Performance Appraisal with heterogenous information

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Abstract

Performance appraisal is a process used for some firms in order to evaluate the employees' efficiency and productivity for planning their promotion policy. Initially this process was carried out just by the executive staff, but recently it has evolved to an evaluation process based on the opinion of different reviewers, supervisors, collaborators, clients and the employee himself (360-degree method). In such a evaluation process the reviewers evaluate some indicators related to the employee performance appraisal. The sets of Reviewers involve in the evaluation process might have different degree of knowledge about the evaluated employee. It then seems suitable to offer a flexible framework in which different reviewers can express their assessments in different domains according to their knowledge, i.e., an heterogeneous evaluation framework. The final aim is to design an performance appraisal model in such a framework that computes a final evaluation for each employee. That will be used by the management team to make their decisions regarding their incentive and promotion policy.

Keywords: *Performance appraisal, heterogeneous information, decision making.*

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1 Introduction

One of the main challenges of companies and organizations is the improvement of productivity and efficiency. Performance appraisal is essential for the effective management and evaluation of corporations. Recently more and more companies are trying to increase their productivity through the human performance measurement. Performance appraisal is used for the evaluation of employees estimating their contributions to the goals of the organization, behavior and results. This evaluation process has been accomplished from different points of view can be found in [1], [7], among others.

In classical performance appraisal methods just supervisors evaluated employees. However, corporations are adopting new methods that use information from different people (appraisers) connected with each evaluated worker. In fact, the 360-degree appraisal is a methodology for evaluating workers's performance that includes the opinions of supervisors, collaborators, customers and themselves (see [3]). Then, each reviewer from the different reviewers' collectives evaluates indicators used for measuring the performance appraisal of the evaluated worker. Usually these indicators involve uncertainty and might have different nature (qualitative or quantitative).

Most of current evaluation processes require quantitative values for the appraisers' assessments (see [2]). Due to the fact that different sets of appraisers are involved in the 360-degree appraisal or integral evaluation, the use of a unique precise scale cannot be suitable because different appraisers can have different expertise and degree of knowledge about the indicators and evaluated employee. From this point of view, we consider that the use of different scales and domains (heterogeneous information) in the evaluation framework adapted to each appraiser or appraisers' collective would be helpful for them and improve the final results [5, 6]. We will then propose a heterogeneous framework in which appraisers may express their assessments by means of numerical, interval-valued or linguistic information.

Therefore the aim of this paper is provide a performance appraisal method that take into account the above considerations. To do so, we present an evaluation method defined in a framework in which different expression domains can be used by appraisers to express their assessments. Subsequently, the evaluation method should manage this heterogeneous information in order to obtain a global evaluation. Then, it is necessary to unify the initial information in a common domain. In this way, the proposed method will conduct all assessments provided by reviewers as fuzzy sets in the common domain to compute such global evaluation that will allow to the management team to make the final decision. Thus, the problem falls, in a natural way, into the collective decision making context. We shall define a fuzzy model of performance appraisal based on classic processes of decision-making, with the following phases:

- Heterogenous Evaluation Framework. The model will deal with information assessed by means of numerical, interval-valued or linguistic assessments.
- Aggregation Process:To obtain a global value of each employee, all information provided by the appraisers must be aggregated. Due to the fact that the framework is heterogeneous this process is carried out in two phases
    1. Unification information phase. The heterogenous information provided the different collectives is conducted into a unique expression domain, Basic Linguistic Term Set (BLTS) (see [6]).
    2. Aggregation phase. In this phase the information is aggregated taking into account different groups of reviewers and different criteria. We use a multi-step aggregation methodology which has the following stages:
        – Computing appraisers' collective criterion values.
        – Computing global criteria values.
        – Computing a final value.
- Rating phase. The aim of this phase is ranking evaluated employees.

The paper is organized as follows. Section 2 is devoted to introduce the terminology and functions of the arisen problem. In Section 3 we introduce a 360 performance appraisal model with non-homogeneous information and in Section 4 some conclusions are pointed out.

2 Preliminaries

Before we introduce the performance appraisal model proposed in the above section some necessary concepts and processes used are revised to facilitate its comprehension.

2.1 The 2-Tuple Fuzzy Linguistic Representation Model

The 2-tuple fuzzy linguistic representation model is based on the concept of *symbolic translation* [4]. This model represents the linguistic information through a 2-tuple (s, α), where s is a linguistic term and α is a numerical value representation of the symbolic translation [4]. So, being $\beta \in [0, g]$ the value which represents the result of a symbolic aggregation operation, then we can assign a 2-tuple (s, α) that expresses the equivalent information of that given by β.

