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Support for decision making in planning the personnel development

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Abstract

The article deals with researching theoretical and applied problems of planning measures for personnel development. The purpose of writing the paper is to formalize the procedures for support of decisions related to personnel development. The paper refines methodological foundations of building models that formalize the management process under study. It was found that the tested subject area belongs to semi-structured systems described using the quantitative and qualitative indicators. Given the nature of the subject area, the mathematical apparatus based on the application of decision theory methods and expert assessments was used for the formalization of processes under consideration. Models for assessing the need for personnel development and selection of training programs were developed. The paper considers features and limitations related to the use of the integral assessment indicator applied to select the most appropriate personnel development program. The model for assessing the need for personnel development offered in the paper can be used to support managerial decisions during appraisal of employees or in other situations that require evaluation of their competence.

AMS subject classification:
Keywords: Personnel development, methods to support managerial decisions, human resource management, employee appraisal, semi-structured management tasks.

1. Introduction

1.1. Importance of planning the personnel development

The most important factor in achieving success of the organization is its human resources. It is a set of skills and capabilities of employees aimed to ensure the company development. Human resource capacity of the organization is largely determined by the competence of its employees. In this regard, the relationship between success of the organization and training activities to improve the competence of its employees becomes apparent (Dubrin & Ireland, 1993), (Shornikova, 2011).

The Human Resources Department, in cooperation with the heads of relevant departments, timely develop and implement measures for personnel retraining (Armstrong, 2002). Training of employees must be based on a clear understanding of which competences they will have and which current and future needs of the organization will be satisfied after their training. Therefore, development should be carried out not randomly, but in the context of the existing development plan of the organization and the production tasks performed by its personnel (Dessler, 2012), (Egorshin, 2003).

Planning the personnel development implies the resolution of a series of interconnected problems, the most important of which, in our opinion, are the following ones:

1. Determination of the need for personnel development, taking into account peculiarities of business processes in the organization.
2. Selection of candidates for training.
3. Selection of the educational institution where employees will undergo training, and the training program.

Many papers devoted to human resource management note an undeniable importance of personnel development. However, the description of that process is often abstract. Typically, training is presented in the form of general recommendations, arbitrarily executed graphic charts or tables (Dubrin & Ireland, 1993), (Gomez-Mejia, 2011), (Dessler, 2012), (Egorshin, 2003).

At the same time, the problems of rational, informed choice of training programs, taking into account employees qualifications and characteristics of the organization's business processes are rarely considered. Insufficient theoretical study of the problems of decision support in planning the personnel development can be a factor that not just greatly complicates the implementation of this process, but also affects the activities of the organization as a whole. This fact determines the relevance of the research in this direction.

1.2. Methodological bases of building models that formalize processes of planning the personnel development

The choice of the mathematical apparatus to describe the processes in the topical area under study depends on its structuring. This concept was first considered in the paper

(Newell & Simon, 1958). The degree of structuring of the topical area is associated with different combinations of quantitative and qualitative, objective and subjective information that characterizes it (Petrovskiy, 2009). The processes considered in the system of personnel management including training are characterized by both quantitative and qualitative indicators with a considerable predominance of the latter.

In the case under study, there are indicators that cannot be measured by quantitative variables, and no physical units can be assigned to them. For example, such parameter as "amount of gained knowledge" is only characterized qualitatively using verbal terms of natural language, while "cost of training" can be accurately described by a quantitative value. Thus, the topical area considered in the paper, according to (Newell & Simon, 1958), refers to the semi-structured objects.

One of the features of semi-structured systems is multicriteriality of their description. For example, comparison of alternative education programs and the choice of the most suitable of them will be made using such indicators as "amount of gained knowledge", "cost of training" and "kind of training". To solve the problems of choice in terms of multicriteriality in semi-structured systems, the decision theory is used (Petrovskiy, 2009). Simultaneous use of both qualitative and quantitative descriptions of the various parameters within a single computing system makes it impossible to directly compare them. In this regard, we must switch to a qualitative system of the values description.

The indicator "cost of training" can be quantified, but this description will not bear the semantic load. The matter is that the value of the same amount of money can be weighted differently by different organizations. Therefore, in situations where the qualitative assessment (high, above average, average, low cost) is more important than quantitative one ($1,000, $700, $400, $100), it is appropriate to use verbal descriptions. It incurs a loss of accuracy, but there are more opportunities for the transfer of semantic content of the parameter values in the context of the situation under consideration.

Thus, in constructing a mathematical model for the topical area under consideration, you should use the apparatus comprising the use of verbal variables. In this case, the decision theory allows to make comparisons of indicators with different physical meanings and measured in different types of data (Larichev & Moshkovich, 1996).

