

# Increasing of organizational and technical system reliability with a help of differential approach

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**Abstract.** This article is devoted to the application of the competence approach for increasing of the stability of the information systems functioning taking into account the human factor. The method of accounting for human factors is proposed. The results of using the competence approach in the construction of reliable organizational and technical systems based on information technologies are presented.

## 1. Basic concepts and principles of differential approach

In modern conditions of society informatization, one of the decisive factors which determine the reliable functioning of organizational and technical systems based on information technologies is not only the high level of professionalism of users who use the information resources of the organization, but also their predisposition to a specific type of activity. Studies based on the principles of a differential approach in psychology allow us to approach the solution of practical problems of identifying people's psychological predisposition to activity [1].

The proposed solution to the problem of improving the reliability of the organizational and technical system is based on taking into account the level of competence of each user regarding the required type of activity, including its psychological properties and educational characteristics. The user of the organizational and technical system will be called the subject. All subjects of the system form a set of subjects  $S = \{s_1, s_2, \dots, s_n\}$ . As it was said earlier, subject  $s \in \{S\}$  has psychological properties and educational characteristics. Psychological characteristic  $P = \{p_1, p_2, p_3, p_4\}$  express the predisposition of the subject  $s \in \{S\}$  to one of the activities  $D = \{d_1, d_2, d_3, d_4\}$ . The educational characteristic  $Q = \{q_1, q_2, q_3, q_4\}$  expresses one of the four characteristics of the subject in the professional activity  $d \in \{D\}$ , namely the existence of education and experience ( $q_1$ ), the existence of only education ( $q_2$ ), the existence of only experience ( $q_3$ ), lack of both experience and education ( $q_4$ ). Based on the foregoing, we obtain the subject composition  $s = \{p_i (i=\overline{1,4}), q_j (j=\overline{1,4})\}$ .

Competence is a subject's  $s \in \{S\}$  ability to carry out actions taking into account his psychological characteristics  $p \in \{P\}$  [2] taken at the moment of his inclusion in the activity and the existence of educational characteristics  $q \in \{Q\}$  corresponding to the type of professional activity.

We introduce an integral indicator – the calculated level of competence  $Km[s, d]$  which represents the efficiency of the subject's  $s \in \{S\}$  activities  $d \in \{D\}$ , taking into account his individual psychological characteristics  $p \in \{P\}$ , educational characteristics  $q \in \{Q\}$ , including his profile education and work experience in the required type of activity  $d \in \{D\}$  [3]. On the basis of the calculated level of competence,

the person (subject) in the organizational and technical system correlates with the information resources by assigning the appropriate access rank.

The basis for further reasoning is the statement that with the same rights of access to the information resource, the user (subject) who have high level of competence  $Km[s, d]$  presents a lesser threat of destructive impact on the organizational and technical system.

## **2. Differentiation of access levels to information resources, taking into account the calculated level of competence**

The human factor in the organizational and technical system is manifested in the form of active influence on the management process through an information resource, if there are access delimitations [4]. The greater calculated level of competence  $Km[s, d]$  of the user (the subject) means greater access rights to the information resource it is granted.

The information resource of the organizational and technical system will be called the object. All objects of the system form a set of objects  $O = \{o_1, o_2, \dots, o_n\}$ . Access to each object  $o \in \{O\}$  is regulated by the appropriate access level. The access rank  $R = \{r_1, r_2, r_3, r_4\}$  contains one of the four access rights that can be assigned to the subject  $s \in \{S\}$  to access the object  $o \in \{O\}$ . This is the right of read, write, and delete access ( $r_1$ ), in other words, full access, read and write access ( $r_2$ ), read-only access ( $r_3$ ), access can be denied ( $r_4$ ).

The object of the information system has characteristic named criticality  $V[c]$ , which is a numerical characteristic of how important the object is, in other words, how critical the object is in the system.  $V[c] = [0, 1]$ . 1 expresses the maximum criticality, and 0 the minimum. Thus,  $o = \{V[c]\}$ .