Definition 1 Let $S = \{s_0, \ldots, s_g\}$ 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 the integer number $i \in \{0, 1, \ldots, g\}$ closest to β.

We note that Δ_S is bijective [4, 5] 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 $S \longrightarrow \langle S \rangle$ that allows us to transform a linguistic term s_i into a 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 $i \in \{0, 1, \ldots, g\}$.

The 2-tuple fuzzy linguistic representation model has a linguistic computational associated model in which different aggregation operators were presented in [4]. This computational model demonstrated that the operations with symmetrical and triangular-shaped labels are conformed without loss of information.

2.2 Dealing with non-homogenous information

Due to the fact that we consider non-homogenous framework for our evaluation model, in which the appraiser could use numerical, linguistic or interval-valued information. We will have to accomplish computations with this type of information and we cannot to operate directly with it. We review in short a process presented in [6] to deal with such a type of information that consists in the following steps:

1. To choose a domain to unify the linguistic information, so-called Basic Linguistic Term Set (BLTS).
2. To conduct the heterogeneous information into the BLTS. First in to fuzzy sets and then into linguistic 2-tuples in the BLTS.

2.2.1 Chosing the BLTS

To deal with non-homogenous information, first it will be conducted in an unique expression domain. This domain will be a linguistic term set called BLTS, noted as $\overline{S}$, that is selected with the aim of keeping as much knowledge as possible (see [6]).

2.2.2 Conducting information into fuzzy sets

Once the BLTS has been chosen in order to accomplish computing processes with non-homogenous information. We will then conduct it in the BLTS by means of fuzzy sets. To do so, we will use the transformation functions presented in [6] from each domain in the heterogeneous framework:

Definition 2 Let $v \in [0, 1]$ be a numerical value and $\overline{S} = \{\overline{s}_0, \overline{s}_1, \ldots, \overline{s}_g\}$ a linguistic term set. The *numerical-linguistic transformation function* $T_{N\overline{S}} : [0, 1] \longrightarrow \mathcal{F}(\overline{S})$ is defined by:

$$T_{N\overline{S}}(v) = \{(\overline{s}_0, \gamma_0), (\overline{s}_1, \gamma_1), \ldots, (\overline{s}_g, \gamma_g)\}$$

with

$$\gamma_i = \mu_{\overline{s}_i}(v) = \begin{cases} 0, \text{ if } x < a \text{ o } v > d, \\ \frac{v-a}{b-a}, \text{ if } a < v < b, \\ 1, \text{ if } b \leq v \leq c, \\ \frac{d-v}{d-c}, \text{ if } c < v < d \end{cases}$$

and

$$\mu_{\overline{s}_i}(a) = \begin{cases} 0, \text{ if } a < b, \\ 1, \text{ if } a = b, \end{cases}$$

$$\mu_{\overline{s}_i}(d) = \begin{cases} 0, \text{ if } d > c, \\ 1, \text{ if } d = c. \end{cases}$$

where $\gamma_i \in [0, 1]$ and $\mathcal{F}(\overline{S})$ is the set of fuzzy sets on $\overline{S}$, and $\mu_{\overline{s}_i}$ is the membership function of the linguistic label $\overline{s}_i \in \overline{S}$.

Definition 3 Let $I = [d, e]$, $d \leq e$ be an interval-value in $[0, 1]$ and $\overline{S} = \{\overline{s}_0, \overline{s}_1, \ldots, \overline{s}_g\}$ a linguistic term set. The *interval-linguistic transformation function* $T_{I\overline{S}} : I \longrightarrow \mathcal{F}(\overline{S})$ is defined by:

$$T_{I\overline{S}}(I) = \{(\overline{s}_0, \gamma_0), (\overline{s}_1, \gamma_1), \ldots, (\overline{s}_g, \gamma_g)\}$$

with

$$\gamma_i = \max_y \min \{\mu_I(y), \mu_{\overline{s}_i}(y)\}, \ i = 0, 1, \ldots, g$$

where $\mathcal{F}(\overline{S})$ is the set of fuzzy sets on $\overline{S}$, and μ_I and $\mu_{\overline{s}_i}$ are the membership functions of the interval-value I and the linguistic label $\overline{s}_i \in \overline{S}$, respectively.

