The rationalization model of the use of enterprise resources

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Abstract. The article proposes a logical-informational model that allows to rationalize the use of enterprise resources, using the example of the mechanism for advanced training of personnel "innovative lift" FSBEI HE "KNRTU". Implementation of innovative elevator mechanisms of FSBEI HE "KNRTU" allows to improve the process of adapting industrial and industrial personnel to the requirements of the profession, mastering professional competencies necessary to perform labor functions, including the implementation of scientific and technological developments and the commercialization of their results. Based on the model of rationalizing the use of enterprise resources, a software product has been developed based on solving linear programming problems aimed at maximizing the target indicator and rationalizing the distribution of resources within the framework of the organizational structure of the enterprise.

1. Introduction

In the modern economy, enterprises are developing in conditions of limited natural resources, material and technical, human resources, which prompts enterprises to search for forms and methods of rationalizing the use of resources. The relevance of the selected research topics is confirmed by a significant number of works in this area. In particular, the following studies are of interest: increasing the efficiency of the organization of the production process in the resource-saving system of petrochemical enterprises [1]; problems of environmental safety of industrial production in the modern economy [2]; modeling of the open innovation management system in the context of the transition to the electronic economy [3]; on modeling various sectors of the economy in the context of sustainable development [4]; on environmental marketing of waste management in the context of sustainable development [5]; principles for assessing the stability of a petrochemical cluster based on energy efficiency indicators of its members [6]; formation and development of industrial clusters in the economy of the region [7]; the formation of a network model of the value chain based on the integration of competitive enterprises in innovation-oriented intersectoral clusters [8] and others.
2. Materials and methods

The article proposes a logical-informational method of rationalizing the use of enterprise resources.

The study solved the multicriteria problem of rationalizing the use of enterprise resources using the example of FSBEI HE “KNRTU”. The “innovative elevator” mechanism is a new promising form of cooperation in production, science and education, which helps to increase the competitiveness and professional adaptation of future specialists for enterprises. The development of proposals for the concept of a methodology for improving the professional adaptation of students at the Federal State Budget Educational Establishment of Higher Education “KNRTU” on the basis of the university’s innovative sites involves a detailed description of the mechanism of the innovation elevator in the context of its overall development priorities, the justification of the need for measures to increase the labor adaptation of university students in order to increase their competitiveness in the market labor.

In order to increase the efficiency of the given lines of activity of the enterprise, a model has been developed that allows rationalizing the use of material, technical and investment resources. At the first stage, the selection of the target performance indicator is carried out, the maximization of which is a priority vector of the enterprise development. The linear model for assessing the impact of the use of resources on the target indicator is:

\[ E = f(x_1, x_2, x_3) = a_n + b_n x_1 + c_n x_2 + d_n x_3 \to \max, \]  

where \( E \) is the effect of the use of resources on the target indicator, units rev.; \( x_1, x_2, x_3 \) - the volume of development of resources (first, second, third types), units rev.

The dependence \( Y_i = f_i(x_1, x_2, x_3) \) is searched for as a linear function using the Fit statement of the Wolfram Mathematica package, which provides the least quadratic deviation from the actual data. Denote by \( Y_{ij} \) the value of the i-th indicator obtained as a result of monitoring in the j-th year of observations, \( x_1, x_2, \) and \( x_3 \) – resource flows in the jth year of observations. Relative error of approximation by the function \( Y_i \) of the actual value of the i-th indicator in the j-th year:

\[ \delta Y_{ij} = \frac{|Y_i(x_1, x_2, x_3) - Y_{ij}|}{Y_{ij}}. \]  

Root mean square relative error characterizing the quality of approximation by the function \( f_i \) of the values of \( Y_{ij} \) measured during monitoring:

\[ \delta Y_i = \sqrt{\sum_{j=1}^{k} \left( \frac{1}{Y_{ij}} \left[ Y_i(x_{1j}, x_{2j}, x_{3j}) - Y_{ij} \right] \right)^2 / k}. \]  