Competence is considered high if the user (subject)  $s \in \{S\}$  has a high psychological predisposition (characteristic)  $p \in \{P\}$  to a particular activity  $d \in \{D\}$ , and also has a high educational profile  $q \in \{Q\}$ . If the user has the highest rank of access ( $r_1$ ), then he gets full access to the information resource.

The assignment of a corresponding access rank to an information resource can be done in various ways. For example, you can use expert methods to choose one of the many alternatives. But such approach requires, at first, the mandatory availability of experts, and, secondly, their consistency in making decisions to ensure the correct results. The class of linear programming problems, namely, the assignment problem, helps to solve the problem of how to make the assignment to a better degree. Advantages of this method consist in its simplicity, that is, in the simplicity of compiling a mathematical model of the problem, as well as in the prevalence of the realized classical methods for its solution in the form of ready-made computer programs and algorithms. Thus, the assignment will be obtained as a result of solving the assignment problem [5].

The access matrix of information resources is formed iteratively, where each of the iterations corresponds to the solution of the assignment problem, which, as mentioned earlier, can be solved by one of the classical methods [6]. The number of iterations is equal to the number of possible access rights. In the formulation of the problem this number is 4, because  $R = \{r_1, r_2, r_3, r_4\}$ . The first iteration starts with solving the assignment problem regarding the maximum access level ( $r_1$ ), continues with the access level  $r_2$  and  $r_3$ , and ends with a minimal access level ( $r_4$ ), with a sequential exception of the subjects  $s \in \{S\}$  at each iteration, for which the access right to the object  $o \in \{O\}$  has already been determined during the previous iteration.

Within the mathematical model of the assignment problem, it is necessary to establish its key parameters for further solutions, such as the applicants and their number, the destination objects and their number, the weight matrix, the method of solving the problem, and, as a result, the assignment matrix. Applicants in the problem model are subjects  $s \in \{S\}$  of the organizational and technical system, their number is equal to the value  $n \in \mathbb{N}$ . Objects of assignment within the framework of the model are objects  $o \in \{O\}$  of the system, their number is equal to  $m \in \mathbb{N}$ . Let  $n = 14$ ,  $m = 4$ ,  $s_i \in \{S\}$  ( $i = \overline{1, n}$ ),  $o_j \in \{O\}$  ( $j = \overline{1, m}$ ). To solve the assignment problem, it is necessary to make the input conditions balanced, because the number of entities is not equal to the number of objects. Number of subjects is  $n = 14$  and number of objects is  $m = 4$ . We add  $n - m = 10$  dummy objects for balancing the problem conditions. Then we get a balanced assignment problem.

Now we need to determine the weight matrix. We denote the weight matrix by  $\{Z\}$ , where  $z_{ij}=Z[s,o]$ .  $z_{ij}$  is the risk of assigning access rights  $r \in \{R\}$  for subject  $s \in \{S\}$  to object  $o \in \{O\}$ .

The table (the weight matrix  $\{Z\}$ ) for solving the assignment problem at the first iteration will look like this. There is the value at the intersection of the row and column  $z_{ij}$ . The value  $z_{ij}$  is the multiplicative convolution of the values of  $Km[s, d]$  and  $V[c]$  so that  $z_{ij}$  expresses the risk, or, in economic terms, the "cost" of assigning the access right  $r \in \{R\}$  to the subject  $s \in \{S\}$  to the object  $o \in \{O\}$ . At the maximum value  $Km[s, d] = 1$ , and a  $z_{ij} = 0$ , which is logical and means the minimum risk of assigning access rights to the subject on the object. At the minimum value  $Km[s, d] = 0$  and  $z_{ij} = 1$  it means the maximum risk of assigning access rights to the subject on the object.