The use of verbal values for qualitative description of variables involves the use of expert technology (Litvak, 2004). It is impossible to use other ways to estimate the values of quality indicators.

A special feature of expert technologies is the possible influence of the subjectivity of the estimates. In addition, an expert can make a mistake. It is believed that the more competent the expert is, the more accurate his/her opinion about the object of the study is. Collective assessment of the expert group is formed on the basis of the opinions of its individual members. In this context, the following two indicators become very important:

1. General competence level of the expert group, which shows whether you can trust the values of their collective assessment. If this figure is low, the expert group in whole or in part should be changed. It should include more competent persons.

2. Importance (weight) of the expert assessments within the group. This indicator shows the impact of the opinion of an individual expert on the collective opinion of the group. The weight of the expert assessments depends on his/her competence in comparison with other group members.

Using verbal descriptions of indicators imposes certain requirements on the choice of rating scales. In this paper, we propose to apply the modified ordinal scales, which provide for the qualitative and point assessment of objects. It should be noted that the point values that reflect the quality indicators are not numbers in the strict sense. This fact limits some quantitative operations with values in points. In developing the ordinal scales used to describe the parameters for the personnel development assessment, we should take into account the following features:

1. The minimum and the maximum points corresponding to the verbal scores in all scales should be the same;

2. The number of verbal scores (scale divisions) should not be more than seven. This limitation is due to the peculiarities of perception of information by a human (Miller, 1956);

3. The quantitative parameters require an additional procedure for translation of numeric values into verbal scores. It is performed with the help of experts.

Some indicators, such as "amount of gained knowledge", are integral and described by a set of competences that are discussed in the training process. The level of competence after training is also evaluated through verbal values. The indicator "amount of gained knowledge" can be estimated by adding the values of individual knowledge and skills, which can be obtained in the course of training.

Calculation of the values of integrated indicators composed of heterogeneous elements allows for a partial compensation of their values. Using total compensation of the values of heterogeneous elements is incorrect (Petrovskiy, 2009). This can cause a situation when an employee with a high degree of initiative but very low skills may be preferable to others. Or high speed of the production will fully compensate for its extremely poor quality.

To avoid these unacceptable situations, the ability to compensate for some parameters by others is allowed only if they meet the minimum acceptable values. The weights of criteria are also used to highlight the importance of certain parameters when compared to others at the multicriteria assessment of alternatives (Petrovskiy, 2009). The value of these parameters is determined by a poll of experts. The minimum allowable values and the importance of the same indicators may differ considerably from each other at different organizations and for different positions.

Taking into account the features of the topical area described above, let us consider modeling of the processes of the personnel development organization.

2. Methodology of modeling the processes of personnel development planning

2.1. Determining the weights of experts

The initial stage of building any model based on the use of expert technologies is to determine the weights of experts. The weight of an expert is the most important parameter that determines the effect on the final opinion of the entire group of experts who solve their task. It has a significant impact on all further calculations performed and conclusions made.

The experts' qualification can be defined using various techniques, such as testing, comparing formal indicators, and mutual evaluation of competence (Petrichenko G.S. & Petrichenko V.G., 2015).

In this paper, we propose to use the method of testing experts. We believe that testing is less subjective and allows to more accurately assess the experts' qualifications in comparison with other methods. All the experts answer the test questions, the purpose of which is to determine their competence in the analyzed topical area. After processing the test results and calculating the experts' score, we need to calculate their weights. Several methods can also be used to calculate the weights. They provide different results, though there is a significant correlation among them (Korobov, 2005).

One well-known method that determines the weights of the experts is the method of ranking. As a result of testing, the experts are assigned ranks in the range $R_j \in [1, n]$. An expert who gets the maximum score has the rank $R_j = 1$, while the expert with the minimum score receives the rank equal to *n*. Then, according to formula (1), the weight for each expert is calculated.

$$w_{\exp_j} = \frac{n + 1 - R_j}{\sum_{j=1}^{n} R_j}, \tag{1}$$

where *n* is the number of experts;

R_j is the rank of the expert; and

$w_{\exp_j}$ is the normalized weight of the *j*-th expert.

The disadvantage of this method is that for calculation of the experts' weights – the ranks (relative values) rather than the points actually scored in the test are used. The ranking method does not take into account the magnitude of gap between the knowledge of one expert and those of the others. Especially strong are distortions in situations where the qualifications of the experts differ slightly. In our opinion, more correct weight distribution can be obtained by using the method of direct placement of weights described by formula (2).

$$w_{\exp_j} = \frac{K_j}{\sum_{j=1}^{n} K_j}, \tag{2}$$

where *n* is the number of experts;

Table 1: Determining the weights of experts using different methods of their calculation.

