S=\{s_0,\dots,s_g\}$ be a set of linguistic terms. The *2-tuple set associated with* S is defined as $\langle S\rangle = S\times[-0.5,0.5)$. We define the function $\Delta_S:[0,g]\longrightarrow\langle S\rangle$ given by

$$\Delta_S(\beta)=(s_i,\alpha),\ \text{ with } \begin{cases} i= \text{ round}\,(\beta), \\ \alpha=\beta-i, \end{cases}$$

where *round* assigns to β its closest integer number $i\in\{0,1,\dots,g\}$.

We note that Δ_S is bijective[18,19] and $\Delta_S^{-1}:\langle S\rangle\longrightarrow[0,g]$ is defined by $\Delta_S^{-1}(s_i,\alpha)=i+\alpha$. In this way, the 2-tuples of $\langle S\rangle$ will be identified with the numerical values in the interval $[0,g]$.

Remark 1. We can consider the injective mapping $H:S\longrightarrow\langle S\rangle$ that transforms a linguistic term s_i into the 2-tuple $(s_i,0)$. On the other hand, $\Delta_S(i)=(s_i,0)$ and $\Delta_S^{-1}(s_i,0)=i$, for every $i\in\{0,1,\dots,g\}$.

The linguistic 2-tuple model not only facilitates the processes of CW, but also in our case supports the transformations suffered by the linguistic information in the ELH in order to unify it and express the results in the original expression domains. In [13] was defined a transformation function of linguistic terms of an ELH between different of its levels.

Definition 2. Let $S^{n(a)}=\{s_0^{n(a)},s_1^{n(a)},\dots,s_{n(a)-1}^{n(a)}\}$ and $S^{n(b)}=\{s_0^{n(b)},s_1^{n(b)},\dots,s_{n(b)-1}^{n(b)}\}$ be two linguistic term sets, with $a\neq b$. The *linguistic transformation function* $TF_a^b:\langle S^{n(a)}\rangle\longrightarrow\langle S^{n(b)}\rangle$ is defined by:

$$TF_a^b(s_j^{n(a)},\alpha_j) = \Delta_S\left(\frac{\Delta_S^{-1}(s_j^{n(a)},\alpha_j^{n(a)})\cdot(n(b)-1)}{n(a)-1}\right) = (s_k^{n(b)},\alpha_k).$$

We can note that in the computing model for information assessed in an ELH, the linguistic transformation function, TF_a^b, performed in the unification phase, a might be any level in the set $\{t=1,...,m\}$ and b is always the level t'. The computational processes are carried out in the level t' and following, the results are expressed by using TF_a^b where b could be any level in the set $\{t=1,...,m\}$ and a is always the level t'. This rule was imposed in [13] to keep the accuracy in computation process with ELH.

3. A Linguistic Integral Evaluation Model

In this section, we present our proposal of an integral evaluation model with multi-granular linguistic information which it is based on the scheme showed in the Fig. 4 whose main phases are:

1. *Evaluation framework*. In this phase, it is defined the framework in which the evaluation will be developed.
2. *Aggregation phase*. This phase is based on the computational model showed in Fig. 3 and it is composed by different levels of aggregation (see Fig. 5):
   (a) Computing *collective criteria values* for each criterion.
   (b) Computing *global criteria values* for each criterion.
   (c) Finally, in the third and last aggregation step is computed a *global value* for each employee.
3. *Rating phase*. In this phase companies carry out the process of classifying and ranking employees paying attention to the objectives established by the Human Resource Department policy.

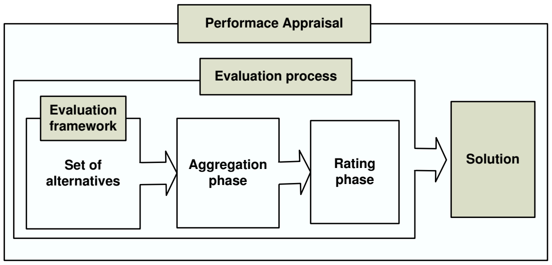

Fig. 4. Evaluation process

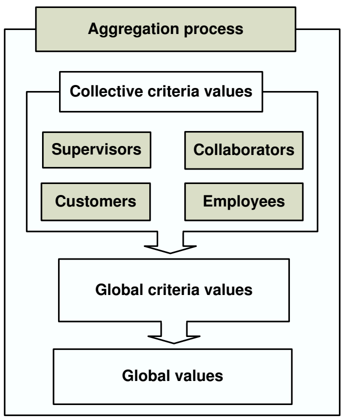

Fig. 5. Aggregation process

In the coming subsections we present in further detail each phase of the proposed multi-granular linguistic integral evaluation model.

3.1. Evaluation framework

In this phase the structure of the evaluation process and the domains, in which the information will be assessed, are defined.

The integral evaluation process measures workers' effort and efficiency taking into account the opinion of different people related to them and the opinion of employees on themselves. As we have aforementioned, the reviewers' collectives have different knowledge about employees, due to this fact and in order to improve the evaluation process, the different reviewers' collectives may use different linguistic expression domains to evaluate employees depending on their knowledge about them and the different evaluated criteria[1].

In order to introduce the construction of the evaluation framework, we show how a company or organization could carry out an integral evaluation process. Let us consider a company which carries out an integral evaluation process on a set of n employees $X = \{x_1, \dots, x_n\}$ regarding a set of p criteria $Y = \{Y_1, \dots, Y_p\}$ and taking into account the following collectives of reviewers:

- $A = \{a_1, \dots, a_r\}$: A set of r supervisors.
- $B = \{b_1, \dots, b_s\}$: A set of s collaborators.
- $C = \{c_1, \dots, c_t\}$: A set of t customers.
- $X = \{x_1, \dots, x_n\}$: A set of n employees.