The assignment or non-assignment of the access right  $r \in \{R\}$  to the subject  $s \in \{S\}$  to the object  $o \in \{O\}$  indicates with a help of the boolean value  $x_{ij}=X[s, o]$  in the assignment matrix  $\{X\}$ .

$$x_{ij} = \begin{cases} 1, & \text{if an access right (R) is assigned for the subject (S) to the object (O)} \\ 0, & \text{if an access right (R) is not assigned for the subject (S) to the object (O)} \end{cases} \quad (1)$$

If for a some subject  $x_{ij} = 1$ , then at the next iteration it is excluded. System constraints. Each row and column contains only one unit:

$$\sum_{j=1}^{14} x_{ij}=1, i=[1, 14] \quad (2)$$

$$\sum_{i=1}^{14} x_{ij}=1, j=[1, 14] \quad (3)$$

The target function  $F$  of the assignment problem at each iteration has the form:

$$\sum_{i=1}^{14} \sum_{j=1}^{14} z_{ij} \cdot x_{ij} \rightarrow \min, i=[1, 14] \quad (4)$$

The problem will be solved using the simplex method and the Hungarian method [7]. The maximum values shown in the figure confirm the statement that at a high calculated level  $Km[s, d]$  (under the condition  $p_i=d_j$ ), the user  $s \in \{S\}$  has more access rights to the system. The lowest values of the level of competence  $Km[s, d]$  are achieved at  $p_i=d_{j+2}$  and  $i=1,2$  or with  $p_i=d_{j-2}$  and  $i=3,4$  and at  $q_i=q_4$ . The solution of the assignment problem by the Hungarian method is reflected in a tabular form. There is the value  $x_{ij}$  at the intersection of the row and column in table 1.

**Table 1.** Assignment matrix.

$r_1$	$o_1$	$o_2$	$o_3$	$o_4$	$o_5$	$o_6$	$o_7$	$o_8$	$o_9$	$o_{10}$	$o_{11}$	$o_{12}$	$o_{13}$	$o_{14}$
$s_1$	1	0	0	0	0	0	0	0	0	0	0	0	0	0
$s_2$	0	0	0	0	1	0	0	0	0	0	0	0	0	0
$s_3$	0	0	0	0	0	1	0	0	0	0	0	0	0	0
$s_4$	0	0	0	1	0	0	0	0	0	0	0	0	0	0
$s_5$	0	0	0	0	0	0	1	0	0	0	0	0	0	0
$s_6$	0	0	0	0	0	0	0	1	0	0	0	0	0	0
$s_7$	0	0	0	0	0	0	0	0	1	0	0	0	0	0
$s_8$	0	0	1	0	0	0	0	0	0	0	0	0	0	0
$s_9$	0	0	0	0	0	0	0	0	0	1	0	0	0	0
$s_{10}$	0	0	0	0	0	0	0	0	0	0	1	0	0	0
$s_{11}$	0	0	0	0	0	0	0	0	0	0	0	1	0	0
$s_{12}$	0	0	0	0	0	0	0	0	0	0	0	0	1	0
$s_{13}$	0	1	0	0	0	0	0	0	0	0	0	0	0	0
$s_{14}$	0	0	0	0	0	0	0	0	0	0	0	0	0	1

The process of forming the access matrix  $\{M\}$  from the intermediate results of the solution of the assignment problem is given below. We write out the access matrix  $\{M\}$ , which was obtained as a result of the first iteration (table 2). Now, we exclude  $s_1, s_4, s_8, s_{13}$  from the calculation, as having obtained their access rights. We continue the calculation on the second and subsequent iterations similarly. At the last iteration, we obtain the access matrix of the following type (table 3).

