Information Technology Knowledge Management in the System of Interaction of Educational and Scientific-Production Structures

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Abstract: A model of intellectual space, reflecting the mechanisms of knowledge representation about the processes of innovative modernization, is proposed. The systematization of knowledge in the areas of mathematical modeling, innovation and project management, and organizational design was carried out. A knowledge base has been created on foreign and Russian information systems used to solve problems of automated selection of the best option from a set of alternative solutions.
The proposed economic and mathematical models describing the strategy of innovative modernization of the production subsystem of a research and production enterprise. Based on the use of a body of knowledge, software has been created for the automated selection of the best option for innovative modernization of the production subsystem of a research and production enterprise.

Key-Words: knowledge base, knowledge management system, research and production enterprise, innovative modernization, economic and mathematical model, variable models, information product.

1 Introduction

In the digital economy, the most significant factors stimulating the development of various socio-economic systems are knowledge, the intellectual component of resources, assets and capital. This is the result of the globalization of the market, the implementation of the concept of a new economy and the emergence of the information society. Informatization of various fields of activity led to a change in communication processes, speeding up the processing, storage and transmission of information. The consequence of this was an increase in the effectiveness and efficiency of interaction between objects and subjects at all levels of economic systems, including the macro level, the meso level and the micro level.

A new economy based on knowledge and innovative development factors is characterized by a number of trends. One of these trends is associated with a significant increase in the share of the intellectual component in the cost structure for the creation and development of process (new technologies) and product (new goods and services) innovations [3]. This leads to the rapid growth of technology-intensive technologies and products. Moreover, the duration of the life cycle of the process and product innovations created in these conditions is constantly reduced, due to the acceleration of innovation processes and the increasing strategic importance of the convergence factor in updating technological innovations.

Another trend is the intellectualization of production. This is especially characteristic of the conditions of digital transformation, carried out by informatization and robotization of production, the transition to new management technologies. Providing a high level of stability of production processes, these factors create the conditions for improving the quality of the final results and the growth of labor productivity. The third trend is to expand the market segment of intellectual products and services, as well as a qualitative change in the structure of this segment. This is achieved by improving the patent, licensing, consulting and educational activities. The combination of these trends, causing high rates of knowledge obsolescence, dictates the need to constantly update the knowledge bases of innovation actors by replenishing these bases with qualitatively new elements.

Therefore, in the macroeconomic strategy of the state one of the key roles is assigned to the system "education-science-production" [2]. In the Russian Federation, an important element of this system is research-and-production enterprises, which combine the scientific and production components into a single research and production process for creating and mastering technological innovations. In this system, educational structures sell knowledge to research-and-production enterprises in the form of consulting and educational services.

These services, based on the innovative ideas of creating technological innovations, managing digital production, are the intellectual capital of the educational organization, its intellectual property. Obtaining knowledge from educational organizations, research and production enterprises use them in their activities, creating a wide range of innovations. Thus, the transfer of knowledge to a new level generates, firstly, an increase in intellectual capital and the fundamental value of a research and production enterprise, and secondly, the acquisition of new knowledge as a result of joint activities of educational and research and production structures.

By participating in the formation of intellectual resources of a research and production enterprise and improving the quality of these resources, educational organizations make extensive use of information systems and technologies. In this case, we can talk about the creation of information-intellectual assets that generate a non-linear increase in the effectiveness of the "education-science-production" system. The basis of these assets is new knowledge that exists in the form of information products. This knowledge is transformed into objects of intellectual property (intangible and intellectual assets) of the subjects of the system, and then into their intellectual capital. Therefore, knowledge should be considered not only as an important source of growth of the fundamental value of the subjects of the “education-science-production” system, but also as a factor forming the competitive advantages of these subjects.

Thus, there is a need for knowledge management [1, 4], which in the management process is considered as an intellectual asset of innovation-oriented structures with an ever-growing fundamental value. This applies equally to all subjects of the "education-science-production" system, both to educational organizations and to research and production enterprises. Moreover, the software provided educational and consulting services in the system of interaction of educational and scientific-industrial structures becomes an integral element of knowledge management. In this case, the transfer of knowledge is implemented as a set of educational and consulting functions provided in a digital format. The desire to ensure a high level of efficiency in the use of scientific and industrial knowledge enterprises dictates the need to improve the organizational mechanisms for the transfer of knowledge and the transformation of traditional educational structures. This leads to the fact that in the educational process they begin to actively use methods of target learning, matrix, virtual, network structures.

The most important elements of the knowledge management process are the creation, storage, search, transfer and use of knowledge. Each of these elements acts as a management function implemented at a certain stage in the life cycle of the knowledge management process. The effectiveness of the implementation of each of these functions determines the performance of the knowledge management system, its stability in a turbulent external environment. In this regard, an important factor in the formation of an effective and sustainable knowledge management system becomes the approaches and principles that underlie its construction.

