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THE EFFECTIVENESS OF THE RESEARCH AND DEVELOPMENT TEAMS WITH AN ACCOUNT FOR PROCESS MANAGEMENT SPECIFICS

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ABSTRACT

Conceptual modeling of R&D effectiveness improvement processes has been carried out. The study was conducted in three different areas of the R&D improvement that allowed identifying a wide range of concepts in the area under study.Based on a systematic approach to the activities in the field of team building and innovative development, the authors developed a questionnaire for a survey of professional teams involved in the R&D and tested it at the instrument-making enterprise, as well as identified negative characteristics that reduced the level of productivity of the creative teams surveyed. Using the system analysis and cognitive modeling approach, the authors revealed the key concepts influencing team decision-making under uncertainty on the national economy scale. The factors affecting the labor effectiveness within the

enterprise are identified on the example of implementation of the R&D support system in a large department of the project organization.

The novelty of the research consists in comprehensive consideration of the scientific activity issues at three different levels of organizational complexity.

The study can be used in the planning of major projects dealing with labor effectiveness improvement in scientific work.

Keywords: Labor Effectiveness, R&D, Cognitive Modeling, Fuzzy Cognitive Map, Digital Platform, Process Classifier, Knowledge Management, Project Process Management.

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1. INTRODUCTION

The research and development (R&D), as well as design and experimental activities, represent a complex system of labor, mental, production, and socio-economic factors that change in accordance with the development of social and technological relations. The post-industrial revolution, which has begun in the second half of the 20th century [1] and gradually developed into an information revolution, gave impetus to the transformation of science into the major driving force of economic development.

Over the past hundred years, the proportion of human capital in the national wealth of the world's largest countries has increased dramatically reaching 80% [2], and currently continues growing. This growth was mainly achieved by increasing the proportion of specialists with higher education. It was shown [3] that GDP per capita in different countries increased sharply depending on education, and this dependence was exponential. However, currently in developed countries about 30% of laborers have higher education, and therefore further growth in this direction will soon become problematic. The next reserve for the growth of human capital is the increase in the number of laborers involved in the R&D activities. However, the high cost of scientific activity and low predictability of results require paying special attention to improving the operational effectiveness and focusing on achieving the planned outcomes.

This work deals with the conceptual design aimed at increasing the effectiveness of R&D activities and identifying the factors influencing these activities.

The article presents three parts of research in different areas related to the effectiveness of the R&D, which differ by the scope of activities. In general, the study of a highly complex R&D system was carried out based on a “bottom-up” and “top-down” approaches [4, 5].

2. METHODS

The first part of the work is carried out using the survey method, which is based on the systematic approach to the study of activities. Using the questionnaires available in this area, a comprehensive questionnaire has been developed, which is adapted to assess the labor effectiveness of project teams. The questionnaire contains the following sections:

1. Team and its qualification;
2. Input resources for teamwork;
3. Team relationships;

4. Abilities to communicate;
5. Work outcomes (outputs).

A number of well-known models and tools were used to develop the questionnaire, such as system approach [6, 7], human capital [2, 8, 9], educational exponent [3, 4, 10, 11], team building [12, 13], innovation development [14-16], psychological testing of personnel [17, 18], etc.

In the second part of the work, the system of the concepts influencing the productivity of scientific (R&D) work has been formed based on the system analysis. The second technique used in this part of the article is the cognitive modeling of fuzzy systems [19]. Within its framework, a model of the system under study is created in the form of Fuzzy Cognitive Map – FCM [20, 21], for which expert opinion is used on the form, structure, and strength of the existing system links. Further, by means of a computer decision-making support system [22, 23] the digital model of the system is processed to determine its static and dynamic characteristics, including the level of consonance (trust) to the concepts [24, 25].

The third part of the work uses the project process approach technique to create the R&D activities' support system based on the Greenline 52 (GL52) electronic system [26, 27]. To identify the problems of system implementation, the survey method is used including both in-depth interviews and a survey using GL52.

3. RESULTS

3.1. Regularities of Project Team Activity

The work carried out by the authors in this area dealt with the study of intellectual labor activity of the R&D teams as well as with reserves of improving labor effectiveness of their work [4]. This part of the work is based on the use of well-known models and tools in the following areas: system-based approach, human capital, educational exponent, team building, innovation development, and psychological testing of personnel.

In terms of reliability, the most problematic is the section of the "Work outcomes" of the questionnaire. In M.R. Belbin's works, the performance of the teams was determined based on the teams' competition that is impossible in practice. Therefore, a special section of the survey has been developed, in which respondents have been asked questions from the following question blocks:

1. Is the team working effectively?
2. Are there any projects that according to management you have performed perfectly?
3. Are there any projects that could not be completed on time?
4. How often have you performed work of international importance?
5. Evaluate the level of novelty of the work performed in the last year or two.

The results of a survey conducted in two teams (Table 1) have shown that this approach allows obtaining quite correct results [4].