Although it would be possible to consider that each reviewer can use different linguistic term sets to evaluate employees attending to each criterion, let us assume that every reviewers' collective uses its own linguistic term set to express their assessments about employees attending each criterion that is more reasonable and make easier the computing process.

Our proposal will manage the multi-granular linguistic information by using ELH. Consequently and before starting the evaluation, the integral evaluation framework associated with this kind of information is defined as:

- Let $n(t_{A,k})$ be the granularity of the linguistic term set used by supervisors to evaluate employee x_j attending to the criterion Y_k and $t_{A,k}$ the level of this set. In this way, the opinion of supervisor i on employee j according to the criterion k is denoted $a_j^{ik} \in S_{A,k}^{n(t_{A,k})}$ for each $i \in \{1, \dots, r\}$, $j \in \{1, \dots, n\}$ and $k \in \{1, \dots, p\}$.

- Similarly for collaborators, $n(t_{B,k})$ is the granularity of the linguistic term set used to evaluate employee x_j attending to the criterion Y_k and $t_{B,k}$ the level of this set. Therefore, $b_j^{ik} \in S_{B,k}^{n(t_{B,k})}$ is the opinion of collaborator i on employee j according to the criterion k for each $i \in \{1, \dots, s\}$, $j \in \{1, \dots, n\}$ and $k \in \{1, \dots, p\}$.

- Regarding customers, $n(t_{C,k})$ is the granularity of the linguistic term set and $t_{C,k}$ the level of this set. Being $c_j^{ik} \in S_{C,k}^{n(t_{C,k})}$ the opinion of customer i on employee j according to the criterion k.

- Finally, $n(t_{X,k})$ is the granularity of the linguistic term set used by employees to evaluate themselves, attending to the criterion Y_k and $t_{X,k}$ is the level of this set. The opinion of employee x_j on him/herself is denoted as $x_j^{jk} \in S_{X,k}^{n(t_{X,k})}$.

Therefore, now the ELH that defines the evaluation framework is built according to the previous expression domains. Being the ELH the union of all previous levels used by different collectives of reviewers to evaluate each employee $S_{\_}^{n(-)}$ and a new term set $\overline{S}^{n(t')} = \{\overline{s}_0^{n(t')}, ..., \overline{s}_{n(t')-1}^{n(t')}\}$ with the following granularity:

$$
\begin{aligned}
n(t') \quad = \quad L.C.M\{ \quad & n(t_{A,1})-1, \ldots, n(t_{A,p})-1, \\
& n(t_{B,1})-1, \ldots, n(t_{B,p})-1, \\
& n(t_{C,1})-1, \ldots, n(t_{C,p})-1, \\
& n(t_{X,1})-1, \ldots, n(t_{X,p})-1\} \\
& +1,
\end{aligned}
$$

where $L.C.M$ is the *Least Common Multiple* according to the second extended hierarchical rule (see Eq.1).

Therefore, the extended linguistic hierarchy which defines the evaluation framework is:

$$
ELH = \bigcup_{t=1}^{t=m+1} \left\{ \begin{array}{l}
\{S_{A,1}^{n(t_{A,1})}, \ldots, S_{A,p}^{n(t_{A,p})}\} \\
\{S_{B,1}^{n(t_{B,1})}, \ldots, S_{B,p}^{n(t_{B,p})}\} \\
\{S_{C,1}^{n(t_{C,1})}, \ldots, S_{C,p}^{n(t_{C,p})}\} \\
\{S_{X,1}^{n(t_{X,1})}, \ldots, S_{X,p}^{n(t_{X,p})}\} \\
\{\overline{S}^{n(t')}\}
\end{array} \right\}.
$$

Once the evaluation framework has been fixed, the appraisers of the different collectives will provide their opinions regarding the employees by means of vectors of linguistic assessments assessed in the different scales of the ELH.

3.2. Aggregation phase

The aim of aggregation process is to obtain a global assessment for each employee that summarizes appraisers' opinions in order to facilitate the classification and raking of employees for applying Human Resources Department policies. These global values make companies easier to have a global view on their employees' performance and make decisions about them. Thus, the global value should come from the aggregation of all individual assessments expressed by the different collectives of reviewers. The aggregation is a process of CW in a multi-granular context defined by an ELH, therefore it should be accomplished according to the scheme presented in Fig.3.

Consequently, to operate in the ELH the linguistic information provided by the appraisers is represented by linguistic 2-tuples (see Remark 1):

- For each collective:

$$H_{\_}^{k} : S_{\_,k}^{n(t_{\_,k})} \longrightarrow \langle S_{\_,k}^{n(t_{\_,k})} \rangle,$$

where

$$\overline{v}_j^{ik} = H_{\_}^{k}(v_j^{ik}) \in \langle S_{\_,k}^{n(t_{\_,k})} \rangle.$$

Where $\_$ stands for the different collectives, $\{A,B,C,X\}$ and $v_j^{ik}, \overline{v}_j^{ik}$ stand for the linguistic value provided by the appraiser and its correspondent 2-tuple.

