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Professional Evaluation. Application of the PageRank Algorithm in Employee Rating

Abstract: Appraisal is a tool used by both management and employees to attain their goals. Properly carried out employee performance appraisal allows to monitor the employee's actions and provides information on the level of his or her performance. Feedback in the form of appraisal motivates the employee to work more effectively and productively. Appraisal also enables to shape the personnel policy – it allows to chart employee career paths and determine training needs of an organization. For appraisal, however, to fulfil the attributed role, it needs to be carried out in a professional manner.

The aim of the article is to draw attention to the importance of employee performance appraisal in the personnel management process and to provide information on the core principles of appraisal. It describes, among others, determinants, criteria as well as selected methods and techniques of appraisal. An interesting point can be the use of the PageRank algorithm which can be a good solution for rating employees.

Key-words: employee performance appraisal, techniques and methods of appraisal, PageRank algorithm.

Introduction

Employee performance appraisals are among important elements of personnel management in an organization. They provide information on employee per-

formance and may form a basis for many personnel decisions. Appraisals are also a vital communication tool between the superior and employee, a guidepost for professional development, training choices and constant optimization of the process of work. For the superior, appraisals are a valuable source of knowledge of the appraised employee, while they offer the employee feedback on his or her performance. Nevertheless, employee performance appraisals are often criticised by employers and employees alike because, as a result of contemporary trends, more and more companies introduce employee appraisal schemes that are merely a formality with no practical importance. Thus, it is of crucial importance to approach appraisal professionally and, first and foremost, think of a solution to satisfy both the parties concerned.

Employee Performance Appraisal and Factors Determining the Appraisal Manner

Generally speaking, it can be quoted from many authors that appraisal is a value judgement applied in the management process and formed as a result of comparing features, qualifications, behaviours or effects of work of a specific employee with those of other employees or an established standard [Król, Ludwiczyński 2006, p. 289]. A similar view is expressed by Pocztowski who states that it is an opinion expressed orally or in writing that evaluates personality traits, behaviours and effects of work [Pocztowski, p. 224]. Employee performance appraisal is a basis for making many rational and fair personnel decisions; thus, creating conditions for the proper development of employees and institutions [Adamiec, Kożusznik 2007, p. 171]. In practice, periodic appraisal of employees' achievements is perceived as a crucial element of human resources management while its form and ways in which its results are used depend, to a large extent, on the management strategy, read literature and tradition of a company [Sajkiewicz 2000, p. 229]. The specialist literature offers various employee performance appraisal classifications. The most commonly applied include current and periodic appraisals. Current appraisal is made in the scope of day-to-day activities, e.g. by superiors or fellow workers. It is used to instruct and correct human behaviours in the process of work by giving feedback on the manner and effects of performed work. Periodic appraisal, most often comprehensive, is carried out from time to time and employs standard systems of periodic employee performance appraisal. It serves not only operating but also strategic purpose by, for example, identifying development potential of appraised individuals [Pocztowski 2007, p. 225].

It stems from the presented definitions that appraisals are an important management tool but it should be emphasized that there are many factors that need to be taken into account at their introduction.

Important factors include, first and foremost, the company size and type of its activities. Different objectives, criteria and techniques apply to small firms,

large corporations, public or academic institutions. In turn, what determines the manner of appraisal is, among others, the type of work, level of requirements or the appraiser's authority. The level of requirements is often connected with an individual approach to the employee. Another approach ought to be adopted to the newly employed, yet another – to experienced employees. Different criteria should also be applied in the appraisal of production workers, salespeople or specialists. Similarly, a specific approach is needed to the appraisal of management and executive personnel. As already mentioned, both the course and result of appraisal are directly influenced by the superior's authority. The higher the authority, the higher the acceptance of appraisal results [Sidor-Rządkowska 2000, pp. 26–45; Oleksyn 1993, p. 58].

