Models and mechanisms for managing competencies of IT services users

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Abstract. The subject of the article is the models and mechanisms for managing the competencies of IT services users applied as intellectual support of decision-makers on issues of professional retraining and professional development of personnel. Models and mechanisms correspond to two problem situations, requiring, respectively, the implementation of a unified or personalized approach to the competencies formation, and are an integration of expert information, models of scalar and vector optimization, game models, as well as discrete optimization methods, simulation and game modeling. The use of the proposed models and mechanisms is demonstrated by examples of the formation of professional retraining and development programs for users of ERP system. However, they can be used to manage the competencies of specialists in other fields.

1. Introduction

One of the important factors determining the duration of the initial (pilot) operation of ERP system is the quality of preparing users for collaboration in the integrated enterprise management system. Obviously, the duration and corresponding losses from incidents caused by unqualified actions of users can be significantly reduced by increasing the level of their competencies. Proficiency enhancement and professional training require a systematic approach, including the development of competencies map for personnel of enterprise units that implements the management functions of the main business processes; the development of a set of training programs that ensures the formation of the required skills; assessment of the actual competence of staff; the choice of approach to the formation of competencies (unified or personalized training); development of models and mechanisms for the formation of training programs. The main focus of the article is on problem statements and mechanisms for the formation of unified and personified training programs.

2. The problem statement in managing the competencies of users of ERP system’s IT services

Let \( \{ p_{ji} \mid i=1, n_j \} \) be a set of training programs implemented by a consulting company with the aim of forming the necessary competencies of ERP system users. Here \( j \) is the number of the business process, \( i \) is the number of the training program, \( p_{ji} \) is the \( i \)-th training program for users of the \( j \)-th business process, \( n_j \) is the number of training programs for the \( j \)-th process, \( m \) is the number of computerized business processes. Let \( k_{ji} \) be the number of users to be trained within the program \( p_{ji} \).
ji jic =c(pj) is the cost of training of one user within the program pj. In the case of a unified approach to training, for all users who implement the functions of a separate business process, a common training program is formed on the basis of assessments qjic=q(pj) of the increase in competence obtained as a result of training of one user within the program. With a personalized approach, a unique training program is formed for each user of each business process on the basis of assessments qjikic=q(pj),k=1,k ji ji ji q= p j, of the increase in competence as a result of training for a particular k-th user in the program pj. For each of the approaches, a set of mathematical models of the problem of training programs formation are proposed: optimization (scalar, vector) and game-theoretic.

3. Optimization models and competencies management mechanisms

3.1. Models and mechanisms for unified management of users competencies

Let us introduce a discrete variable xji that is equal to 1 if users are to be trained in accordance with the program pj and equal to 0 otherwise. Then the direct task of forming the optimal user training program can be formulated as follows:

\[ q = \sum_{j=1}^{m} \sum_{i=1}^{n_j} k_{ji} q_{ji} x_{ji} \rightarrow \max ; \sum_{j=1}^{m} \sum_{i=1}^{n_j} k_{ji} c_{ji} x_{ji} \leq c^* ; \sum_{i=1}^{n_j} k_{ji} x_{ji} \geq k_{ji}^*, j=1,m. \] (1)

Here \( k_{ji}^* \) is the restriction set by the business process manager j on the minimum number of employees to be trained.

The solution to problem (1) is such a training program of users \( \{x_{ji}|j=1,n_j \}|j=1,m \) that maximizes the total “increase” \( q \) of users competencies with a given restriction on the maximum amount of funds \( c^* \) allocated for training, and which satisfies the restrictions on the minimum required number of users to be trained by business process management. The structural decomposition of problem (1) and the example of a solution are given in [1].

The inverse to problem (1) is problem (2):

\[ c = \sum_{j=1}^{m} \sum_{i=1}^{n_j} k_{ji} c_{ji} x_{ji} \rightarrow \min ; \sum_{j=1}^{m} \sum_{i=1}^{n_j} k_{ji} q_{ji} x_{ji} \geq q^* ; \sum_{i=1}^{n_j} k_{ji} x_{ji} \geq k_{ji}^*, j=1,m. \] (2)

The structural decomposition of problem (2) and the example of a solution are given in [2].