Indicators	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Points scored (max=50)	34	43	40	37	39
Experts' rank	5	1	2	4	3
Weights of experts using the ranking method	0.067	0.333	0.267	0.133	0.2
Ratio of the weights of experts using the ranking method	0.201	1	0.802	0.399	0.601
Weights of experts using the method of direct placement	0.176	0.223	0.207	0.192	0.202
Ratio of the weights of experts using the method of direct placement	0.789	1	0.928	0.861	0.906
Ratio of the experts' result to the best result in points	0.791	1	0.930	0.860	0.907

K_j is the points scored by an expert in his/her assessment; and

$w_{\exp_j}$ is the weight of the j-th expert.

As an example, we can consider the situation with five experts whose weighting coefficients are calculated using the two methods discussed above and shown in Table 1.

The data shown in Table 1 indicate that the method of direct placement of weights accounts for the difference between the qualified experts more accurately.

Besides the weights of experts, we need to determine the overall level of competence of their group. One possibility is the method described in the paper, according to which the permissible level of competence of the expert group must comply with the double inequality (3) (Lukicheva, 2009).

$$0.67 \leq LKEG \leq 1, \tag{3}$$

where *LKEG* is the level of competence of the expert group.

If the group does not meet the requirement (3), other experts should be selected. The value of the level of competence of the expert group is determined from the expression (4).

$$LKEG = \frac{1}{n} \times \sum_{j=1}^{n} LKEG_j, \tag{4}$$

where n is the number of experts; $LKEG_j$ is the level of competence of the expert.

The level of competence of each expert is determined using formula (5).

$$LKEG_j = \frac{K_j}{K_{\max}}, \tag{5}$$

Table 2: Determining the level of competence of the group.

Indicators	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Points scored (max=50)	34	43	40	37	39
Level of competence of the expert	0.68	0.86	0.8	0.74	0.78

where $LKEG_j$ is the level of competence of the expert;

K_j is points scored by an expert in his/her assessment; and

$K_{\max}$ is the maximum number of points that an expert could score in his/her assessment.

Let the maximum possible number of points that can be scored in testing be 50.

The calculation of the indicators of competence of individual experts and the whole group is given in Table 2.

According to (4) and the data in Table 2, the level of competence of the expert group is 0.772. Thus, the assessments of this group of experts within the topical area under study can be considered correct.

The result of this phase of building the model of organization of personnel development is the model of the expert committee represented by formula (6).

$$Exp = \left\{ w_{\exp_1}, w_{\exp_2}, w_{\exp_3}, \dots, w_{\exp_j} \right\}, \tag{6}$$

Its components $w_{\exp_1}, w_{\exp_2}, w_{\exp_3}, \dots, w_{\exp_j}$ represent the weight coefficients of the importance of estimates of appropriate experts that meet the following system of the conditions (7):

$$\begin{aligned} &w_{\exp_1}, w_{\exp_2}, w_{\exp_3}, \dots, w_{\exp_j} \geq 0, \\ &w_{\exp_1} + w_{\exp_2} + w_{\exp_3} + \dots + w_{\exp_j} = 1. \end{aligned} \tag{7}$$

2.2. Model of the assessment of the need for the personnel development

Duties of employees are a part of the model of assessing the need for the personnel development. They stipulate the need for certain competences for employees occupying the position *x*, which are described as follows (8):

$$D_E = \{d^{\Sigma}_{sk_1}, d^{\Sigma}_{sk_2}, d^{\Sigma}_{sk_3}, \dots, d^{\Sigma}_{sk_m}\}_E, \tag{8}$$

where $d^{\Sigma}_{sk_m}$ is the requirement for the *m*-th competence $_{sk_m}$. Using the symbol "$\sum$" shows that the value of $d^{\Sigma}_{sk_m}$ is the final estimate obtained after studying the opinions of all the experts.

To describe the value of the verbal variable $d^{\Sigma}_{sk_m}$ "requirement for competences", a term set of values is used: ["absence", "elementary", "below average", "average", "above average", "excellent"]. They correspond to the following points: [0; 2; 4; 6; 8; 10]. Value of $d_{sk\Sigma}$ is defined using formula (8).

$$w_{\exp_1} \times d_{sk_m 1} + w_{\exp_2} \times d_{sk_m 2} + \cdots + w_{\exp_j} \times d_{sk_m j} + \cdots + w_{\exp_n s} \times d_{sk_m n} = d^{\Sigma}_{sk_m}, \quad (9)$$

where $d_{sk_m n}$ is the requirement for the m-th competence $_{sk_m}$ from the point of view of the n-th expert;

$d^{\Sigma}_{sk_m}$ is the requirement for the m-th competence $_{sk_m}$ from the point of view of the expert group; and

$w_{\exp_j}$ is weight of the n-th expert.