Hence, employee performance appraisal is an important component of the management process. It contributes to the efficient functioning of an organization, meeting its goals and developing conditions for achieving a high job satisfaction level by employees. Among numerous functions served by employee performance appraisal, the first to be mentioned is the evaluative function consisting in the appraisal of employee performance to date, the way he or she fulfils duties entrusted to him or her and the degree of his or her usefulness in the occupied position [Atamańczuk 2000, p. 7]. The motivating function should be emphasized (appraisal motivates people to work better and more effectively and impacts on their attitudes) as well as the information and decision-making functions. The information function occurs in two forms. The appraiser gets to know the employee and the subordinate learns what the superior knows about him or her. He or she is informed about what to expect, whether he or she will be punished or rewarded and what decisions will be made concerning his or her career and future. In turn, decision-making appraisal helps to make decisions on the further work of appraised employees. It is worth stressing that it can also be viewed as an element of organizational culture [see Sułkowski 2009].

Results of appraisal, when used, may change a decision or improve it. If decisions are guided by impression or intuition, the appraiser can make a mistake and promote an incompetent person or deny promotion to a competent one.

It should also be added that the consistent application of employee performance appraisal greatly affects the creation of a pro-effective and pro-innovative organizational culture [Dzieńdziora 2008, p. 36].

The above proves that the carrying out of managerial functions and actions in specific areas of human resources management is rather impossible without employee performance appraisal.

Appraisal System and Its Elements

A basic appraisal system consists of objectives, criteria, subject, object and techniques. In practice, it is most commonly assumed that the principal objective of employee performance appraisal is to, first and foremost, improve the effec-

tiveness and quality of work done. Although it seems obvious, it should be emphasized that there may be various appraisal objectives. Moreover, they depend on the strategy adopted by a company. A. Pocztowski mentions organizational and psychosocial goals [Pocztowski 2007, pp. 225–226]. The former serve to obtain information necessary to decide personnel issues, such as hiring, training and training courses planning, career planning, rewarding etc. In turn, the latter consist in shaping behaviours and actions of employees through the regular provision of information that confirms their achievements or failures as well as career development opportunities.

Another classification of objectives is presented by Steward. The author lists the following objectives [Steward 1994, p. 250]:

– Corrective objective – shows weak points of employees to be corrected and eliminated;
– Stabilizing objective – consists in continuing to do what is good. It confirms the rightness of actions carried out properly and without fault;
– Developmental objective – indicates directions for specific employees to follow in order to develop. To meet the developmental objective is to point to the appraisee the direction of his or her development consistent with the direction of the company's development.

However, for the objectives to be fulfilled and for employee performance appraisals to serve their assigned function, be objective and produce information actually related to personnel, they are proposed to be made by applying the below principles. The most important of those include, among others [Pawlak 2003, p. 233]:

– universality of appraisal – everyone is subject to appraisal in an enterprise. There may be no one who is not subject to appraisal. No group of employees can be biased in favour of and no other groups can be biased against;
– knowledge of appraisal principles – allows for the better orientation of the employee's behaviours and actions;
– appropriate structure of appraisal system – an appraisal system should comprise types of appraisal used in a company, objectives, criteria and methods of appraisal. It is to be functional and useful;
– formalization of appraisals – principles of employee performance appraisal should be governed by a company's internal rules and regulations. As a result, they are based on unambiguous criteria and principles;
– compatibility of criteria – appraisal principles applied to specific employee groups should be compatible with the nature of their work;
– appraisers' background – the company should provide appropriate training for management staff so that no mistakes are made in appraisal and subordinates are appraised in a uniform manner;

– fairness of appraisal – appraisal ought to set out the same requirements for all individuals;
– objectivity of appraisal – appraisal should be based on facts rather than personal impressions and preferences of appraisers;
– feedback – the appraised employee has the right to get acquainted with the appraisal made. When informed of his or her deficiencies, the employee can work on overcoming them. When informed of his or her strong points, the employee will be assured that his or her actions have been right.