Once the linguistic information is expressed by linguistic 2-tuples, the processes of CW starts following the scheme of the Fig. 3. First, it must be unified into the level t' of the ELH. To do so, the transformation function $TF_t^{t'}$ (see Definition 2) is applied as follows:

- For each collective, the linguistic transformation function for each criterion $k = 1, \ldots, p$ is defined by:

$$TF_{t_{\_,k}}^{t'} : \langle S_{\_,k}^{n(t_{\_,k})} \rangle \longrightarrow \langle \overline{S}^{n(t')} \rangle$$

where

$$TF_{t_{\_,k}}^{t'}(\overline{v}_j^{ik}) = (s_j^{n(t')}, \alpha_j) \in \langle \overline{S}^{n(t')} \rangle.$$

When the information has been unified in $\langle \overline{S}^{n(t')} \rangle$, the aggregation process of the integral performance appraisal (see Fig. 5) is carried out. We present in further detail each step of this process, additionally we introduce some necessary definitions.

First step: Computing collective criteria values.

For each appraisers' collective, their assessments about a criterion, Y_k, are aggregated by means of an aggregation operator, G^{-}. In our proposal the first step of the aggregation process is carried out by means of a generic aggregation operator $G^{\mathbf{w}}_{-}$, that could be different for every reviewers' collective and every criterion according to the necessities of the problem. For each appraisers' collective, their assessments about a given criterion Y_k are then aggregated by means of G^{-}.

- Supervisors. Let $G^{\mathbf{w}}_{A,k} : \langle \overline{S}^{n(t')} \rangle^r \longrightarrow \langle \overline{S}^{n(t')} \rangle$ be the aggregation function that assigns a 2-tuple in $\langle \overline{S}^{n(t')} \rangle$ for all individual assessments about the criterion Y_k. Every candidate has then associated a 2-tuple in $\langle \overline{S}^{n(t')} \rangle$, with respect to the supervisors' collective and to the criterion Y_k, $k = 1, \ldots, p$:

$$v^k_A(x_j) = G^{\mathbf{w}}_{A,k}\big(\overline{a}^{1k}_j, \ldots, \overline{a}^{rk}_j\big) \in \langle \overline{S} \rangle.$$

Similarly for the remaining collectives.

- Collaborators.

$$G^{\mathbf{w}}_{B,k} : \langle \overline{S}^{n(t')} \rangle^s \longrightarrow \langle \overline{S}^{n(t')} \rangle,$$

$$v^k_B(x_j) = G^{\mathbf{w}}_{B,k}\big(\overline{b}^{1k}_j, \ldots, \overline{b}^{sk}_j\big) \in \langle \overline{S} \rangle.$$

- Customers.

$$G^{\mathbf{w}}_{C,k} : \langle \overline{S}^{n(t')} \rangle^t \longrightarrow \langle \overline{S}^{n(t')} \rangle,$$

$$v^k_C(x_j) = G^{\mathbf{w}}_{C,k}\big(\overline{c}^{1k}_j, \ldots, \overline{c}^{tk}_j\big) \in \langle \overline{S} \rangle.$$

- Employees.

$$v^k_X(x_j) = \overline{x}^k_j \in \langle \overline{S} \rangle.$$

We can note that the opinions of the others evaluated employees are not taking into account in the aggregation process because including these opinions could bias the outcomes of the process.

Second step: Computing global criteria values.

In this step of the aggregation process, the previous collective assessments for each collective and each criterion are aggregated by means of a *2-tuple weighted average operator* to obtain a global value for each criterion and for each employee according to all collectives. We propose to aggregate information by means of this operator because it allows companies to establish different weights for each reviewers' collective taking into account their importance in the performance appraisal process.

Definition 3. Let $\mathbf{w} = (w_1, \ldots, w_m) \in [0,1]^m$ be a weighting vector such that $\sum_{i=1}^m w_i = 1$. The *2-tuple weighted average operator* associated with $\mathbf{w}$ is the function $M^{\mathbf{w}} : \langle \overline{S} \rangle^m \longrightarrow \langle \overline{S} \rangle$ defined by

$$M^{\mathbf{w}}\big((\overline{s}_1, \alpha_1), \ldots, (\overline{s}_m, \alpha_m)\big) = \Delta_{\overline{S}} \left(\sum_{i=1}^m w_i \, \Delta^{-1}_{\overline{S}}(\overline{s}_i, \alpha_i) \right).$$

The collective assessments then obtained in the previous step, $v^k_A(x_j)$, $v^k_B(x_j)$, $v^k_C(x_j)$ and $v^k_X(x_j)$ for each collective and for every $k \in \{1, \ldots, q\}$, are aggregated by $M^{\mathbf{w}}_k : \langle \overline{S}^{n(t')} \rangle^4 \longrightarrow \langle \overline{S}^{n(t')} \rangle$, where $\mathbf{w} = (w_A, w_B, w_C, w_X)$ and $\sum w_{-} = 1$, obtaining a global value modelled by a linguistic 2-tuple for each criterion Y_k:

$$v^k(x_j) = M^{\mathbf{w}}_k\big(v^k_A(x_j), v^k_B(x_j), v^k_C(x_j), v^k_X(x_j)\big) =$$
$$= \Delta_{\overline{S}}\Big(\sum w_{-}\, \Delta^{-1}_{\overline{S}}(v^k_{-}(x_j))\Big) \in \langle \overline{S} \rangle.$$

Third step: Computing global values.