Then, the competences in the training are ranked by experts in ascending order of importance. Unlike the determination of the weights of experts, in determining the weights of competences, it is preferable to use the method of ranking. According to formula (10), the weights of each m-th competence (w_{sk_m}) are determined, normalized in the range [0; 1], according to the estimates of all the experts (Korobov, 2005).

$$w_{sk_m} = \sum_{j=1}^{n} \left(w_{\exp_j} \times \left(\frac{m + 1 - R_{sk_i j}}{\left(\sum_{i=1}^{m} R_{sk_i}\right)} \right) \right) \quad (10)$$

Another key indicator for assessing the objective need for training is "mastery of competences" by an employee occupying the position x. For him/her, the competence indicator is described using the variable q_{sk} (qualification). Qualification of the employee may be presented in the form of formula (11).

$$Q_E = \{q^{\Sigma}_{sk\,1}, q^{\Sigma}_{sk\,2}, q^{\Sigma}_{sk\,3}, \ldots, q^{\Sigma}_{sk\,m}\}_E, \quad (11)$$

where sk_m is the m-th skill taken from the list of duties D_E, the presence or absence of which is characterized by the value $q^{\Sigma}_{sk\,m}$.

To calculate the value $q^{\Sigma}_{sk\,m}$ that characterizes the degree of mastery of the m-th competence, taking into account the opinions of all the experts, formula (12) is used, similar to (9). For the characteristics of mastery of $q^{\Sigma}_{sk\,m}$ competence, the same meanings are applied as to the description of the requirements for the positions.

$$w_{\exp_1} \times q_{sk_m 1} + w_{\exp_2} \times q_{sk_m 2} + \cdots + w_{\exp_j} \times q_{sk_m j} + \cdots + w_{\exp_n} \times q_{sk_m n} = q^{\Sigma}_{sk_m}, \quad (12)$$

where $q_{sk_m n}$ is the respondent's mastery of the m-th competence sk_m from the point of view of the n-th expert; and $w_{\exp_j}$ is the weight of the n-th expert.

Using formulas (9) and (12), all the indicators are calculated that form the profile of requirements for the position and the profile of qualifications of the assessed employee.

Their difference will show the discrepancy between the requirements to the positions and the capabilities of the employee (13).

$$\begin{array}{ccccc} \underline{D_x} & & \underline{Q_x} & & \underline{RC_x} \\ d^{\Sigma}_{sk_1} & & q^{\Sigma}_{sk_1} & & rc^{\Sigma}_{sk_1} \\ d^{\Sigma}_{sk_2} & - & q^{\Sigma}_{sk_2} & = & rc^{\Sigma}_{sk_2} \\ \ldots & & \ldots & & \ldots \\ d^{\Sigma}_{sk_m} & & q^{\Sigma}_{sk_m} & & rc^{\Sigma}_{sk_m} \end{array} \tag{13}$$

The value of the need $rc^{\Sigma}_{sk_m}$ for training on any competence is determined by the rule given in (14).

$$\begin{array}{ll} rc^{\Sigma}_{sk_m} = d^{\Sigma}_{sk_m}, & if\, d^{\Sigma}_{sk_m} > q^{\Sigma}_{sk_m} \\ rc^{\Sigma}_{sk_m} = 0, & if\, d^{\Sigma}_{sk_m} \leq q^{\Sigma}_{sk_m} \end{array} \tag{14}$$

This calculation principle is logical, because you cannot add "elementary" level to "average" to get an assessment of knowledge "above average". The indicator "final need for training" TR^{Σ}_x is calculated using formula (15).

$$w_{sk_1p} \times rc^{\Sigma}_{sk_1} + w_{sk_2p} \times rc^{\Sigma}_{sk_2} + \ldots + w_{sk_mp} \times rc^{\Sigma}_{sk_m} = TR^{\Sigma}_x \tag{15}$$

Further calculations will depend on the features of the task being solved.

If training is mandatory and the experts have a task to select the most needed employees working in the same position, the descending ordering of the appropriate TR^{Σ}_x is carried out. Depending on the quota of persons who may be sent for training, n employees with the highest TR^{Σ}_x are selected.