Depending on goals to be met by appraisal, different appraisal criteria are also applied. A criterion is a feature that forms a basis for employee performance appraisal. Employee performance appraisal can use a single criterion when a single feature is compared or rely on several criteria. In the latter case, it is justified to determine weights of specific criteria [Pawlak 2003, p. 221]. Another vital issue is the number of criteria. It varies depending on the type and objective of appraisal. The most commonly used are the following [Sajkiewicz 2000, p. 231]:

– Qualification-related criteria encompass all the knowledge and skills acquired at school and in the course of self-education, and experience gained in previous jobs. Those criteria are connected with specific positions.
– Efficiency-related criteria comprise material and financial results of work. In the case of those criteria, the most important thing is to determine how to measure work efficiency of individual employees or their teams. They should be agreed on with and accepted by employees. They include: quality, standards, meeting deadlines, economies achieved, attracting new customers, reducing production time etc.
– Behavioural criteria serve to appraise employees' behaviours. Their use in a small firm is justified because it can be difficult or impossible to measure results of work in some positions; hence, attempts are made to determine specific patterns of behaviour such as: persistence, regularity in work, diligence, professionalism, honesty, loyalty, attitude to customers and superiors.
– Personality-related criteria include relatively constant traits of human psyche that are significant taking into account requirements in a given position. Such criteria are applied because some positions require certain predispositions such as: creativity, interpersonal skills, firmness, resistance to stress or composure.

Apart from the above-mentioned criteria, there is a mixed type combining the above features. Along with general appraisal criteria, detailed criteria required in a given position can also be adopted [Jasiński 1999, p. 102].

The next stage in the appraisal process is to choose an appropriate assessment technique, adequate for an assessed effect. It is important for the technique to be right to measure the effects concerned, guarantee precision and accuracy. It should also take into account costs of its use. In practice, various techniques of appraisal are employed. They can be divided into relative and absolute ones [Kostera 1997, p. 472]. Several of them are presented below.

One of employee performance appraisal methods is **paired comparison**. As the name suggests, it consists of comparing each employee with any other employee (applying an earlier established criterion) and building a comparison matrix. Then the so called "indicator of positive choices" is calculated for each employee that serves to ultimately rank the employees.

At first glance, the method seems to be simple and easy. The literature states that the paired comparison method is applied in small groups. If one wants to assess, for example, 20 employees, 190 comparisons have to be made; if there are 40 employees, the number of required comparisons increases to 780; if, however, 100 people are to be assessed in such a way, the number of necessary operations will reach 4950. The number of combinations arises from the following formula: N(N-1):2 [Sidor-Rządkowska 2005, p. 85]. Thus, application of that method makes sense only in small organizations, for single level employees. That method is considered to be insufficiently progressive and appropriate solely for general appraisal. An example of the matrix is shown in Figure 1.

Figure 1. Example of appraisal using the paired comparison method

	A	B	C	D	E
A		A	A	A	A
B			C	D	E
C				C	E
D					E
E					

Source: Kostera 2000.

$$\frac{number\ of\ positive\ choices}{total\ number\ of\ choices} \times 100\% = \text{indicator of positive choices}$$

A	B	C	D	E
4/4 x 100 =100%	0/4 x 100 = 0%	2/4 x 100 = 50%	1/4 x 100 = 25%	3/4 x 100 = 75%

Employee A, who has four positive indications, ranked first. Employee A's indicator of positive choices is as high as 100%, followed by employee E – 75%, C – 50%, D – 25%, B – 0%.