These approaches and principles may be oriented towards the application of existing knowledge management technologies. However, often the basis of a knowledge management system is original development, for example, using an interrelated set of methods and technologies that involve working with meaning, data semantics, information and knowledge. In this case, the construction of a knowledge management system covers the ontologies of subject areas, the development of technologies for their construction and maintenance, the formation of semantic metadata, semantic search, inference systems, semantic profiling of expert knowledge, semantic portals and networks, and so on. At the same time, it is necessary to create an appropriate technological support for the functioning of a knowledge management system, including description languages, models and software tools of the system.

The complexity of solving the problem of knowledge management in organizing the interaction of educational and research-and-production structures is associated with a number of factors, primarily the lack of a generally accepted concept of building such systems. The proposed structuring of this problem allows us to define a set of interrelated tasks of knowledge management, united by a common goal. This approach allowed, by integrating elements of artificial intelligence into this system, to create a knowledge management system adapted to the peculiarities of the interaction of educational and scientific-production structures.

2 Problem Formulation

At present, the problem of import substitution is acute for the real sector of the Russian economy. The solution of this problem is connected with the implementation of innovative modernization, which provides for a fundamental change in the characteristics of the products, existing technologies and production systems. This kind of modernization involves solving a wide range of tasks. This spectrum covers, first, the design, technological, organizational and managerial tasks. Their solution involves the creation of new products (product innovations), the development of new technologies for their production (process innovations), the formation of new organizational and production structures and the principles of managing these structures (organizational and managerial innovations), integration of highly automated equipment and information systems into the production environment. Secondly, intellectual resources of a new quality are necessary for servicing the structures created as a result of innovative modernization [4].

Particularly relevant is the range of such tasks for research and production enterprises, which, creating and mastering prototypes of product innovations, are in the Russian economy a production “locomotive” of the national innovation system. The intellectual basis of such activities are human resources with high creative potential, capable of displaying autonomy and creative initiative in the digital space. The task of forming intellectual resources with similar characteristics is solved by scientific and industrial enterprises on the basis of organizing effective interaction with educational structures that have an innovative orientation.

This raises the need for knowledge management. Such management assumes the accumulation of knowledge to a level that is sufficient to conduct an effective innovative modernization of the production subsystem of a research and production enterprise. For this purpose, it is advisable to use modern knowledge management technologies. These technologies are based on a set of technical and software tools and ensure the effective implementation of the life cycle of knowledge, including their creation, accumulation, storage and consumption.

The development of a theoretical basis for carrying out an innovative modernization of the production subsystem of a research and production enterprise is rather laborious, since it is a multifaceted process that links different knowledge domains into a single system [1, 2, 5]. The description of such a process requires the development of a set of complex economic and mathematical models, as innovative modernization covers a set of heterogeneous business processes.

These processes are associated with the choice of the production program and the elements (equipment, robotics, and so on) of the organizational and production structures created, the definition of investment needs, and so on. Therefore, knowledge management should be implemented as a system and rely on modern information technologies that provide timely access to knowledge, speeding up knowledge-sharing processes not only between specialists and departments of a research-and-production enterprise, but also the subjects of the education-science-production system.

The approach to knowledge management as a single system creates the basis for the effective use of ontologies and methods for semantic information processing. Building a knowledge management system when conducting an effective innovative modernization of the production subsystem of a research and production enterprise has led to the need to use ontology, which is a way to describe the structure of knowledge in a number of subject areas.

In the end, the innovation modernization process generates new knowledge, the use of which will allow to realize the idea of innovative modernization of the production subsystem of a research and production enterprise at a higher level, having solved qualitatively new modernization problems. In particular, this concerns, firstly, the task of choosing the optimal ratio between the parameters of flexibility and productivity in the established organizational and production structures, secondly, the tasks of internal logistics in organizing robotic units with optimal loading of their elements (equipment and robotics).

3 Problem Solution

3.1. Creating a Knowledge Base about Information Products for Solving Problems of Automated Selection of the Best Solution

When solving the problem of innovative modernization of the production subsystem of a research-and-production enterprise, a model of intellectual space was created, reflecting the mechanisms of knowledge representation about the processes of innovative modernization. For this, knowledge was systematized in a number of subject areas. These areas were the spheres of mathematical modeling, innovation and project management, and organizational design.

In order to systematize knowledge in the field of project management, a database of information systems available on the Russian market has been created, which are used to solve problems of automated selection of the best option from a set of alternative solutions. The structure of this database included software products belonging to classes of either closed or open software systems.

The created database covers both foreign (Microsoft Project, Welcom, Oracle Primavera, COMFAR and PROPSPIN) and Russian (Project Expert, Alt-Invest, TEO-Invest, Spider Project, ELMA Projects +, Advanta, Invest-Project, FOCCAL and INVESTOR) software solutions. The study of the generated knowledge base showed that each of the software packages, solving a wide range of project management tasks, can be used to calculate the integral financial and economic indicators. On the basis of these indicators, a management decision is made to select the best project option.