If the experts face the question of advisability of sending an employee for training, the calculation continues. It is appropriate to use qualitative indicators to decide on the need for personnel development. For this purpose, the factor "need for training" CRE^{Σ}_x is calculated as the ratio of the amount of knowledge gaps to the required knowledge. The indicator "final qualifications" for the position given by experts is defined (16).

$$w_{sk_1} \times d^{\Sigma}_{sk_1} + w_{sk_2} \times d^{\Sigma}_{sk_2} + \cdots + w_{sk_m} \times d^{\Sigma}_{sk_m} = TD^{\Sigma}_x. \tag{16}$$

The factor "need for training" is the ratio of the indicator "total need for training" TR^{Σ}_x to the "final qualification requirements" TR^{Σ}_x (17).

$$CRE^{\Sigma}_x = \frac{TR^{\Sigma}_x}{TD^{\Sigma}_x}. \tag{17}$$

The value of the coefficient "need for training" in passing the training will always be in the range $CRE^{\Sigma}_x \in [0; 1]$. The larger the value of CRE^{Σ}_x is, the higher the need for training is. In order to form a conclusion about expediency of sending an employee for training, we should make the decision rule. It may consist of the following verbal assessments:

Table 3: Decision rule that specifies the need for training.

Verbal assessment	Range boundaries
training is impractical	$0 \leq CRE_x^\Sigma \leq 0.2$
training is possible	$0.21 \leq CRE_x^\Sigma \leq 0.3$
training is required	$0.31 \leq CRE_x^\Sigma \leq 0.5$
training is necessary	$0.51 \leq CRE_x^\Sigma \leq 0.1$

1. training is impractical;
2. training is possible;
3. training is required;
4. training is necessary.

The boundaries of the numerical ranges of the verbal assessments are determined by experts using formula (18).

$$w_{\exp_1} \times \lim b_1^x + w_{\exp_2} \times \lim b_2^x + \cdots + w_{\exp_n} \times \lim b_n^x = \lim b_\Sigma^x, \tag{18}$$

where $\lim b_n^x$ is the boundary of the x-th range given by the n-th expert.

Possible values of the range boundaries for the decision rule are shown in Table 3.

Based on the values of the coefficient CRE_x^Σ and the established range boundaries, the decision support system allows to make a conclusion about the feasibility of training an employee under assessment.

2.3. Model of selecting the program for personnel development

If an employee requires training, a training program should be chosen. In this case, the data of his/her profile of training need *RCx* defined in (13) are used. First, many alternative forms of training programs that improve the qualifications by all the required $rc_{sk_m}^\Sigma > 0$ are formed. Then, to assess the passage of training programs, a matrix is built (19):

$$\begin{array}{l|lllll|l|l} programs & compe & tence & & & & price & type \\ \hline prog_1 & qp^\Sigma_{1\,1} & qp^\Sigma_{2\,1} & qp^\Sigma_{3\,1} & \ldots & qp^\Sigma_{p\,1} & pr^\Sigma{}_1 & type_1 \\ prog_2 & qp^\Sigma_{1\,2} & qp^\Sigma_{2\,2} & qp^\Sigma_{3\,2} & \ldots & qp^\Sigma_{p\,2} & pr^\Sigma{}_2 & type_2 \\ \ldots & & & & & & & \\ prog_z & qp^\Sigma_{1\,z} & qp^\Sigma_{2\,z} & qp^\Sigma_{3\,z} & \ldots & qp^\Sigma_{p\,z} & pr^\Sigma{}_z & type_z \end{array} \tag{19}$$

where z is the cardinality of the set of alternative training programs;

p is the cardinality of the set of required competences. Non-strict inequality $p \leq m$ must be satisfied for p, because an individual under assessment may sufficiently master some of the required competences. The value of p may be different for different employees occupying similar positions;

qp_p^Σ is the evaluation of the mastery of the p-th competence that can be achieved after training on the z-th training program according to the final opinion of experts;

pr_z^Σ is the estimate of the cost of training on the z-th training program according to the final opinion of experts; and

$type_z$ is the type of training provided by the z-th training program.

For training programs where non-strict inequality (20) is satisfied for all the competences, which means that the resulting knowledge will equal or exceed the required one, the final total score sk_z^Σ is calculated. The training programs where the inequality is not satisfied for at least one competence are excluded from further processing.

$$qp_{p_z}^\Sigma \geq rc_{sk_p}^\Sigma \tag{20}$$

The total score sk_z^Σ that allows to obtain a convolution of the indicator "amount of gained knowledge" on the z-th training program taking into account the weights of w_{sk_p} competences is calculated using formula (21).

$$w_{sk_1} \times qp_{sk_1}^\Sigma + w_{sk_2} \times qp_{sk_2}^\Sigma + \cdots + w_{sk_p} \times qp_{sk_p}^\Sigma = sk_z^\Sigma \tag{21}$$

The weights of importance of competences w_{sk_p} were defined earlier using formula (10).

Another factor influencing the choice of training program is its cost. Experts are used to assess the cost criterion, as well as for indicators of the qualification.