Other presented techniques is **rating scales**. They are among the most common methods of assessing employee performance. The most popular of them is the point rating scale. It lists, one after another, the most significant appraisal criteria, e.g. creativity, accuracy, skills, quality of work, quantity of work etc.; thereafter, an appraiser evaluates each of the criteria separately [Kostera 2000, p.73]. The dilemma of the rating scale is the number of grades it is to include. Some claim that unpaired scales, e.g. five-point ones, are better because they allow to select the middle grade for average scores. There are, however, more proponents of odd scales that prevent the appraiser from giving the average grade and force him or her to make an unequivocal decision. An advantage of using that technique is the simplicity of its application, easy comparison of received results with results of other employees and clarity of received results. In turn, a disadvantage is that the method is not employee development oriented [Sidor-Rządkowska 2005, p. 91].

The result of point rating is often misleading and thus the so called **weighted scales** are introduced. Those scales are similar to point scales, the only difference being that weights determining the significance of a specific criterion are attached to each of the appraised criteria. The overall result is calculated by multiplying the weight by the criterion, summing the results and dividing the sum by the number of criteria. The received result is the so called weighted mean [Karach 2009, p. 150].
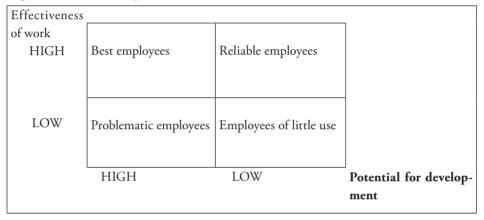
Somewhat different type is so called **behavioural anchored rating scales – BARS**. Ratings received based on them are regarded as especially reliable and objective. Preparing such a scale is very laborious and requires specialized knowledge. The first step is to perform the analysis of a position; then major tasks carried out in a given position and being of the crucial importance for meeting the company's goals are chosen. Taking those into account, descriptions of desirable and undesirable behaviours are made. The task of the appraiser is to determine the occurrence of desirable and undesirable behaviours in the appraisee's work. It should be mentioned that advantages of that technique balance difficulties associated with implementing the discussed method.

The last of the presented methods is the **personnel portfolio** technique – a comprehensive appraisal technique. It was created on the basis of the BCG (Boston Consulting Group) marketing matrix. It consists in grouping employees into categories characteristic and typical from the company's strategic point of view which is based on potential for development and effects of employees' work. Work effectiveness concerns the past and is appraised on the basis of present results and behaviours leading to them, i.e. effectiveness and behav-

ioural criteria. In turn, potential for development determines the future useful-
ness of an employee to the company. Appraisal consists in dividing employees
into four main groups (Figure 2) [Pocztowski 2007, p. 243-244]:

As a consequence of placing an employee in one of four fields an appropri-
ate personnel strategy is adopted for him or her. It is recommended that the
personnel portfolio be combined with other techniques enabling more precise
appraisal of performance and potential.

Figure 2. Personnel portfolio

Effectiveness of work		
HIGH	Best employees	Reliable employees
LOW	Problematic employees	Employees of little use
	HIGH	LOW **Potential for development**

Source: Pocztowski 2007, p. 244.

The presented techniques are only just a few in the list comprising techniques
and tools used in the process of employee performance appraisal but, due to the
length of the article, the list has been limited. They are more comprehensively
described in the works of [Sidor-Rządkowska 2003 and 2006; Juchnowicz, Smyk
2000; Karach 2009; Ward 2005; Lapsinger, Lucia 2007 et al.].

Application of the PageRank Algorithm in Employee Rating

PageRank Google is an algorithm used to rank websites, authored by Larry
Page and Sergey Brin. The principle underlying the PageRank algorithm is
that it assigns a certain numerical value to every website. The factor determin-
ing that value appears to be the number of links on the web leading to a given
website. Quality of any such reference depends on the ranking of the websites
from which they originate. To be more precise, valuable links turn out to be
those that are posted on high-ranking websites.

We will briefly explain how the PageRank algorithm works. It goes with-
out saying that there is a limited number of websites on the web. In the below
discussion, we assume that there are precisely n websites. For the sake of dis-
cussion clarity, we will put all websites in a sequence, assigning consecutive
numbers of the $\{1,2,3,...,n\}$ set to them.