In this step, companies work out a *global value*, $v(x_j)$, regarding all criteria and according to all appraisers for each employee. It is obtained by aggregating the global criteria values related to each employee $x_j \in X$, by means of a 2-tuple weighted average operator (see Definition 3)

$$M^{\mathbf{w}} : \langle \overline{S}^{n(t')} \rangle^p \longrightarrow \langle \overline{S}^{n(t')} \rangle$$

obtaining a 2-tuple in $\langle \overline{S}^{n(t')} \rangle$:

$$v(x_j) = M^{\mathbf{w}}\big(v^1(x_j), v^2(x_j), \ldots, v^p(x_j)\big) \in \langle \overline{S}^{n(t')} \rangle.$$

We can note that the weighting vectors appearing in this step of the aggregation procedure $(w_1, \ldots, w_p)$ are determined by companies attending to their Human Resources Department goals.

3.3. Rating phase

Finally, in order to obtain the final ranking of the employees $x_j \in X$, the global values obtained in the last step of the aggregation phase, $v(x_j)$, are used for sorting and ranking employees according to the Human Resources Department policy.

Before ranking employees, the companies usually carry out an initial selection process, establishing a minimum value (threshold) for each criterion Y_k (in our case, a linguistic value) and they only take into account, for establishing ranks, those employees that have overcome these thresholds for every criterion (see Fig.6).

It is remarkable that this initial selection process is achieved by companies with the aim of knocking out those employees that did not obtain the minimum results for each criterion.

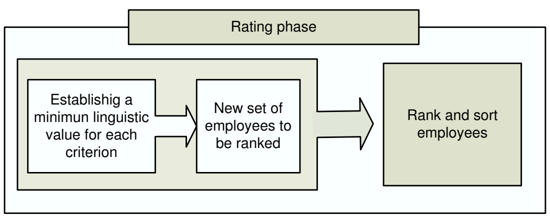

Fig. 6. Rating phase

Let $\underline{v} = (\underline{v}^1, \ldots, \underline{v}^p) \in \left(\overline{S}^{n(t')}\right)^p$ be a vector that establishes the thresholds of the criteria.* Notice that $\underline{v}$ is equivalent to $\left((\underline{v}^1, 0), \ldots, (\underline{v}^p, 0)\right) \in \langle \overline{S}^{n(t')} \rangle^p$.

In order to do the initial selection process of employees, we use the following ordinary lexicographic order[18] on $\langle \overline{S}^{n(t')} \rangle$:

$$(\overline{s}_k^{n(t')}, \alpha_k) \succeq (\overline{s}_l^{n(t')}, \alpha_l) \Leftrightarrow \begin{cases} k > l, \\ \text{or} \\ k = l \ \text{ and } \ \alpha_k \geqslant \alpha_l \end{cases}$$

That ranks the linguistic 2-tuples in $\langle \overline{S}^{n(t')} \rangle$.

After the initial selection process, companies have a new set of employees to be ranked:

$$\widehat{X} = \{x_j \in X \mid \forall k \in \{1, \ldots, p\} \quad v^k(x_j) \succeq (\underline{v}^k, 0)\}.$$

Once this initial selection process has been achieved, the management team can analyze the global or intermediate results of those employees belonging to $\widehat{X}$, for instance by comparing the collective opinions and the self-evaluation for each employee in each criterion (much more comparisons are possible).

Our model provides linguistic results at all the stages of the aggregation process that are easy to understand and interpret by the management team and by the different reviewers due to the fact that the model can provide the results in the original linguistic term set used by the reviewers. The organization can then decide about different aspects of its Human Resources' policies from all the results obtained in the different steps of the aggregation process, which it is an important improvement with regards to the traditional methods of performance appraisal.

4. An Illustrative Example

In order to show how a company or organization could carry out performance appraisal process with the proposed model (Fig. 4), we provide an example. Let us suppose a company that is carrying out an integral evaluation over its employees which involves evaluations from supervisors, collaborators, customers and employees themselves. Without loss of generality we consider two employees to be evaluated: x_1, x_2. The company wants to know who of them is the best candidate to promote to a manager position in the customer Department. The employees are evaluated according to two criteria:

- Y_1: communicating with customers. Communicative skill.
- Y_2: teamwork and cooperation skill.

The integral appraisal begins with the selection of the reviewers by the human resources manager. These reviewers should be people who daily interact with the evaluated employees. In our example, the manager selects the following groups of reviewers:

- Four supervisors, $A = \{a_1, \ldots, a_4\}$.
- Eight collaborators, $B = \{b_1, \ldots, b_8\}$.

*This vector has been expressed in the last level of the *ELH*, $\overline{S}^{n(t')}$, due to the fact that this level has been used to accomplish all computations, although it could be expressed in the original term sets of each collective of reviewers and then transformed to $\overline{S}^{n(t')}$

- Twelve customers, $C = \{c_1, \ldots, c_{12}\}$.

Each group of reviewers will use its own linguistic term sets $S_{-}^{n(t)}$ (which semantics is given by triangular fuzzy numbers), to provide their knowledge of every criterion (see Fig. 7):

Supervisors	S_{A1}^{9}	S_{A2}^{9}
Collaborators	S_{B1}^{7}	S_{B2}^{7}
Customers	S_{C1}^{5}	S_{C2}^{5}
Employees	S_{X1}^{5}	S_{X2}^{3}

Where S_{A1}^{9} and S_{A2}^{9} have nine linguistic terms, S_{B1}^{7} and S_{B2}^{7} have seven linguistic terms, S_{C1}^{5}, S_{C2}^{5} and S_{X1}^{5} have five linguistic terms and S_{X2}^{3} has three linguistic terms.