A scale based on a term set {"absence", "elementary", "below average", "average", "above average", "excellent"}, which correspond to the numerical values {10; 8; 6; 4; 2; 0}, is formed for a verbal variable "cost of training". The reverse order of points in a scale of compliance is due to the fact that the increase in the cost is not a positive but a negative factor when choosing alternatives. Using the proposed scale, experts assign grades for each of the possible training programs based on their cost. In view of the pre-defined weights of experts $w_{\exp_j}$, the final evaluation of the criterion "cost" of the training program will be as follows (22):

	$\exp_1$	$\exp_2$	...	$\exp_m$	$\exp^\Sigma$
$prog_1$	$w_{\exp_1} \times pr_{1\exp_1}+$	$w_{\exp_2} \times pr_{1\exp_2}+$	...	$+w_{\exp_n} \times pr_{1\exp_n}$	$= pr_1^\Sigma$
$prog_2$	$w_{\exp_1} \times pr_{2\exp_1}+$	$w_{\exp_2} \times pr_{2\exp_2}+$	...	$+w_{\exp_n} \times pr_{2\exp_n}$	$= pr_2^\Sigma$
...	...	...	...	...	...
$prog_z$	$w_{\exp_1} \times pr_{z\exp_1}+$	$w_{\exp_2} \times pr_{z\exp_2}+$	...	$+w_{\exp_n} \times pr_{z\exp_n}$	$= pr_z^\Sigma$

(22)

The summation of the products of evaluations of individual experts and their weights results in the final estimate of the value of cost pr_z^Σ of training for each alternative. Then, experts express their opinions on the highest possible cost of training. This indicator is calculated using formula (23).

$$w_{\exp_1} \times pr_{\exp_1 \max} + w_{\exp_2} \times pr_{\exp_2 \max} + \cdots + w_{\exp_B} \times pr_{\exp_B \max} = pr_{\max}^\Sigma \tag{23}$$

The maximum cost of training is influenced by many factors, including among others the following:

- financial capacity of the organization that sends employees for training;
- specifics and professional orientation of the training program;
- duration of training; and
- image of the educational organization.

The maximum permissible cost of education is compared to the corresponding indicators describing the personnel training programs. Among the possible alternatives, the ones are selected which satisfy the inequality (24), the meaning of which is the same as for (20).

$$pr_{\max}^{\Sigma} \geq pr_{z}^{\Sigma} \tag{24}$$

Quite often, the choice of the training program depends not only on the amount of gained knowledge and the cost of training, but also on the type of training. The score scale of the types of training should be drawn up by experts taking into account characteristics of the position and the organization. In general, the list of possible ways of training is different in different organizations. The paper proposes the following tentative list of possible ways of training:

1. Self-education or self-study. A program of employee self-study is developed in an organization by the experts.
2. Participation in webinars, seminars, lectures or listening to the invited lecturers at the workplace or in other organizations.
3. Retraining courses lasting up to two weeks.
4. Retraining courses lasting from two weeks to a month.
5. Retraining in educational or specialized institutions lasting more than a month.

For the variable "type of training", the scale is formed from the verbal values of the list discussed above that correspond to the points {1, 3, 5, 7, 10}. Defining acceptable ways of training has its own peculiarity. It lies in the fact that some training methods may require too long absence of personnel from work, which is not always acceptable. Therefore, unlike conventional inequalities used to assess the competence and cost criteria, the double inequality should be used to select the allowable types of training (25).

$$type_{\max}^{\Sigma} \geq type_{z} \geq type_{\min}^{\Sigma}, \tag{25}$$

where

$type_{\max}^{\Sigma}$ is the type of training of the maximum allowable length, for example up to one month;

$type^{\Sigma}_{\min}$ is the minimum acceptable training, for example in the form of a seminar; and

$type_z$ is the type of training defined by the z-th program.

Values of $type^{\Sigma}_{\max}$ and $type^{\Sigma}_{\min}$ are based on expert evaluations using formulas (26) and (27).

$$w_{\exp_1} \times type_{\exp_1 \max} + w_{\exp_2} \times type_{\exp_2 \max} + \ldots + w_{\exp_B} \times type_{\exp_B \max} = type^{\Sigma}_{\max} \quad (26)$$

$$w_{\exp_1} \times type_{\exp_1 \min} + w_{\exp_2} \times type_{\exp_2 \min} + \ldots + w_{\exp_B} \times type_{\exp_B \min} = type^{\Sigma}_{\min} \quad (27)$$