**Table 2.** Result of the first iteration.

M[S,O]	O1	O2	O3	O4
S1	rwd			
S2				
S3				
S4				rwd
S5				
S6				
S7				
S8			rwd	
S9				
S10				
S11				
S12				
S13		rwd		
S14				

**Table 3.** Result of the last iteration.

M[S,O]	O1	O2	O3	O4
S1	rwd			
S2	rw			
S3	r			
S4				rwd
S5				rw
S6				r
S7				a/d
S8			rwd	
S9			rw	
S10		r		
S11			r	
S12			a/d	
S13		rwd		
S14		rw		

Now, we solve the same problem with a help of simplex method. There is the value  $x_{ij}$  at the intersection of the row and column (table 4).

**Table 4.** Assignment matrix.

r1	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14
S1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
S3	0	0	0	0	0	0	0	0	0	0	0	0	1	0
S4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
S6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
S7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
S8	0	0	1	0	0	0	0	0	0	0	0	0	0	0
S9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
S10	0	0	0	0	0	0	0	0	0	1	0	0	0	0
S11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
S12	0	0	0	0	0	0	0	1	0	0	0	0	0	0
S13	0	1	0	0	0	0	0	0	0	0	0	0	0	0
S14	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Result of the first iteration and result of the last iteration coincides with the result of the solution using the Hungarian method. With the current formulation of the problem, namely (1), (2), (3), (4), this linear programming problem can easily be solved by the Hungarian, simplex method and the potential method, with the only difference being that for solving with the help of method of potentials the following condition must be added to conditions (1) - (4):

$$\sum_{i=0}^{14} a_i = \sum_{j=0}^{14} b_j, \text{ where } a_i = b_j = 1 \forall i, j \in [0; 14] \quad (5)$$

And change condition (1) to conditions of the form:

$$x_{ij} \geq 0 \quad (6)$$

The results of solving the assignment problem by the Hungarian and the simplex method are similar. It should be noted that there are differences in the results of the solution by the Hungarian method and by the simplex method, however, if you pay attention you see that then all of them are in the field of dummy variables (tables 1 and 4). It means that assignments turned out to be different in these areas, but in this case the assignments in the field of real variables coincided completely. Therefore, it was concluded that the results of the solutions by two different methods are similar. The simplex method has the advantage over the Hungarian method and the potential method, so it is planned to use it later. There is the advantage in its extensibility, that is, the simplex method can be used to solve not only the classical

assignment problem, but also for the whole class of optimization problems of linear programming. The Hungarian method does not have such an advantage. Let us give an example. Let condition (2) be replaced by a condition of the form:

$$\sum_{j=1}^{14} x_{ij} \leq h_i, i=[1, 14] \quad (7)$$

Condition (7) is equivalent to the fact that the subject  $s \in \{S\}$  can be assigned more than one kind of objects from  $\{O\}$  but not more than  $h_i$ .

**Lemma 1.** It is impossible to solve the assignment problem by the Hungarian method with constraints (1), (7), (3), (4).

**Evidence:** Assume that it is possible to solve the assignment problem by the Hungarian method with constraints (1), (7), (3), (4), then, in terms of the Hungarian method, there is a perfect match, in other words, a complete matching in the bipartite graph  $G$ . Condition (7) assumes that there are at most  $h_i$  edges at the vertex  $s \in \{S\}$ . In the case if  $h_i \neq 1$  there can exist more than one edge, but not more than  $h_i$  edges for some vertex  $s \in \{S\}$ . Then, there is no complete matching that includes the vertex  $s \in \{S\}$  and all vertices  $o \in \{O\}$  associated with it by the definition of the full matching. Thus, we obtain a contradiction. Lemma 1 is proved. ■

The potential method also has less extensibility. Let us give an example. We leave condition (7) unchanged. By condition (7), the corresponding condition (5) changes to a condition of the form:

$$\sum_{i=0}^{14} a_i = \sum_{j=0}^{14} b_j, \text{ where } a_i \in \mathbb{N}, b_j \in \mathbb{N}, \forall i, j \in [0; 14] \quad (8)$$

**Lemma 2.** It is impossible to solve the assignment problem by the method of potentials with constraints (6), (7), (3), (4), (8)

**Evidence:** Let it be possible to solve the assignment problem by the method of potentials with constraints (6), (7), (3), (4), (8). Then, by the degeneracy theorem of the transport problem, the optimal solution exists if and only if the balance equation is observed (8).