$$S_{A1}^{9} = \{s_0^{A1,9}, s_1^{A1,9}, s_2^{A1,9}, s_3^{A1,9}, s_4^{A1,9}, s_5^{A1,9}, s_6^{A1,9}, s_7^{A1,9}, s_8^{A1,9}\}.$$

$$S_{A2}^{9} = \{s_0^{A2,9}, s_1^{A2,9}, s_2^{A2,9}, s_3^{A2,9}, s_4^{A2,9}, s_5^{A2,9}, s_6^{A2,9}, s_7^{A2,9}, s_8^{A2,9}\}.$$

$$S_{B1}^{7} = \{s_0^{B1,7}, s_1^{B1,7}, s_2^{B1,7}, s_3^{B1,7}, s_4^{B1,7}, s_5^{B1,7}, s_6^{B1,7}\}.$$

$$S_{B2}^{7} = \{s_0^{B2,7}, s_1^{B2,7}, s_2^{B2,7}, s_3^{B2,7}, s_4^{B2,7}, s_5^{B2,7}, s_6^{B2,7}\}.$$

$$S_{C1}^{5} = \{s_0^{C1,5}, s_1^{C1,5}, s_2^{C1,5}, s_3^{C1,5}, s_4^{C1,5}\}.$$

$$S_{C2}^{5} = \{s_0^{C2,5}, s_1^{C2,5}, s_2^{C2,5}, s_3^{C2,5}, s_4^{C2,5}\}.$$

$$S_{X1}^{5} = \{s_0^{X1,5}, s_1^{X1,5}, s_2^{X1,5}, s_3^{X1,5}, s_4^{X1,5}\}.$$

$$S_{X2}^{3} = \{s_0^{X2,3}, s_1^{X2,3}, s_2^{X2,3}, \}.$$

Evaluation Framework

Therefore, the ELH that defines our evaluation framework is built as follows:

$$ELH = \bigcup_{t=1}^{t=5} \left\{ \begin{array}{l} S_{-}^{9}, S_{-}^{7}, \\ S_{-}^{5}, S_{X2}^{3}, \\ \overline{S}^{25} \end{array} \right\},$$

being $t' = 5$ the added term set with 25 terms (see Fig. 7) according to ELH rules. In it, the processes of CW are carried out in an accurate way.

Once the evaluation framework has been fixed, the appraisers provide their opinions about the evaluated employees (see Tables 1 and 2). It is then applied the other phases of the evaluation process presented in Section 3 (see Fig. 4) to rate the employees.

Table 1. Assessments provided by employees about themselves

x_1		x_2	
Y_1	Y_2	Y_1	Y_2
$x_1^{11} = s_2^{X1}$	$x_1^{12} = s_2^{X2}$	-	-
-	-	$x_2^{11} = s_1^{X1}$	$x_1^{12} = s_1^{X2}$

Table 2. Assessments for each employee and each criterion

x_1		x_2	
Y_1	Y_2	Y_1	Y_2
$a_1^{11} = s_7^{A1}$	$a_1^{12} = s_6^{A2}$	$a_2^{11} = s_4^{A1}$	$a_2^{12} = s_7^{A2}$
$a_1^{21} = s_8^{A1}$	$a_1^{22} = s_7^{A2}$	$a_2^{21} = s_3^{A1}$	$a_2^{22} = s_8^{A2}$
$a_1^{31} = s_6^{A1}$	$a_1^{32} = s_5^{A2}$	$a_2^{31} = s_4^{A1}$	$a_2^{32} = s_8^{A2}$
$a_1^{41} = s_6^{A1}$	$a_1^{42} = s_7^{A2}$	$a_2^{41} = s_4^{A1}$	$a_2^{42} = s_7^{A2}$
$b_1^{11} = s_6^{B1}$	$b_1^{12} = s_4^{B2}$	$b_2^{11} = s_4^{B1}$	$b_2^{12} = s_6^{B2}$
$b_1^{21} = s_6^{B1}$	$b_1^{22} = s_5^{B2}$	$b_2^{21} = s_5^{B1}$	$b_2^{22} = s_6^{B2}$
$b_1^{31} = s_5^{B1}$	$b_1^{32} = s_6^{B2}$	$b_2^{31} = s_4^{B1}$	$b_2^{32} = s_6^{B2}$
$b_1^{41} = s_5^{B1}$	$b_1^{42} = s_6^{B2}$	$b_2^{41} = s_3^{B1}$	$b_2^{42} = s_6^{B2}$
$b_1^{51} = s_6^{B1}$	$b_1^{52} = s_6^{B2}$	$b_2^{51} = s_3^{B1}$	$b_2^{52} = s_5^{B2}$
$b_1^{61} = s_6^{B1}$	$b_1^{62} = s_5^{B2}$	$b_2^{61} = s_4^{B1}$	$b_2^{62} = s_5^{B2}$
$b_1^{71} = s_4^{B1}$	$b_1^{72} = s_5^{B2}$	$b_2^{71} = s_3^{B1}$	$b_2^{72} = s_6^{B2}$
$b_1^{81} = s_5^{B1}$	$b_1^{82} = s_6^{B2}$	$b_2^{81} = s_5^{B1}$	$b_2^{82} = s_5^{B2}$
$c_1^{11} = s_1^{C1}$	$c_1^{12} = s_4^{C2}$	$c_2^{11} = s_1^{C1}$	$c_2^{12} = s_4^{C2}$
$c_1^{21} = s_1^{C1}$	$c_1^{22} = s_4^{C2}$	$c_2^{21} = s_1^{C1}$	$c_2^{22} = s_4^{C2}$
$c_1^{31} = s_2^{C1}$	$c_1^{32} = s_4^{C2}$	$c_2^{31} = s_0^{C1}$	$c_2^{32} = s_4^{C2}$
$c_1^{41} = s_1^{C1}$	$c_1^{42} = s_4^{C2}$	$c_2^{41} = s_0^{C1}$	$c_2^{42} = s_4^{C2}$
$c_1^{51} = s_2^{C1}$	$c_1^{52} = s_4^{C2}$	$c_2^{51} = s_1^{C1}$	$c_2^{52} = s_4^{C2}$
$c_1^{61} = s_3^{C1}$	$c_1^{62} = s_4^{C2}$	$c_2^{61} = s_1^{C1}$	$c_2^{62} = s_4^{C2}$
$c_1^{71} = s_1^{C1}$	$c_1^{72} = s_4^{C2}$	$c_2^{71} = s_0^{C1}$	$c_2^{72} = s_3^{C2}$
$c_1^{81} = s_1^{C1}$	$c_1^{82} = s_4^{C2}$	$c_2^{81} = s_1^{C1}$	$c_2^{82} = s_4^{C2}$
$c_1^{91} = s_2^{C1}$	$c_1^{92} = s_3^{C2}$	$c_2^{91} = s_1^{C1}$	$c_2^{92} = s_4^{C2}$
$c_1^{101} = s_2^{C1}$	$c_1^{102} = s_4^{C2}$	$c_2^{101} = s_0^{C1}$	$c_2^{102} = s_4^{C2}$
$c_1^{111} = s_2^{C1}$	$c_1^{112} = s_4^{C2}$	$c_2^{111} = s_2^{C1}$	$c_2^{112} = s_4^{C2}$
$c_1^{121} = s_2^{C1}$	$c_1^{122} = s_4^{C2}$	$c_2^{121} = s_1^{C1}$	$c_2^{122} = s_4^{C2}$