Due to the structural similarity of the functions c and q, both problems can be effectively solved by the dichotomous programming method [3]. The following important feature of this method should be noted. When solving each of the sequence of assessment problems into which the original problem is decomposed, a subset of solutions is formed that are permissible by constraints and are Pareto optimal by c and q. The combination of the solutions of the last estimation problems of the direct and inverse problems, due to the noted feature, is a Pareto subset of solutions to the vector optimization problem:

\[ (q,c) \rightarrow \max ; \sum_{i=1}^{n_j} k_{ji} x_{ji} \geq k_{ji}^*, j=1,m. \] (3)

Based on his preferences, the decision maker (DM) can choose the best option from this subset. The procedure for determining the optimum of problem (3) on the indicated Pareto subset of solutions can be formalized by applying the complex estimation mechanism [4]. The procedure and the example of solving problem (3) are given in [2].
3.2. Models and mechanisms of personified management of users competencies

Let us introduce a discrete variable \( x_{ij} \), which is equal to 1 if the \( k \)-th user of the \( j \)-th process is to be trained according to the program \( p_{ij} \), and 0 otherwise. Then the direct task of forming the optimal user training program can be formulated as follows:

\[
q = \max \sum_{j=1}^{m} \sum_{i=1}^{k_j} \sum_{k} q_{ij} x_{ij} \quad \text{subject to} \quad \sum_{j=1}^{m} \sum_{i=1}^{k_j} \sum_{k} c_{ij} x_{ij} \leq c^*; \quad \sum_{i=1}^{k_j} x_{ij} \geq k_j^*, \quad j=1,m.
\] (4)

In task (4), a training program is formed for each specific user. The inverse of the formulated problem (4) is the problem (5):

\[
c = \min \sum_{j=1}^{m} \sum_{i=1}^{k_j} c_{ij} x_{ij} \quad \text{subject to} \quad \sum_{j=1}^{m} \sum_{i=1}^{k_j} \sum_{k} q_{ij} x_{ij} \geq q^*; \quad \sum_{i=1}^{k_j} x_{ij} \leq k_j^*, \quad j=1,m.
\] (5)

The vector optimization problem takes the form:

\[
(q,c) \rightarrow \max \sum_{j=1}^{m} \sum_{i=1}^{k_j} x_{ij} \geq k_j^*, \quad j=1,m.
\] (6)

Problems (4) – (6) are also solved as problems (1) – (3) by the method of dichotomous programming using the complex assessment mechanism.

4. The game model of personified management of users competencies

The use of optimization models assumes that persons whose interests are affected by the problem being solved (in our case, this is the center that manages the funds for training and business process managers whom we will call players), agreed on a common goal-setting, that is, they agreed that the jointly formed objective function and restrictions fully reflect the interests of both the center and the players (the case of coinciding interests). In the general case, such an assumption is incorrect, and, therefore, the problem under study should be considered as a game-theoretic, in which each player solves the problem with his objective function, and the center with his own [5,6]. The solution to the original problem needs to find a compromise scheme that harmonizes the interests of the players and the center.

Let each player (the head of the corresponding business process) \( j, j=1,m \), solve the problem:

\[
q_j = \max \sum_{i=1}^{k_j} \sum_{k} q_{ij} x_{ij} \quad \text{subject to} \quad \sum_{i=1}^{k_j} \sum_{k} c_{ij} x_{ij} \leq c_j^*.
\] (7)

Player \( j \) seeks to maximize the growth of user competencies while limiting the allocated resources for staff training.

The task of the center, reflecting its interests, is formulated as follows:

\[
q = \max \sum_{j=1}^{m} \frac{q_j}{c_j} \frac{q_{j_{\text{max}}}}{c_{j_{\text{max}}}} \quad \text{subject to} \quad \sum_{j=1}^{m} c_j^* \leq c^*.
\] (8)

Here \( q_{j_{\text{max}}} = \sum_{i=1}^{k_j} \sum_{k} q_{ij} \), \( c_{j_{\text{max}}} = \sum_{i=1}^{k_j} \sum_{k} c_{ij} \). The value \( q_{j_{\text{max}}} \) describes the growth of competencies of the \( j \)-th group of users in the absence of resource restrictions, \( c_{j_{\text{max}}} \) – the amount of resources required by the \( j \)-th group to train all users in all programs, and the value \( q_{j_{\text{max}}} / c_{j_{\text{max}}} \) – the specific effectiveness of training
“everyone in all programs”. The center’s task, according to (8), is to find such $c_j^*$ that minimize the total deviations of the planned specific learning efficiencies of users of individual groups with a given resource limit from the specific efficiencies corresponding to the absence of such restrictions. That is, the center’s task is to “equalize” the degree of readiness of various groups for implementation regarding the maximum possible readiness.