The adequacy coefficient of the function \( Y_i - adY_i \) is determined as follows:

\[ adY_i = 100/(2\delta Y_i + 1). \]  

Therefore, the values of the adequacy coefficient \( adY_i \) always lie in the interval (0; 100). If \( adY_i \) is close to 100, then this means that the linear fitting is almost 100% consistent with the monitoring results for all \( k \) years. If \( adY_i<50 \), then the linear approximation does not fully describe the dependence of \( Y_i \) on \( x_1, x_2, x_3 \) and, in all likelihood, there are some factors of a socio-political nature that have a significant impact on \( Y_i \). In this case, using \( Y_i(x_1, x_2, x_3) \) in the calculations will give results that allow you to see only some trends.

In addition to the objective function, the formulation of the linear programming problem requires the introduction of a system of constraints. To this end, it is proposed to select the minimum values of key performance indicators for the period under consideration, which will be used as limitations in the linear programming problem to maximize the effect. Maximization of the objective function (1) is achieved with a given system of constraints:

\[ Y_i = f(x_1, x_2, x_3) = a_n + b_n x_1 + c_n x_2 + d_n x_3 \geq \min_k Y_{ik}; \]
\( x_1 + x_2 + x_3 \leq \text{the sum of the volumes of all resources}; \)

\[ x_1, x_2, x_3 \geq 0; \]

\[ \min_{k} Y_{ik} \] – the minimum value of the \( i \)-th indicator obtained during monitoring for \( k \) years of observations,

where \( Y_i \) – \( i \)-th key performance indicator; \( i = 1, \ldots, n \); \( n \) is the number of key performance indicators.

When calculating the effect of the use of resources in accordance with priority, the indicators used are proposed to assign weighting factors that are selected based on the development strategy of the enterprise in the period under review and may vary. The sum of the coefficients in front of the functions must be equal to 1. The coefficients in front of \( Y_i \) characterize the priority of the \( i \)-th indicator in comparison with other indicators.

Thus, the task is to search for the extreme value of a linear function in a polyhedron located in three-dimensional space, which is given by a system of \( n \) linear inequalities. The minimum and maximum values of any linear function are always achieved at one of the vertices of the polyhedron. The solution of the system of equations is carried out using the Wolfram Mathematica package and then, using the Select operator of this package, the solutions of those systems for which all the constraints are satisfied are selected. The result of the solution is the vertices of the polyhedron in which the extremum is sought.

The proposed methodology was tested on the example of FSBEI HE “KNRTU” to assess the efficiency of resource use when implementing the strategy of an innovative elevator for industrial and industrial personnel for enterprises, with the aim of further adjusting program measures.

In addition, the article proposed a model of advanced training "Innovation Lift" on the example of FSBEI HE "KNRTU".

A promising form in the field of training industrial and industrial personnel is the innovative elevator of advanced personnel training, which is a new form of cooperation in production, science and education, which will increase the competitiveness and professional adaptation of future specialists for enterprises. This model is an example of a market model of co-competition.

The mechanism of the innovative elevator contributes to the adaptation of industrial and production personnel to the requirements of the profession, their assimilation of professional and social norms of behavior necessary for the performance of labor functions related to the conduct of scientific research and the commercialization of their results, which generally increases the competitiveness of future specialists in the labor market.

The innovative student lift of FSBEI HE “KNRTU” includes the following floors.

Professional adaptation of training for enterprises begins on the ground floor, upon receipt of the theoretical foundations corresponding to the specialty obtained and with the development of interdisciplinary courses, to learn the basics of related professions. It is planned to simultaneously train personnel, in the framework of which educational programs are held together - scientists carrying out research work, engineers offering the possibility of realizing these ideas, economists calculating the profitability of production, technicians creating new industries. The organization of an interdisciplinary group of students contributes to the development of teamwork practices. Therefore, at the first stage of training, students master the theoretical basis for the development of new technologies.