After determining the resulting points that measure the obtained competence, cost and way of training and analysis of constraints (20), (24), (25), training programs that meet all eligibility criteria will be selected. For further analysis of the preference, it is proposed to use synthesis of the "ideal point" and "hierarchy analysis" methods (Vishnekov *et al.,* 2010). The "ideal point" method in the classic version is based on the search for the distance to the point with the ideal characteristics. An alternative that has the minimum distance to the ideal point determined by formula (28) is recognized as the best.

$$\sqrt{(type_z - type^{\Sigma}_{ideal})^2 + (pr^{\Sigma}_z - pr^{\Sigma}_{ideal})^2 + (sk^{\Sigma}_z - qp^{\Sigma}_{ideal})^2} = D^{\Sigma}_z \quad (28)$$

Let's define the coordinates of the ideal point. In this case, for the price factor $pr^{\Sigma}_{ideal} = pr_{\min} = 0$. For qualifying performance, the coordinates of the ideal point are calculated using formula (29).

$$qp^{\Sigma}_{ideal} = \sum_{n=1}^{p} w_{sk_p} \times 10, \quad (29)$$

where p is the number of criteria used for training, and 10 is the highest possible score.

To get the value of $type^{\Sigma}_{ideal}$, assessment of experts should be used, who should express an opinion on the most appropriate form of training (30) taking into account the respective weighting factors *wexpj*, and the previously defined values of $type^{\Sigma}_{\max}$, $type^{\Sigma}_{\min}$.

$$w_{\exp_1} \times type_{ideal\,1} + w_{\exp_2} \times type_{ideal\,2} + \ldots + w_{\exp_n} \times type_{ideal\,n} = type^{\Sigma}_{ideal} \quad (30)$$

A significant drawback of the "ideal point" method in its classic version in the search for solutions in multicriteriality is that it does not take into account the importance of various indicators to assess training programs.

The hierarchy analysis method does not have this drawback, since experts determine the relative weights of various criteria by comparing them with each other. At the final stage, with the values of criteria and their weights, the preferred option is determined. However, it also has certain disadvantages associated with the possibility of obtaining

Table 4: Comparison of the importance of the assessment criteria for training programs.

Criteria	sk	pr	t	Eigenvector, S	Criterion weight, V
Sk (skills)	*1*	C_{sk}^{pr}	C_{sk}^{t}	$S_{sk} = \sqrt[3]{C_{sk}^{pr} \times C_{sk}^{t}}$	$V_{sk} = S_{sk}/(S_{sk} + S_{pr} + S_t)$
Pr (price)	C_{pr}^{sk}	*1*	C_{pr}^{t}	$S_{pr} = \sqrt[3]{C_{pr}^{sk} \times C_{pr}^{t}}$	$V_{pr} = S_m/(S_{sk} + S_{pr} + S_t)$
T (type)	C_{t}^{sk}	C_{t}^{pr}	*1*	$S_t = \sqrt[3]{C_{t}^{sk} \times C_{t}^{pr}}$	$V_t = S_t/(S_{sk} + S_{pr} + S_t)$

conflicting solutions due to inconsistent views of experts. At a small number of assessment indicators, like in this example, this drawback is easily eliminated.

In the first phase, each expert determines the relative weight of criteria – obtained competences, amount of training, and type of training. The coefficients that take into account the importance of various dimensions (criteria for assessment of the training programs) are calculated in the same way as for the corresponding phase of the hierarchy analysis method, and are presented in Table 4.

In the second phase, the values of the criteria weights V_{sk}^{Σ}, V_{pr}^{Σ}, V_t^{Σ} are calculated taking into account the opinions of all the experts (31).

$$\begin{gathered} w_{\exp_1} \times V_{\exp_1 sk} + w_{\exp_2} \times V_{\exp_2 sk} + ... + w_{\exp_n} \times V_{\exp_n sk} = V_{sk}^{\Sigma} \\ w_{\exp_1} \times V_{\exp_1 pr} + w_{\exp_2} \times V_{\exp_2 pr} + ... + w_{\exp_n} \times V_{\exp_n pr} = V_{pr}^{\Sigma} \\ w_{\exp_1} \times V_{\exp_1 t} + w_{\exp_{\cdot 2}} \times V_{\exp_2 t} + ... + w_{\exp_n} \times V_{\exp_n t} = V_t^{\Sigma} \end{gathered} \tag{31}$$

In view of the proposed modifications, the distance to the "ideal point" for the z-th training program characterized by the values of the criteria sk_z^{Σ}, pr_z^{Σ}, $type_z$ and weights of the criteria V_{sk}^{Σ}, V_{pr}^{Σ}, $V_t^{\Sigma}$is measured using formula (32).

$$\sqrt{(type_{ideal}^{\Sigma} - type_z)^2 \times (V_t^{\Sigma})^2 + (pr_z^{\Sigma})^2 \times (V_{pr}^{\Sigma})^2 + (qp_{ideal}^{\Sigma} - sk_z^{\Sigma})^2 \times (V_{sk}^{\Sigma})^2} = D_z^{\Sigma} \tag{32}$$

After ordering a set of alternative programs by an increase in the value of D_z^{Σ}, their list is presented to DMP for a final decision. The alternative, which has the minimum value of D_z^{Σ}, is the most suitable way of training, since it will be the closest to the "ideal point".