Aggregation phase

First, the information provided by the appraisers is unified in the t' level of the ELH, in our case $t' = 5$. The results of such transformations are showed in Tables 3 and 4.

Table 3. Unified assessments from each employee about themselves

Employees	x_1		x_2	
	Y_1	Y_2	Y_1	Y_2
x_1	$(\bar{s}_{12},0)$	$(\bar{s}_{12},0)$	-	-
x_2	-	-	$(\bar{s}_{12},0)$	$(\bar{s}_{12},0)$

Table 4. Unified assessments for each collective and each criterion

Supervisors	x_1		x_2	
	Y_1	Y_2	Y_1	Y_2
a_1	$(\bar{s}_{21},0)$	$(\bar{s}_{18},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{21},0)$
a_2	$(\bar{s}_{24},0)$	$(\bar{s}_{21},0)$	$(\bar{s}_{9},0)$	$(\bar{s}_{24},0)$
a_3	$(\bar{s}_{18},0)$	$(\bar{s}_{15},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$
a_4	$(\bar{s}_{18},0)$	$(\bar{s}_{21},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{21},0)$
Collaborators				
b_1	$(\bar{s}_{24},0)$	$(\bar{s}_{16},0)$	$(\bar{s}_{16},0)$	$(\bar{s}_{24},0)$
b_2	$(\bar{s}_{24},0)$	$(\bar{s}_{20},0)$	$(\bar{s}_{20},0)$	$(\bar{s}_{24},0)$
b_3	$(\bar{s}_{20},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{16},0)$	$(\bar{s}_{24},0)$
b_4	$(\bar{s}_{20},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$
b_5	$(\bar{s}_{24},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{20},0)$
b_6	$(\bar{s}_{24},0)$	$(\bar{s}_{20},0)$	$(\bar{s}_{16},0)$	$(\bar{s}_{20},0)$
b_7	$(\bar{s}_{16},0)$	$(\bar{s}_{20},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$
b_8	$(\bar{s}_{20},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{20},0)$	$(\bar{s}_{20},0)$
Customers				
c_1	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_2	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_3	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{0},0)$	$(\bar{s}_{24},0)$
c_4	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{0},0)$	$(\bar{s}_{24},0)$
c_5	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_6	$(\bar{s}_{18},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_7	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{0},0)$	$(\bar{s}_{18},0)$
c_8	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_9	$(\bar{s}_{12},0)$	$(\bar{s}_{18},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$
c_{10}	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{0},0)$	$(\bar{s}_{24},0)$
c_{11}	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$
c_{12}	$(\bar{s}_{12},0)$	$(\bar{s}_{24},0)$	$(\bar{s}_{6},0)$	$(\bar{s}_{24},0)$

Once the information has been unified, the assessments provided by the different collectives are aggregated following the steps presented in 3.2 (see Fig. 5).

Computing collective criteria values:

In this step of the aggregation procedure and without loss of generality we are going to use OWA operators because they satisfy some interesting properties as *compensativeness*, *idempotency*, *symmetry* and *monotonicity*.