Table 1 Final work assessment of the two teams

No	Indicator	A	B
1	Work effectiveness	4.3	4.5
2	Assessment by management	3.6	3.9
3	Completion schedule	3.3	3.7
4	International level	3.5	3.7
5	Novelty level	3.8	4.3
	Arithmetic average	3.7	4.0
	Coefficient of variation	10%	9%

The results of the survey of two design teams of the design bureau have shown that the most problematic characteristic of the teams' work is the effectiveness of the R&D communications, which need to be systematically improved through training and preparation of the appropriate infrastructure.

Combined characteristics of the teams' work according to their own estimates [4] are moderately high (Table 2), but they are fairly well matched (coefficient of variation equals to 12 and 13%) that indicates the correctness of the approach used in the survey.

It has also been shown that at the organizational level, the following working conditions of employees need to be ensured in various areas:

- Providing more correct project time management;
- Informing staff about how their performance will be assessed, and how immerging issues will be addressed;

Improving labor remuneration methods based on work results.

Table 2 Cumulative characteristics of the teams' work

	Question block	Team A	Team B
1	Teams' work results	3.7	4.0
2	Input resources	3.8	3.9
3	The R&D communications effectiveness	3.1	3.1
4	The level of relationships in teams	4.3	4.2
5	Including the performance of roles by R.M. Belbin	4.3	4.2
	Team average score	3.8	3.9
	Coefficient of variation	13%	12%

Summing up the research outcomes, it can be argued that the possibility of implementing the synergetic effect in the activities of individual research/project teams in high-tech industry sectors is currently given insufficient attention.

3.2. Conceptual Modelling of the R&D Performance Effectiveness

Conducted studies have shown that the range of factors affecting the effectiveness of scientific work is quite broad, and thus it is necessary to consider it more holistically and on a wider scale than a single team. Therefore, studies have been conducted on multifactor assessment of the R&D labor management programs across the country using the cognitive modeling method [5].

The list of factors (concepts) influencing the effectiveness of scientific activity [28-35] is presented in Table 3. A survey of qualified experts was conducted to assess the level of significance of factors for both Russian (R) and worldwide science in general (W). The results

of the assessment of the significance level in the ten-point system are presented in Table 3 (where M is the mathematical expectation, and S is the standard deviation).

As is obvious from the survey findings, the most important factor is the "Corporate R&D support system", which amounts to 8.7. "Computer support" factor is also highly appreciated being equal to 8.2.

Cognitive modeling of labor activity system has shown that a number of concepts mainly of mental block (critical thinking training, innovative thinking methods, ability to identify and solve problems and think systematically, communication skills, and knowledge of foreign languages) are characterized by a low level of consonance (confidence), which was below 50%. This is due to the fact that the links affecting these concepts on the part of other concepts and the whole system are not numerous and strong enough. A similar phenomenon can be observed in reality as well because the introduction of mental methods to improve scientific work effectiveness is implemented very inconsistently.

The preliminary work carried out in the field of improving scientific work effectiveness has given the impetus to another research line, which can more naturally contribute to the achievement of the desired result. At that, the creation of corporate R&D support system based on a computer support system was chosen as the target tool.

Table 3 Assessment of the significance of labor effectiveness concepts

	No	**Concepts**	**M(W)**	**M(R)**	**S(W)**	**S(R)**
Measurable concepts	1	Level of education	8.3	7.4	0.5	0.8
	2	Intellectual level (IQ)	7.7	7.1	2.2	1.4
	3	Communication skills, links	7.2	6.0	1.5	2.2
	4	Foreign languages skills	7.0	5.0	1.5	1.8
	5	Scientific work effectiveness		5.8		1.1
	6	Remuneration of labor	7.3	4.0	2.2	1.2
	7	Computer support	8.2	6.3	1.0	1.3
Mental concepts	8	Self-control, will	8.1	6.0	1.8	1.8
	9	Critical thinking training	7.6	5.5	1.3	1.8
	10	Learning new knowledge and skills	7.3	6.1	1.3	1.4
	11	Innovative thinking methods	7.4	5.6	1.2	1.5
	12	Ability to identify and solve problems	7.7	5.5	1.6	1.1
	13	Ability to think systematically	8.0	6.0	1.3	1.1
External influence	14	Financing and resource providing	8.2	4.6	0.8	1.3
	15	Demand for research developments	8.4	4.6	0.9	1.4
	16	Strategic development programs	8.0	5.6	1.7	1.5
	17	Corporate R&D support system	8.7	4.9	0.9	1.1
	18	Innovative business culture	7.0	4.9	1.6	1.5
Team work	19	Agreed common goal	7.3	5.7	1.7	1.7
	20	Psychological atmosphere in the team	7.4	6.0	1.3	2.0
	21	Team work training	6.8	5.9	1.0	2.0
	22	Variety of competences	7.6	6.5	1.4	1.8
		Average value	**7.7**	**5.7**	**1.4**	**1.5**

3.3. Development and Implementation of the Digital R&D Support System

Project process management (PPM) opens broad possibilities to automate knowledge management operations and improve the effectiveness of laborers at the enterprises involved in R&D.