3. Results

The development of the mathematical apparatus for research in semi-structured socio-economic systems and its subsequent application have their own characteristics.

Firstly, the values characterizing the alternatives in the expert systems are somewhat subjective. They are presented by the experts guided by their understanding of processes. In this respect, it is correct to speak about the search for a rational rather than an optimal solution for personnel management (Petrovskiy, 2009).

Secondly, it should be kept in mind that the results obtained are approximate. They evaluate alternatives with a certain degree of error in the calculations. For this reason, the alternatives that are slightly inferior to the technically best solution should not be immediately discarded. Along with the best solution, it makes sense to consider a number of possible alternatives.

Regarding the scope of use of the above procedures in support for managerial decision-making, we can say that they allow us to solve a number of interrelated tasks:

1. Assess the need for personnel development;
2. Plan training for employees who need it;
3. Define the appropriate options of retraining in terms of such indicators as the amount of gained knowledge, cost, type of training; and
4. Adjust the organization's needs for qualified personnel.

The procedures described in the paper should be applied for the formation of science-based managerial decisions in the implementation of measures for the personnel development, which should result in a positive effect on the functioning of the organization. Also, the procedures considered in the paper can be applied in the implementation of other measures in the field of personnel management:

1. Motivational impact. Quite a lot of employees perceive the possibility of training as an encouragement on the part of management. Professional development often precedes career development and salary growth. In addition, training increases the demand for an employee on the labor market.
2. Assessment of the personnel. The model of the assessment of the need for personnel development presented in this paper is proposed to be used for the formation of the requirements for a position and research of the personnel development during their appraisal.
3. Formation of the team. One of the stages of solving the problem of formation of the team is to select employees based on their qualifications. The model of the assessment of the need for personnel development is applicable in this case as well.

It should be noted that the purpose of this article is, above all, the development of models that would allow to improve the implementation of measures for personnel development. However, the above list of other tasks, which may result in partial use of the developed models, proves the correctness of the provisions of the system approach and the close relationship of processes in personnel management system. When developing procedures for analyzing a single management task, the means to find solutions to others are found.

4. Conclusion

Considering the prospects for further research of theoretical and practical issues raised in this article, we can define the following possible areas.

Development of a software module for automated planning of the personnel development

Mathematical formalization of the description of management processes is only an intermediate stage of improving the system of the corporate personnel management. The next step would be to design a database designed to record, store and process information about planning the personnel development. It should be created taking into account the formalized description of procedures for assessing the need for personnel development and selection of personnel development programs, as well as integration with the corporate information system of the organization. Creating a database that works independently from the corporate information system of the organization would be inappropriate, since it would make informational interaction with it difficult.

Using the linguistic variables

The transition from verbal to linguistic variables is one of the most likely ways to improve the models presented in this study. In its turn, the emergence of linguistic variables implies the automatic use of the mathematical apparatus of fuzzy numbers. In this case, fuzziness is quite useful for describing processes in the semi-structured topical areas, such as the process of assessing various aspects of personnel performance. Apparatus of fuzzy calculations was created by L. Zadeh in the 60s of the XX century (Zadeh, 1965). So far, the use of the fuzzy approach has been tested in various areas of human activity, and its effectiveness has been proved. With regard to research in the field of personnel management, we can specify the papers (Gorkaviy & Soloviev, 2010), (Sirb & Dragolea, 2013), (Skorokhod, 2005), (Skorokhod, 2009) dedicated to the use of the fuzzy approach to the assessment of personnel. However, the amount of research in this area if compared to the publications in the field of general management is small.

In this case, the use of fuzzy numbers will help solve problems when performing calculations, especially those associated with rounding errors. For example, in determining the final opinion of experts in the form of the weighted average amount, a value of 4.45 can be obtained. However, the scale used involves only integer values. On the one hand, 4.45 should be translated as 4 according to the rounding rules, but on the other hand, such rounding causes the error in the calculations for more than 10% from the result obtained. If we take into account that this situation arises in the calculation of a considerable number of indicators, the end result will be an approximation. In general, the use of fuzzy calculations considerably increases the accuracy of the results, which should positively influence the quality of managerial decisions.

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