To solve the center’s problem (8), we apply the local optimization method. The basic solution is determined according to the following distribution of resources:

$$c_j^* = c^* \sum_{j=1}^{m} \max_{c_j} j=1,m$$

(9)

Let $\{(q_j|l=1,L),c_j^*\}, j=1,m$ be the sets of solutions formed by the players as a result of solving problems (7) with resources allocated by the center (9) and $q^* = \sum_{j=1}^{m} \frac{q_j}{c_j} \max_{c_j} j=1,m$ – the corresponding optimal value of the criterion for solution of the center’s problem (8).

The developed procedure for improving the basic solution includes the following steps.

1. Let us increase by 10% the value $c^*': c^* = 1.1c^*$.
2. Define $c_j^{*'}$ by formulas (9) for the amount of resources $c^*'$.

Let $\{(q_j|l=1,L),c_j^{*'}\}, j=1,m$ be the sets of solutions formed by the players as a result of solving problems (7) with new resources values allocated by the center.

3. Let us construct the set of decisions of the center as the product of the sets of decisions of the players:

$$\prod_{j=1}^{m} \{(q_j|l=1,L),c_j^{*'}\}, j=1,m$$

(10)

4. Remove from the set (10) the solutions for which $\sum_{j=1}^{m} c_j^{*'} > c^*'$.

5. On the remaining elements of the set we find a solution with a minimum criterion value $q^{*'} = \sum_{j=1}^{m} \frac{q_j}{c_j} \max_{c_j} j=1,m$.

6. Compare the value of criterion $q$ for the basic solution with the value of criterion $q^{*'}$ obtained at the first iteration of improvements. If the criterion value has not improved, then the local optimization procedure is completed. Otherwise, go to step 1.

5. Example

Consider a task that is described by three business processes ($m = 3$) and includes, respectively, three ($n_1=3$), two ($n_2=2$) and two ($n_3=2$) training programs for the respective users. Let us assume $c^* = 1100$. Data on the increase in users’ competencies as a result of training within relevant programs are shown in Table 1.

|          | $p_{11}$ | $p_{12}$ | $p_{13}$ | $p_{21}$ | $p_{22}$ | $p_{31}$ | $p_{32}$ |
|----------|----------|----------|----------|----------|----------|----------|----------|
| $q_{11}^1$ | 5        | 3        | 5        | $q_{21}^1$ | 3        | 4        | $q_{31}^1$ | 3        | 5        |
| $q_{12}^2$ | 1        | 3        | 5        | $q_{22}^2$ | 4        | 3        | $q_{32}^2$ | 4        | 5        |
The results of solving the center’s problem for the basic distribution of resources are shown in table 2.

Table 2. The solution results for the center’s problem of basic resource allocation.

| j  | 1   | 2   | 3   |
|----|-----|-----|-----|
| c_j| 36  | 19  | 20  |
| q_j| 510 | 306 | 216 |
| q  | 0.01451 | 0.01348 | 0.03704 |

The results of solving the center’s problem for the first iteration of the resources redistribution are given in table 3.

Table 3. The solution results for the center’s problem at the first iteration.

| j  | 1   | 2   | 3   |
|----|-----|-----|-----|
| c_j| 630 | 342 | 108 |
| q_j| 0.01218 | 0.00987 | 0.03704 |

The results of solving the center’s problem for the second iteration of resource redistribution are shown in table 4.

Table 4. The solution results for the center’s problem at the second iteration.

| j  | 1   | 2   | 3   |
|----|-----|-----|-----|
| c_j| 630 | 342 | 108 |
| q  | 0.01218 | 0.00987 | 0.03704 |

The second iteration did not lead to an improvement in the value of the criterion of the center’s problem. Therefore, the decision corresponding to this criterion value is taken as optimal.

6. Conclusion
The application of the proposed models and mechanisms of competency management requires the preliminary development of competencies maps that describe the requirements for skills, as well as the
development of effective mechanisms for assessing the actual competencies of users both according to the results of training and the results of their practical work.

References

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