The change in condition (5) inevitably entails a change in conditions (7) and (3) for the observance of the balance equation (8):

$$\sum_{j=1}^{14} x_{ij} = a_i, i=[1, 14] \quad (9)$$

$$\sum_{i=1}^{14} x_{ij} = b_j, j=[1, 14] \quad (10)$$

However, we assumed that condition (9) remains the same as condition (7). The conditions (6), (7), (3), (4), (8) always change to the conditions (6), (9), (10), (4), (8). It is impossible to solve the problem of assigning the problem with the method of potentials with constraints (6), (7), (3), (4), (8). Lemma 2 is proved. ■

The classical or modified simplex method allows us to solve the assignment problem as with the conditions (1), (7), (3), (4), and with the conditions (6), (7), (3), (4). Similarly, we can change condition (3) to conditions of the form:

$$\sum_{i=1}^{14} x_{ij} \leq h_i, j=[1, 14] \quad (11)$$

And also add new conditions to (2) and (3). Because of the specifics of the classical methods for solving the transport problem and the assignment problem, as a special case of the transport problem, they (classical methods) have a number of disadvantages that do not allow them to be used in solving the specific (not classical) assignment problem. Later this disadvantage will not allow expanding the formulation of the problem, the introduction of other, not classical constraints. The access matrix (table 3) confirms the assertion that the higher the user's competence is, the higher the access right must be. The remaining access rights must be further defined. We will carry out the additional access rights on the basis of the following principle. An undefined access right to a resource (object)  $o \in \{O\}$  cannot be

higher than the calculated access right for the object with the same criticality. When determining the access right to a resource (object)  $o \in \{O\}$  with an increased criticality, the access right decreases down to the prohibition of access in proportion to the increase in criticality. When determining the access right to a resource (object)  $o \in \{O\}$  with an decreased criticality the access right increases up to the full access in proportion to the decrease in criticality. If  $s_i = s_j$  access rights for these entities are equal in favor of greater access rights. As a result, we obtain the final access matrix  $\{M\}$  of the following type (table 5).

**Table 5.** The final access matrix.

M[s,o]	o <sub>1</sub>	o <sub>2</sub>	o <sub>3</sub>	o <sub>4</sub>
s <sub>1</sub>	rwd	rw	rw	rwd
s <sub>2</sub>	rw	r	r	rwd
s <sub>3</sub>	r	a/d	a/d	rw
s <sub>4</sub>	rw	r	r	rwd
s <sub>5</sub>	r	a/d	a/d	rw
s <sub>6</sub>	a/d	a/d	a/d	r
s <sub>7</sub>	a/d	a/d	a/d	a/d
s <sub>8</sub>	rwd	rwd	rwd	rwd
s <sub>9</sub>	rwd	rwd	rwd	rwd
s <sub>10</sub>	rw	r	r	rwd
s <sub>11</sub>	rw	r	r	rwd
s <sub>12</sub>	r	a/d	a/d	rw
s <sub>13</sub>	rwd	rwd	rwd	rwd
s <sub>14</sub>	rwd	rw	rw	rwd

### 3. Conclusion

The proposed method for increasing of organizational and technical system reliability, taking into account the human factor based on the principles of a differential approach, allows develop a rules for the access delineation, which minimize the destructive effects of the user on the system. Besides, the methodology allows the manager to reduce the risk of switching some user to the insider category. The differential approach is noteworthy for its indispensability in areas of personal growth and self-improvement in the creation of creative and successful management teams, and is indispensable assistant for manager of any level.

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