Remark 2 Real numbers, intervals and triangular fuzzy numbers can be represented through trapezoidal fuzzy numbers: (a, a, a, a) where a is the real number; (a, a, b, b) is the interval $[a, b]$; and (a, b, b, c) is the triangular fuzzy number (a, b, c) (see [8]).

Definition 4 Let $S = \{s_0, s_1, \ldots, s_h\}$ and $\overline{S} = \{\overline{s}_0, \overline{s}_1, \ldots, \overline{s}_g\}$ be two linguistic term sets, with $h \leq g$. The *linguistic transformation function* $T_{S\overline{S}} : S \longrightarrow \mathcal{F}(\overline{S})$ is defined by:

$$T_{S\overline{S}}(s_j) = \{(\overline{s}_0, \gamma_0), (\overline{s}_1, \gamma_1), \ldots, (\overline{s}_g, \gamma_g)\}$$

with

$$\gamma_i = \max_y \min \{\mu_{s_j}(y), \mu_{\overline{s}_i}(y)\}, \ i = 0, 1, \ldots, g$$

where $\mathcal{F}(\overline{S})$ is the set of fuzzy sets on $\overline{S}$, and μ_{s_j} and $\mu_{\overline{s}_i}$ are the membership functions of the linguistic labels $s_j \in S$ and $\overline{s}_i \in \overline{S}$, respectively.

2.2.3 Unification into linguistic 2-tuples

In order to simplify the computations and improve the understanding of the results, we now transform the fuzzy sets in the BLTS into linguistic 2-tuples in the BLTS [6].

Definition 5 Given the linguistic term set $\overline{S} = \{\overline{s}_0, \overline{s}_1, \ldots, \overline{s}_g\}$, the function $\chi : \mathcal{F}(\overline{S}) \longrightarrow \overline{S} \times [-0.5, 0.5)$, is defined by

$$\chi\left(\{(\overline{s}_0, \gamma_0), (\overline{s}_1, \gamma_1), \ldots, (s_g, \gamma_g)\}\right) = \Delta_{\overline{S}}\left(\frac{\sum_{j=0}^{g} j\,\gamma_j}{\sum_{j=0}^{g} \gamma_j}\right).$$

3 Performance appraisal model with non-homogeneous information

Here, we present the 360 performance appraisal model dealing with heterogeneous information. To do so, we propose a model that consists of:

1. Heterogeneous Evaluation Framework
2. Aggregation process
   (a) Unification information phase
   (b) Aggregation phase
3. Ranking phase

This model is presented in further detail below.

3.1 Evaluation framework

We now present the scheme with the main features and terminology of this type of problems that evaluate the employees taking into account the opinions of different collectives related to them including the evaluated employee.

Let us suppose there is a set of employees $X = \{x_1, \ldots, x_n\}$ to be evaluated by the following collectives:

- A set of supervisors (executive staff): $A = \{a_1, \ldots, a_r\}$.
- A set of collaborators (fellows): $B = \{b_1, \ldots, b_s\}$.
- A set of customers: $C = \{c_1, \ldots, c_t\}$.
- X (the opinion of each employee about himself can be taken into account).

Employees will be evaluated attending to different criteria: $Y = \{Y_1, \ldots, Y_p\}$.

The assessments provided by the members of the collectives $a_i \in A$, $b_i \in B$ and $c_i \in C$ on the employee x_j according to the criterion Y_k are denoted by a_j^{ik}, b_j^{ik} and c_j^{ik}, respectively. Moreover, x_j^{jk} is the assessment of x_j on himself with respect to Y_k. Therefore, there are $(r + s + t + 1)\,p$ assessments for each employee provided by the different collectives. In this contribution we consider a heterogeneous information framework. So, we assume that each member of the collectives can use different domains [5, 6] to assess each criterion Y^k, $k = 1, \ldots, p$ attending to their knowledge about employees evaluated:

- $a_j^{ik} \in [0,1]$ or $a_j^{ik} \in I = [d,e]$, $I \in [0,1]$ or $a_j^{ik} \in S_A^k$ for each $i \in \{1, \ldots, r\}$ and each $j \in \{1, \ldots, n\}$.
- $b_j^{ik} \in [0,1]$ or $b_j^{ik} \in I = [d,e]$, $I \in [0,1]$ or $b_j^{ik} \in S_B^k$ for each $i \in \{1, \ldots, s\}$ and each $j \in \{1, \ldots, n\}$.
- $c_j^{ik} \in [0,1]$ or $c_j^{ik} \in I = [d,e]$, $I \in [0,1]$ or $c_j^{ik} \in S_C^k$ for each $i \in \{1, \ldots, t\}$ and each $j \in \{1, \ldots, n\}$.
- $x_j^{jk} \in [0,1]$ or $x_j^{jk} \in I = [d,e]$, $I \in [0,1]$ or $x_j^{jk} \in S_X^k$ for each $j \in \{1, \ldots, n\}$.