As mentioned above, the PageRank algorithm assigns to each website a value determined by the number of references on the web that lead to a given website. Thus, we begin by creating a matrix compiling information about links on the web. It will be denoted by $G = (g_{ij})_{n \times n}$. Coefficients of the matrix are determined by the following relationship: $g_{ij} = 1$ when there is a reference from website j to website i, $g_{ij} = 0$ when there is no such reference. Then, we define number c_j as the number of links originating from website j.

The next step is to define the p_{ij} number as the probability that a person browsing website j will choose a link leading to website i from among all links posted on website j. Certainly, if we consider website j where there are no links posted, $p_{ij} = 0$ will be assumed for all i. Such websites are called "dangling". For websites j where there are links, the described probability is calculated applying the $p_{ij} = \dfrac{g_{ij}}{c_j}$ formula.

The described probabilities for all websites j are collected in the $P = (p_{ij})_{n \times n}$ matrix.

Let us remind the reader that by using the algorithm we are to assign a specific value denoted by w_i to each website i. The value is to be determined by the number of links leading to website i. Moreover, the measure of quality of every such link is the value assigned to the website where a given link is found. Intuition also tells us that the smaller the number of links on the website linking to website i, the higher the quality of each of them.

Hence, let us assign a hypothetical ranking value w_j to each website j. Then, in accordance with our above discussion, value w_i assigned to website i has to conform to the following relationship:

$w_i = \sum_{j=1}^{n} p_{ij} w_j$.

Let us note that, if we define vector $w \in R^n$ whose coefficients will be values assigned to specific websites, then, according to the above formula, the following has to occur: $w = Pw$. It arises from the received matrix equation that w is the eigenvector of matrix P corresponding to the eigenvalue of 1. It is relatively easy to prove that such a vector exists and calculate its value when the matrix is stochastic (sums of elements of each column equal 1) and irreducible (an example of such matrix is a matrix with all positive elements, which is sufficient for our discussion). Then, we can use the $w = \dfrac{1}{n} \lim_{k \to \infty} P^k e$ formula where e is a vector consisting only of ones [Meyer 2001, pp. 533–535, 673–675]. In such a case, we will receive values assigned to each website on our web and be able to rank the websites according to assigned values in a non-ascending order [Bryan, Leise, 2006, pp. 569–581].

The only other issue to be taken care of is to have a stochastic and irreducible P matrix. To that end, two modifications are applied whose description and motivation will be provided on the example of employee performance appraisal.

The method of employee performance appraisal based on the PageRank algorithm seems to solve many problems that occur in that field. It is based on an assumption that appraisal may not be one-sided, time-consuming or incomprehensible to employees who participate in it. Thanks to that method, appraisal taking into account preferences of the entire staff can be inexpensively made in small firms where all employees know one another. In turn, in larger enterprises the same method can be used within specific departments.

What is needed to apply that method is to ask employees to fill in a short questionnaire in which they should provide their own basic data and say which fellow workers they consider the most valuable.

For example:

Name and Surname:……………………….…….Department:.................................   Which employees do you appraise most highly? (You can put any number of surnames.)

At this point, association with the PageRank algorithm is quite noticeable. If we imagine that each employee runs a website, filling in the above-shown questionnaire by employee X can be understood as posting links to the listed colleagues on his or her website. Hence, we can rank employees according to the above-described algorithm.

What is left is to explain why the PageRank algorithm is suitable for such ranking. It goes without saying that excellent employees are able to more accurately appraise who is better at performing one's duties as they themselves are the best experts in it. Moreover, votes coming from individuals indicating many colleagues should be valued lower as the votes may prove their indecisiveness. Thus, it can be seen that such ranking should take into account not only the number of votes obtained but also their origin. Considering those factors, it is easy to conclude that the PageRank algorithm is a very good solution for such employee evaluation rank.