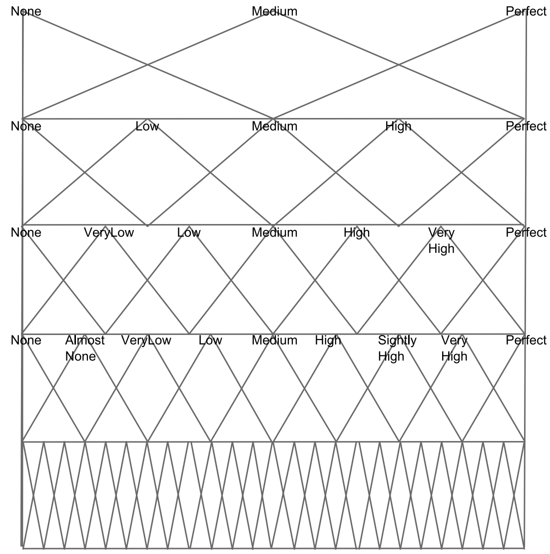

Fig. 7. Linguistic term sets used in the example

Definition 4. [30] Let $\boldsymbol{w} = (w_1, \ldots, w_m) \in [0,1]^m$ be a weighting vector such that $\sum_{i=1}^{m} w_i = 1$. The *ordered weighted averaging* (OWA) operator associated with $\boldsymbol{w}$ is the function $F^{\boldsymbol{w}} : \mathbb{R}^m \longrightarrow \mathbb{R}$ defined by

$$F^{\boldsymbol{w}}(a_1, \ldots, a_m) = \sum_{i=1}^{m} w_i b_i,$$

where b_i is the i-th largest element in the collection $\{a_1, \ldots, a_m\}$.

We have to keep in mind that the information is expressed by means of linguistic 2-tuples. Therefore, to aggregate them we use the 2-tuple OWA operators.

Definition 5. [18] Let $((l_1, \alpha_1), \ldots, (l_m, \alpha_m)) \in \langle \overline{S} \rangle^m$ be a vector of linguistic 2-tuples, and $\boldsymbol{w} = (w_1, \ldots, w_m) \in [0,1]^m$ be a weighting vector such that $\sum_{i=1}^{m} w_i = 1$. The *2-tuple OWA operator* associated with $\boldsymbol{w}$ is the function $G^{\boldsymbol{w}} : \langle \overline{S} \rangle^m \longrightarrow \langle \overline{S} \rangle$ defined by

$$G^{\boldsymbol{w}}\big((l_1, \alpha_1), \ldots, (l_m, \alpha_m)\big) = \Delta_{\overline{S}} \left(\sum_{i=1}^{m} w_i \beta_i^* \right),$$

where β_i^* is the i-th largest element of $\left\{ \Delta_{\overline{S}}^{-1}(l_1, \alpha_1), \ldots, \Delta_{\overline{S}}^{-1}(l_m, \alpha_m) \right\}$.

The weighting vectors used in this step of the aggregation procedure might be computed in different way, in our example are determined by a *fuzzy linguistic quantifier*[30].

Definition 6. A *relative linguistic quantifier* on a numeric scale is a function $Q:[0,1]\longrightarrow[0,1]$ defined by

$$Q(x)=\begin{cases}0, & \text{if } x\leqslant a,\\ \dfrac{x-a}{b-a}, & \text{if } a<x<b,\\ 1, & \text{if } x\geqslant b,\end{cases}$$

where $a,b\in[0,1]$ and $a<b$.
We note that $Q(0)=0$, $Q(1)=1$ and Q is monotonic[32]: $Q(x)\geqslant Q(y)$ whenever $x\geqslant y$.
The weights associated with the OWA operator $F^{\boldsymbol{w}}$ are determined in the following way[30]:

$$w_i=Q\left(\frac{i}{m}\right)-Q\left(\frac{i-1}{m}\right),\ i=1,\ldots,m,$$

where Q is defined as in Definition 6.

Particulary, in this example we use the quantifier "most", whose parameters are $(0.3,0.8)$, to aggregate information.

Therefore, for each collective and each criterion the assessments are aggregated. The weighting vectors for each collective are showed in Table 5, and the collective criteria values obtained for each employee in Table 6. Moreover, the collectives criteria values obtained for each employee can be expressed in the original term sets (see Table 7).

Table 5. Weighting vectors for reviewers' collective criteria values

"most"
$(0,0.4,0.5,0.1)$
$(0,0,0.15,0.25,0.25,0.25,0.1,0)$
$(0,0,0,0.067,0.167,0.167,0.167,0.167,0.167,0.1,0,0)$

For each criterion and each employee the previous collective assessments are aggregated by using a weighted average operator whose weighting vectors selected by the company for each collective are:

$$w_A=0.2 \qquad w_B=0.2$$
$$w_C=0.5 \qquad w_X=0.1$$

The global criteria values for each employee are showed in Table 8 and the global criteria values expressed in the supervisors' original term sets are showed in Table 9. It is remarkable that the global criteria values have been expressed in the original term set of supervisors in order to facilitate making the final decision to the manager of the Human Resource Department.

Table 6. Reviewers' collective criteria values for each employee $v^k_{-}(x_j)$

x_1	
Y_1	Y_2
$v^1_A(x_1)=(\bar{s}_{20},0.4)$	$v^2_A(x_1)=(\bar{s}_{18},0)$
$v^1_B(x_1)=(\bar{s}_{22},-0.4)$	$v^2_B(x_1)=(\bar{s}_{23},-0.4)$
$v^1_C(x_1)=(\bar{s}_{11},-0.4)$	$v^2_C(x_1)=(\bar{s}_{23},0.4)$
$v^1_X(x_1)=(\bar{s}_{12},0)$	$v^2_X(x_1)=(\bar{s}_{12},0)$
x_2	
Y_1	Y_2
$v^1_A(x_2)=(\bar{s}_{11},-0.2)$	$v^2_A(x_2)=(\bar{s}_{24},-0.3)$
$v^1_B(x_2)=(\bar{s}_{14},-0.4)$	$v^2_B(x_2)=(\bar{s}_{22},0)$
$v^1_C(x_2)=(\bar{s}_{4},0)$	$v^2_C(x_2)=(\bar{s}_{23},0.4)$
$v^1_X(x_2)=(\bar{s}_{12},0)$	$v^2_X(x_2)=(\bar{s}_{12},0)$