We note that any appropriate linguistic term set S_{-}^k is characterized by its cardinality or *granularity*, $|S_{-}^k|$.

3.2 Aggregation Process

To operate with heterogeneous information, first it should be unified and then aggregated. Following we present this process.

3.2.1 Unification information phase

To operate with non-homogeneous information assessed in different domains (numerical, interval-valued and linguistic) first of all we have to conduct the non-homogeneous information provided by the different collectives into an unique expression domain, BLTS, $\overline{S} = \{\overline{s}_0, \overline{s}_1, \ldots, \overline{s}_g\}$, with

$$g \geq \max\{|S_A^1|, \ldots, |S_A^p|, |S_B^1|, \ldots, |S_B^p|, |S_C^1|, \ldots, |S_C^p|, |S_X^1|, \ldots, |S_X^p|\}.$$

Once the BLTS has been chosen, the non-homogeneous information is unified by means of fuzzy sets in $\overline{S}$ using the functions $T_{N\overline{S}}$, $T_{I\overline{S}}$ and $T_{S\overline{S}}$ presented in Definitions 2, 3 and 4.

- Supervisors:

$$T_{N\overline{S}} : [0,1] \longrightarrow \mathcal{F}(\overline{S}),\ or$$

$$T_{I\overline{S}} : I \longrightarrow \mathcal{F}(\overline{S}),\ or$$

$$T_{S_A^k\overline{S}} : S_A^k \longrightarrow \mathcal{F}(\overline{S}).$$

- Collaborators: the functions $T_{N\overline{S}}$, $T_{I\overline{S}}$ and $T_{S_B^k\overline{S}}$ are defined analogously to the supervisors functions.
- Customers: the functions $T_{N\overline{S}}$, $T_{I\overline{S}}$ and $T_{S_C^k\overline{S}}$ are defined analogously to the supervisors functions.
- Employee: the functions $T_{N\overline{S}}$, $T_{I\overline{S}}$ and $T_{S_X^k\overline{S}}$ are defined analogously to the supervisors functions.

In this way, the information obtained in the evaluated process will be expressed into an unique linguistic term set, through fuzzy sets in $\overline{S}$.

In order to facilitate the aggregation process and the understandability of the results, we transform the fuzzy sets in $\overline{S}$ into linguistic 2-tuples using the functions χ and Δ presented in Definitions 5 and 1, respectively:

- Supervisors:

$$H_N^{Ak} : [0,1] \xrightarrow{T_{N\overline{S}}} \mathcal{F}(\overline{S}) \xrightarrow{\chi} [0,g] \xrightarrow{\Delta_{\overline{S}}} \langle\overline{S}\rangle,\ or$$

$$H_I^{Ak} : I \xrightarrow{T_{I\overline{S}}} \mathcal{F}(\overline{S}) \xrightarrow{\chi} [0,g] \xrightarrow{\Delta_{\overline{S}}} \langle\overline{S}\rangle,\ or$$

$$H_L^{Ak} : S_A^k \xrightarrow{T_{S_A^k\overline{S}}} \mathcal{F}(\overline{S}) \xrightarrow{\chi} [0,g] \xrightarrow{\Delta_{\overline{S}}} \langle\overline{S}\rangle.$$

- Collaborators: analogous functions H_N^{Bk}, H_I^{Bk} and H_L^{Bk} are defined for collaborators.
- Customers: analogous functions H_N^{Ck}, H_I^{Ck} and H_L^{Ck} are defined for customers.
- Employee: analogous functions H_N^{Xk}, H_I^{Xk} and H_L^{Xk} are defined for employees.

We can note that all the information provided by the different collectives (supervisors, collaborators, customers and employee) has already unified into 2-tuples in the BLTS.

3.2.2 Aggregation phase

The aim of this phase is to obtain a value that assess the performance of the evaluated worker according to the different reviewers' collective and the different criterion. This assessment is computed in 3 stages. From the initial individual appraisers' assessment going trough collective, global assessments criteria and eventually the final assessment that reflects the employee performance. These values are computed by means of aggregation operators for linguistic 2-tuples [4]. The aggregation phase consists in the following steps:

1. *Computing appraisers' collective criteria values*, $v_{\_}^k(x_j)$: For each appraisers' collective, their assessments about a given criterion Y_k are aggregated by means of a aggregation operator, G^{-}, that can be different for each appraisers' collective. For each collective and for every $k \in \{1,\ldots,p\}$, the process is conducted in the following manner.