Let us remind the reader, however, that matrices produced by the algorithm are to be stochastic and irreducible. Hence, we will present modifications of created matrices and their interpretations.

First, we will reduce the matrix to the stochastic form. A skilled observer will notice that what we need to do to receive that form is to only modify columns for employees who did not cast vote for any fellow worker (as they comprise only zeros). It is rational to assume that such individuals are unable to decide who is the best (or find all to be not very good employees). Anyway, such individuals claim that all fellow workers and superiors work comparably.

Therefore, their votes can be interpreted as putting all surnames in the question-naire. Hence, we replace all-zero columns with columns whose all elements equal $\frac{1}{n}$. At this point, we receive a stochastic matrix.

What is to be done now is to reduce the matrix to its irreducible form or, in other words, see to it that all its elements are positive. It should be kept in mind that, when filling in the questionnaire, employees put surnames of indi-viduals they consider the best workers, which does not mean that they do not appreciate the rest. Thus, it can be assumed that employees not entered in the questionnaire also get part of the vote. In order to do that, it is enough to as-sume an appropriate coefficient $\alpha \in (0,1)$ (any coefficient chosen as preferred) which will reflect the weight of surnames put in the questionnaire ($\alpha = 0.85$ is assumed for the PageRank). Non-entered surnames are assigned the $1 - \alpha$ weight. That modification produces a stochastic and irreducible matrix in the following form:

$$R = \alpha P + (1 - \alpha)E,$$

where P is the stochastic matrix created above and E is the matrix of the nxn dimension whose all elements equal $\frac{1}{n}$ [Govan, Meyer 2006].

The presented method has several flaws: it does not take into account the diversity of appraisal (if the surname of an appraised employee features in a questionnaire, he or she has been appraised highly, if it does not – the appraisal is low) and the resulting rank contains information only about the general virtues of employees. The first problem can be very easily solved. What is to be done is to modify the questionnaire by adding any kind of appraisal diversification. For example:

Name and Surname:…….…….……….………….…….… Department:…........................
Which fellow workers do you assess...?
(You can put any number of surnames in each column)

very well	Well	as average	rather negatively	negatively

Then, by assigning appropriate weights to entered surnames and applying appropriate modifications, diversified appraisal can be produced.

The problem of the excessively general employee appraisal can be solved by creating several parallel ranks by asking more detailed questions: For example:

Name and Surname:…………………….…………Department:……………………
(You can put any number of surnames to answer each question)
Which fellow workers and superiors do you appraise most highly in respect of discipline?

Which fellow workers and superiors do you appraise most highly in respect of work?

Which fellow workers and superiors do you appraise most highly in respect of interpersonal relations?

In such a case employees should be ranked separately for each question by using the above-presented method. Both the improvements can, of course, be made simultaneously; one should be careful, however, not to make the questionnaire too complicated.

Summary

Undoubtedly, employee performance appraisals are an important component of personnel policy. Their role increases as the need for modern and effective tools to manage personnel occurs; hence, they should be made in a professional way. Proper appraisal significantly affects communication within the company, remuneration, development or promotion opportunities. Both theoreticians and practitioners are thinking about ways of appraisal that would satisfy both the parties concerned. It is not easy to choose an appropriate method and technique and, as stated in the article, it depends on many factors. It is recommended that several methods be used in the scope of one appraisal, in particular for different groups or types of positions.

The application of the PageRank algorithm seems to be a good solution. It can be used whenever we want to perform rating where an important factor is interactions among classified subjects taking into account values of those subjects. It should be added, however, that it requires appropriate knowledge. Given that the authors of the article did not present their own research (they are in progress) refer to the analysis of world literature.

To conclude, it ought to be said that there is no universal method to be applied in all organizations as each organization is different and requires an individual solution that precisely meets its needs.

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