Table 7. Reviewers' collective criteria values for each employee in the original term sets

x_1	
Y_1	Y_2
$v^1_A(x_1)=(\text{Very high},-0.2)$	$v^2_A(x_1)=(\text{Sighly high},0)$
$v^1_B(x_1)=(\text{Very high},0.4)$	$v^2_B(x_1)=(\text{Perfect},-0.35)$
$v^1_C(x_1)=(\text{Medium},-0.23)$	$v^2_C(x_1)=(\text{Perfect},-0.1)$
x_2	
Y_1	Y_2
$v^1_A(x_2)=(\text{Medium},-0.4)$	$v^2_A(x_2)=(\text{Perfect},-0.1)$
$v^1_B(x_2)=(\text{Medium},0.4)$	$v^2_B(x_2)=(\text{Perfect},-0.5)$
$v^1_C(x_2)=(\text{Low},-0.33)$	$v^2_C(x_2)=(\text{Perfect},-0.1)$

Computing global criteria values:

For each criterion and each employee the previous collective assessments are aggregated by using a weighted average operator whose weighting vectors selected by the company for each collective are:

$$w_A=0.2 \qquad w_B=0.2$$
$$w_C=0.5 \qquad w_X=0.1$$

The global criteria values for each employee are showed in Table 8 and the global criteria values expressed in the supervisors' original term sets are

showed in Table 9. It is remarkable that the global criteria values have been expressed in the original term set of supervisors in order to facilitate making the final decision to the manager of the Human Resource Department.

Table 8. Global criteria values for each employee $v^k(x_j)$

x_1	
Y_1	Y_2
$v^1(x_1) = (\bar{s}_{15}, -0.1)$	$v^2(x_1) = (\bar{s}_{21}, 0.02)$
x_2	
Y_1	Y_2
$v^1(x_2) = (\bar{s}_8, 0.08)$	$v^2(x_2) = (\bar{s}_{22}, 0.04)$

Table 9. Global criteria values for each employee $v^k(x_j)$ expressed in the original linguistic term set $S^9_{A,-}$

x_1	
Y_1	Y_2
(High, −0.03)	(Very high, 0.01)
x_2	
Y_1	Y_2
(Low, −0.31)	(Very high, 0.35)

Computing a global value:

As it was aforementioned, now company works out a global assessment for each employee in X and each criterion. The weighting vector for criterion Y_1 and Y_2 is $(0.4, 0.6)$ (in this example, company considers more important criterion Y_2 than criterion Y_1). The global values then obtained for each employee are $v(x_1) = (\bar{s}_{19}, -0.428)$ and $v(x_2) = (\bar{s}_{17}, -0.544)$ (see Table 10 to see the global values in the initial term sets).

Rating Phase

In the rating phase, the company may establish a minimum linguistic value for each criterion. In our case, $\underline{v} = (\underline{v}^1, \underline{v}^2) \in \overline{S}^{25}$, being $\underline{v}^1 = \bar{s}_8$ and $\underline{v}^2 = \bar{s}_{18}$. We then obtain the following new set of candidates to be ranked: $\widehat{X} = \{x_1, x_2\}$, because:

$$\begin{array}{lclcl} v^1(x_1) & = & (\bar{s}_{15}, -0.1) & \succeq & (\bar{s}_8, 0), \\ v^2(x_1) & = & (\bar{s}_{21}, 0.02) & \succeq & (\bar{s}_{18}, 0), \\ v^1(x_2) & = & (\bar{s}_8, 0.08) & \succeq & (\bar{s}_8, 0), \\ v^2(x_2) & = & (\bar{s}_{22}, 0.04) & \succeq & (\bar{s}_{18}, 0). \end{array}$$

Thus, in this example $\widehat{X} = X$.

Taking into account the results of the last step of the aggregation phase and the ordinary lexicographic order on $\langle \overline{S}^{25} \rangle$, the candidate x_1 is the best to be promoted to manager in the customer Department because $v(x_1) = (\bar{s}_{19}, -0.428) \succ v(x_2) = (\bar{s}_{17}, -0.544)$, and both employees belong to $\widehat{X}$.

Although the global values for each employee have been expressed in the last level of the ELH, it would be useful to express these values in the reviewers' original terms sets in order to improve the process of performance appraisal and the understanding of the results by the different collectives (see Table 10).

Table 10. Global values for each employee $v^k(x_j)$ expressed in the reviewers' original linguistic term set

	x_1	x_2
Supervisors	(Sighly high, 0.19)	(High, 0.48)
Collaborators	(Very high, −0.357)	(High, 0.11)
Customers	(High, 0.09)	(High, −0.26)

5. Concluding Remarks

Performance appraisal is a process that allows companies and organizations to determine efficiency and effectiveness of their employees. In this paper, we have presented a flexible linguistic integral evaluation model, taking into account that appraisers are expressing subjective perceptions and might present different degrees of knowledge about evaluated employees. Thus, in our proposal appraisers could express their assessments in different linguistic scales according to their knowledge, defining a multi-granular linguistic evaluation framework. In order to operate in this framework, we have managed linguistic information by means of the extended linguistic hierarchies approach because they overcome the limitations of other approaches, offering flexibility, an accurate computational model and the results are expressed in the initial scales.

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