    - *Supervisors.*

    $$v_A^k(x_j) = F_{\_}^{Ak}\left(a_j^{1k},\ldots,a_j^{rk}\right),$$

    where $F_{\_}^{Ak}$:

    $$F_N^{A,k} : ([0,1])^r \xrightarrow{\mathbf{H}_N^{Ak}} \langle\overline{S}\rangle^r \xrightarrow{G^{A,k}} \langle\overline{S}\rangle,\ or$$

    $$F_I^{A,k} : (I)^r \xrightarrow{\mathbf{H}_I^{Ak}} \langle\overline{S}\rangle^r \xrightarrow{G^{A,k}} \langle\overline{S}\rangle,\ or$$

    $$F_L^{A,k} : (S_A^k)^r \xrightarrow{\mathbf{H}_L^{Ak}} \langle\overline{S}\rangle^r \xrightarrow{G^{A,k}} \langle\overline{S}\rangle$$

    being,
    $\mathbf{H}_N^{Ak} = (H_N^{Ak},\overset{r}{\ldots},H_N^{Ak})$,
    $\mathbf{H}_I^{Ik} = (H_I^{Ak},\overset{r}{\ldots},H_I^{Ak})$, and
    $\mathbf{H}_L^{Ak} = (H_L^{Ak},\overset{r}{\ldots},H_L^{Ak})$, respectively.

    - *Collaborators.*

    $$v_B^k(x_j) = F_{\_}^{Bk}\left(b_j^{1k},\ldots,b_j^{sk}\right),$$

    where $F_{\_}^{Bk}$ and $H_{\_}^{Bk}$ are analogous to the supervisors functions.

    - *Customers.*

    $$v_C^k(x_j) = F_{\_}^{Ck}\left(c_j^{1k},\ldots,c_j^{tk}\right),$$

    where $F_{\_}^{Ck}$ and $H_{\_}^{Ck}$ are analogous to the supervisors functions.

- *Employee*. Each employee has associated a 2-tuple over the BLTS, with respect to the criterion Y_k:

$$v_X^k(x_j) = H_-^{Xk}(x_j^{jk}) \in \langle \overline{S} \rangle.$$

2. *Computing global criteria values*, $v^k(x_j)$: The previous collective assessments $v_A^k(x_j)$, $v_B^k(x_j)$, $v_C^k(x_j)$ and $v_X^k(x_j)$ are aggregated by means of a appropriate aggregate operator

$$G^k : \langle \overline{S} \rangle^4 \longrightarrow \langle \overline{S} \rangle$$

obtaining a 2-tuple over the BLTS for each criterion Y_k:

$$v^k(x_j) = G^k\big(v_A^k(x_j), v_B^k(x_j), v_C^k(x_j), v_X^k(x_j)\big) \in \langle \overline{S} \rangle.$$

3. *Computing a final value*, $v(x_j)$: It is obtained by aggregating the global criteria values related to the employee x_j, by means of a appropriate aggregate operator

$$G : \langle \overline{S} \rangle^p \longrightarrow \langle \overline{S} \rangle$$

obtaining a 2-tuple over the BLTS:

$$v(x_j) = G\big(v^1(x_j), \ldots, v^p(x_j)\big) \in \langle \overline{S} \rangle.$$

3.3 Rating phase

The final outcomes obtained in each step of the aggregation process, $v_A^k(x_j)$, $v_B^k(x_j)$, $v_C^k(x_j)$, $v^k(x_j)$ and $v(x_j)$, are used either for sorting and ranking the employees or to establish the companies' policy in the rating phase. The employees will be then sorted and ranked according to the corresponding 2-tuples over the BLTS obtained in each stage of the aggregation phase. The outputs that could be sort and rank from the aggregation process are:

1. *Appraisers' collective criteria values, for collectives*.
2. *Global criteria values*.
3. *Final value*.

Obviously, other comparisons are possible. From the aggregated assessments and rankings obtained the organization can make decisions about its human resources' policy.

4 Conclusions

This contribution has introduced a performance appraisal method that is able to offer a evaluation framework dealing with different types of information in order to facilitate the expression of the information to the different appraisers involve in such a process.

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