The purpose of the transition to the PPM consists in redesigning the processes in the organization in such a way that operational effectiveness would allow increasing significantly the volume of executed orders without a significant increase in the number of employees. In particular, it is planned that a significant number of hours of routine work of specialists at the enterprise can be released for creative activity.

The transformation cycle includes the following:

1. Determining the current state of business processes;
2. Developing ideas and initiatives to improve current processes;
3. Formulating tasks and implementing development projects;
4. Assessing key performance indicators (KPIs) of both employees and process managers;
5. Conducting structural changes at the organization to support the implementation of improved business processes (BP).

Since this is a cyclical action, BP standards and regulations are constantly improving on a number of basic criteria. These include the speed and volume of work performed, as well as its feasibility and the required quality. The development and analysis of existing processes are carried out based on the international process classifier [36] APQC (American Productivity and Quality Center). In particular, "Knowledge, improvements, and change management" is the most relevant section, which includes:

1. Creating and managing an organizational performance strategy;
2. Performance criteria;
3. Developing an enterprise-wide knowledge management system;
4. Change management.
5. The next implementation step is the opening access to the actions presented by managers at their workplaces in the GL52 program, which includes the following modules [26]:
6. The organizational structure of the company;
7. Determining business processes and tasks;
8. Generating initiatives and proposals;
9. Long- and medium-term planning;
10. Project management;
11. Employee motivation management;
12. Training and development;
13. Corporate knowledge and change management.

The implementation procedure provides an opportunity for each specialist of the enterprise registered in the program to offer improvement of existing procedures and thereby simplify the employees' efforts when performing work. In fact, these proposals are initiatives that can reduce the cost of business processes and accelerate their implementation. The GL52 program processes employees' initiatives and supports the life cycle of the initiative from registration of the idea to implementation and monitoring of expected results.

These transformations are introduced using a motivation system. In this particular case, a system to assess the effectiveness of employees was used. This system opens up opportunities for career growth, awarding bonuses in accordance with the economic effect resulted from the implementation of the idea, and the successful completion of certification. The role of mid-level managers is also changing noticeably. The initiative given for consideration stands a good chance to turn into a project, which can affect the entire business process content.

Project-based involvement of employees in the development of new optimized processes at the enterprise seems to be a more promising way. The main criterion of the project approach is economic feasibility when combined with employee motivation.

Project process approach, when using the GL52 program, has led to the use of a four-tier control system:

1. Employee self-control;
2. Supervisor's control;
3. Control of subcontractors based on the process outcomes;
4. Control at the level of jurisdiction.

At the fourth tier, the controlling and auditing service can obtain integrated results on the achievement of target indicators. Eventually, the cycle ends with the appearance of a new business process instead of the old one, and this cyclic process can be repeated when new initiatives arise.

Summing up the third part of the work, let's team the selected concepts into a list:

1. The R&D support system;
2. PPM;
3. Digital control platform of PPM;
4. The PPM implementation process;
5. KPIs;
6. Ideas' and initiatives' generation and collection system;
7. Employee training and development system;
8. The APQC process classifier;
9. Knowledge management in the organization;
10. Change management;
11. Electronic business process model;
12. Employee motivation management;
13. Excessive operational load;
14. Employment of dismissed workers;
15. Target indicators monitoring system.

It is apparent that these concepts differ significantly in their composition from those highlighted in the first two parts of the work. Their content focuses on the use of the digital R&D design and process management system, which aims at involving employees in the organization's activity management. The creation of such a system opens ample opportunities for improving the effectiveness of the R&D activities, both at the team level and with respect to some of the factors identified at the level of the national economy.

4. DISCUSSION

The present work includes the results of studies to improve the work efficiency of research teams, whose members are able and willing to work productively in the field of the R&D. The solution to the issues of conceptual modeling of productivity of scientific teams being under the mercy of competence and information requires the construction of a holistic model of a complex (in fact – super-complex) system, which then can be modeled in more detail by the human-machine system. Consideration of such a complex system from the outset at the same level of detail can make the work unrealistically complex or one-sided. Therefore, in this article three fragments of the problem characterized by complex architectonics are considered. These fragments have intersecting subsystems with common objective criteria [37-39].

5. CONCLUSION

The key problems of effectiveness in the R&D activity are revealed at different organizational scales.

At the level of professional teams, emerging problems concern the R&D communications of specialists, evaluation and payment of job performance, and project execution time management. At the micro level, problems appear with the performance indicators of R&D activities, which are established by the parent organization in the form of KPIs.

It is revealed that not all mid-level managers have project management skills. At the macro level, the complexity in the use of mental tools to improve the work effectiveness was revealed, as well as the high importance of creating an R&D support system in the company, and computer support.

Joint consideration of the issue at three different organizational levels allows solving the problem of conceptual modeling of the super-complex fuzzy system more holistically.

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