On the second floor, it is planned to organize various competitions, conferences, and job fairs together with the faculties and with the departments of the FSBEI HE "KNRTU" Participation of undergraduate students, undergraduates, graduate students is supposed to offer their innovative ideas or scientific and technical developments in the events of FSBEI HE “KNRTU” and other universities of Russia. Also, for the implementation of the innovative elevator mechanism at this stage, the participation of students in round tables, case studies, business games to develop teamwork skills is relevant.

The third floor is aimed at improving the practical skills of bringing research and development to the market, calculating business plans and developing the final product based on a technical model. In addition, this stage includes the search for financing projects, introducing them to potential investors.
Practical developments are carried out on the basis of the Engineering Center, created on the basis of FSBEI HE "KNRTU".

The fourth floor provides for student participation at the start of production of an experimental batch of an innovative product. After mastering the theoretical course, students are united in groups (from different specialties) to carry out research and development, under the guidance of entrepreneurs and teachers on the basis of FSBEI HE "KNRTU". Students in practice learn to create development, organize and manage an enterprise, i.e. increase their professional competencies.

On the fifth floor there is an organization of our own production, installation of a production line or employment taking into account the experience gained, which implies the inclusion of future specialists in the community of entrepreneurs. To do this, FSBEI HE “KNRTU” cooperates with small innovative enterprises, partner enterprises, holds competitions of innovative projects to attract representatives of the venture capital business and assists in employment issues.

3. Results and discussion

We will test the methodology using the example of FSBEI HE “KNRTU” to assess the efficiency of resource use in implementing the innovation lift strategy. To form an array of research data, indicators of extrabudgetary funding for program activities and key performance indicators of FSBEI HE “KNRTU” in 2012-2018 were determined, reflecting the effectiveness of staffing training, which is expressed as participation in the development and implementation of innovative projects (patents). In addition to the objective function (6), the formulation of the linear programming problem requires the introduction of a system of restrictions, for which the minimum values of key indicators of the university’s effectiveness in 2012-2018 are selected.

Thus, the linear regression model for assessing the effect on the activities of FSBEI HE “KNRTU” from investing in measures to increase the efficiency of staffing and linear regression models of constraints in the form of equations of selected indicators of the effectiveness of the advanced training of university staff in the framework of the “innovative elevator” program allow us to formalize the linear problem programming to maximize the effect:

$$E(x_1, x_2, x_3) = 58,40 - 4,37x_1 - 0,43x_2 + 30,29x_3 \rightarrow \text{max.}$$ (6)

With the following system of restrictions:

$$\begin{align*}
Y_1(x_1, x_2, x_3) &= -139,04 - 35,79x_1 - 0,60x_2 + 254,89x_3 \geq 7; \\
Y_2(x_1, x_2, x_3) &= 98,05 + 0,82x_1 + 0,03x_2 - 5,08x_3 \geq 95,6; \\
Y_3(x_1, x_2, x_3) &= 128,82 + 17,17x_1 + 0,52x_2 - 122,51x_3 \geq 57; \\
Y_4(x_1, x_2, x_3) &= -629,87 - 331,79x_1 - 0,47x_2 + 2389,79x_3 \geq 1437; \\
Y_5(x_1, x_2, x_3) &= -5,64 - 6,27x_1 - 0,01x_2 + 44,99x_3 \geq 30; \\
x_1 + x_2 + x_3 &\geq 300; x_1, x_2, x_3 \geq 0
\end{align*}$$

(7)

where $E$ is the effect of the measures taken (number of patents, units); $x_1$ - investment of measures for the organization of scientific and production activities; $x_2$ - investment of measures for staffing the development of the complex; $x_3$ - investment of infrastructure support measures for training personnel, million rubles; $U_1$ - grants won by students, units; $U_2$ - received directions to work (employment),%; $U_3$ - results of an independent assessment of the quality of students' knowledge,%; $U_4$ - the number of students who participated in the implementation of research and development, people; $U_5$ - the number of small innovative enterprises, units.

The dependence $y_i = f_i(x_1, x_2, x_3)$ was searched for as a linear function using the Fit operator of the Wolfram Mathematica package, which provides the least quadratic deviation from the actual data (university results in 2012-2018). The quality of the linear approximation (adequacy) can be estimated through the mean square relative error characterizing the deviation of the linear approximation from the actual results of the university. To illustrate and facilitate the assessment of the adequacy of each
indicator, the coefficients of the adequacy of the function are calculated (formula 3). The results are presented in table 1.

**Table 1.** Quality indicators of the model of the effect of investing subsystems of staffing.

| Functions | Relative error with linear fitting function | Adequacy ratio |
|-----------|-------------------------------------------|----------------|
|           | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 |
| E         | 0.045   | -0.072  | 0.056   | 0.097   | 0.313   | -0.251  | 74     |
| Y1        | 0.037   | 0.141   | 0.060   | 0.012   | 0.272   | -0.346  | 61     |
| Y2        | 0.001   | 0.001   | 0.001   | -0.001  | -0.001  | 0.001   | 100    |
| Y3        | 0.021   | -0.001  | -0.014  | 0.116   | 0.004   | 0.137   | 90     |
| Y4        | 0.003   | 0.004   | 0.0061  | 0.031   | 0.008   | 0.036   | 97     |
| Y5        | 0.017   | -0.010  | 0.003   | -0.029  | 0.025   | -0.002  | 97     |

The task is to search for the extremal value of a linear function in a polyhedron located in three-dimensional space, which is given by a system of 9 linear inequalities. The minimum and maximum values of any linear function are always achieved at one of the vertices of the polyhedron. The result of the solution will be the vertices of the polyhedron in which the extremum is sought. Thus, 12 vertices of the polyhedron are obtained in which an extremum is sought. The results are presented in figure 1, which shows the found vertices of the polyhedron, where the vertex with coordinates (111.4; 13.3; 16.3) is marked in red, in which the value of the objective function is maximum.

Rationalization of the activities of the Innovative Lift program in 2019 It has the expected effect of an increase in the total number of patents, which will amount to 61 patents, which is 42% higher than in 2018 (43 patents).

**Figure 1.** The result of solving the problem of maximizing the target indicator “number of patents” by rationalizing the investment of human resources subsystems of FSBEI HE “KNRTU”.

A set of recommendations has been developed in the work to improve the efficiency of the implementation of the Innovative Lift program, which is as follows. To rationalize the activities of the university in the framework of increasing the professional adaptation of university students according to the support plan, it is necessary to reduce the investment of measures for the organization of scientific and production activities (X1) from 148.7 million rubles in 2018 to 111.4 million rubles in 2019. (25%), reduce investment in personnel support measures for the development of the complex from 78.8 million rubles in 2018 to 13.3 million rubles (84%) and invest in infrastructure support measures for personnel training (X3) from 21.7 million rubles in 2018 to 16.3 million rubles in 2019 (75%).

The resulting rationalization will be reflected in the activities of the university as follows. Creating an intellectual property management system will increase the total number of patents; expanding the presence of FSBEI HE “KNRTU” in Russian and international markets of scientific and technical products will increase the number of grants won by students; expansion of training programs for masters, graduate students and doctoral students will improve the results of an independent assessment of the quality of students' knowledge,%; the opening and implementation of new educational programs and directions will contribute to the employment of graduates; the creation and equipping of collective use centers and scientific laboratories with unique equipment will increase the number of students...
participating in research and development; the building up and diversification of the university’s innovation belt will contribute to the growth in the number of small innovative enterprises. A set of recommendations has been developed in the work to improve the efficiency of the implementation of the Innovative Lift program, which is as follows. To rationalize the activities of the university in the framework of increasing the professional adaptation of university students according to the support plan, it is necessary to reduce the investment of measures for the organization of scientific and production activities (X1) from 148.7 million rubles in 2018 to 111.4 million rubles in 2019. (25%), reduce investment in personnel support measures for the development of the complex from 78.8 million rubles in 2018 to 13.3 million rubles (84%) and invest in infrastructure support measures for personnel training (X3) from 21.7 million rubles in 2018 to 16.3 million rubles in 2019 (75%).

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