However, the analysis of Russian and foreign software products included in the knowledge base showed that they do not allow a research and production enterprise to solve the problems of automated selection of the best modernization strategy of the production subsystem. This is due to a number of circumstances. Firstly, the software products included in the knowledge base do not fully reflect the design, technological and organizational specifics of innovative
solutions included in the knowledge base of a research and production enterprise, new modernization, and secondly, the specifics of the formation of investment capital. In addition, a significant drawback of the software systems included in the database was the insufficient detailing of the economic and mathematical models underlying the software product.

To develop an innovation modernization strategy, a working group was created, which included representatives of the educational structure - experts in the field of the theory of mathematical modeling and software engineering, as well as practitioners - representatives of a research and production enterprise. The use of individual knowledge of the participants of the created working group allowed to form a set of requirements for economic and mathematical models describing the strategy of innovative modernization of the production subsystem of a research and production enterprise.

Firstly, the mathematical apparatus used to model the processes of innovative modernization should allow to reflect the real dynamics of the market demand for product innovations created by the research and production enterprise. A research-and-production enterprise, shaping the strategy of innovative modernization of its production subsystem, should be guided by the dynamics of the market needs for product innovations.

Secondly, in order for the customization factor to contribute to a real increase in the consumer value of the product innovations produced by a research and production enterprise, a wide range of variables must be present in the economic and mathematical models describing the strategy of innovative modernization. This spectrum should reflect the characteristics of product, process and organizational and managerial innovations, as well as investment resources. Third, when modeling the processes of innovation modernization, it is necessary to take into account the totality of restrictions on production factors. Otherwise, the model underlying the software product will not adequately reflect the realities of the innovative modernization of the production subsystem of a research-and-production enterprise.

3.2 Development of a Set of Economic and Mathematical Models Describing the Processes of Innovative Modernization of the Production Subsystem of an Enterprise

To eliminate the shortcomings characteristic of the models underlying the existing software
$\alpha^{k}{}_{gjr}$ – the capital intensity of processing product innovations of the g group on the equipment of the

knowledge was required in the field of economic and mathematical modeling. This knowledge was obtained in the framework of consulting services that were provided to the research and production enterprise by an educational structure. The knowledge gained was used to create an economic-mathematical model containing a detailed range of variables with which the process of innovative modernization of the production subsystem of a research and production enterprise was described.

The variables in the economic-mathematical model developed by a working group consisting of representatives of an educational organization and a research and production enterprise reflect, firstly, the characteristics of technological (process and product) innovations, secondly, the created organizational-production structures and, in third, the characteristics of investment in modernization. For the selection of variables and methods for their description, knowledge of scientists of the educational organization and practitioners of a research and production enterprise were used. As such variables in the model were taken into account:

i – position number in the product innovation nomenclature;

I – number of product innovations;

g – product group index in product innovation ($g = 1…., G$);

G – number of groups of elements in product innovation;

x_{it} – the volume of release of product innovations of the name i at the step t of carrying out innovative modernization ($i = 1…., I;\ t = 1….., T$);

m_i – the amount of direct material costs for the release of product innovations names i;

c_i – selling price of product innovations i;

$b^{н}_{it}$ and $b^{в}_{it}$ – the lower and upper price limit for the product innovation of the name i at step t of carrying out innovative modernization;

$V_{i,t}$ – boolean variable whose value is 1 if $b^{н}_{it} \le x_{it} \le b^{в}_{it}$ and equals 0 - otherwise.

j – equipment group number ($j = 1,…., J$);

J – number of equipment groups;

jr – automation level r of equipment of group j;

k – number of g innovation processing option ($k = 1,…, K_g$);

K_g – number of processing options for innovation g;

$$\sum_i \sum_j \sum_k \sum_r \sum_g \quad (a^k_{gjr}\, p_{gi}\, x_{it} - f_{jrt}\, y_{jrt}) \le 0,$$

j group at the automation level r and the processing option k;

Z^k_{gjr} – the cost of processing product innovations of group g on equipment group j for option k, which has an automation level r;

f_{jrt} – time fund of equipment group j, which has an automation level r in year t;

y_{jrt} – the quantity of equipment of group j that has an automation level r;

Y_{jrt} – the number of available at the disposal of the enterprise in the year t of equipment group j, which has an automation level r;

d_{jr} – the cost of machine hours of equipment of group j, which has an automation level r;

q_{jrt} – investments in year t in creating an element of group j, which has an automation level r;

ρ_{jrt} – expected sales price in year t of group j equipment, which has an automation level r;

s_{jr} – the area occupied by an element of equipment of group j, which has an automation level r;

S – required area value;

P – area owned by the company;

φ – investment in creating one square meter of additional space;

Π – nnual cost of renting one square meter of additional space;

ψ – current annual costs of maintaining and operating one square meter of additional space;

$K^{TI}{}_t$ – technological innovation in year t;

K – integral value of investments in the creation, development and use of the established production system;

Q – the amount of investment in the project, the source of coverage of which are borrowed funds;

b – borrowed funds;

E – discount rate.

Constraints in the economic-mathematical model covered:

First, restrictions on the volume of production (sales) of product innovations of the name i:

$$x_{it} - V_{it} b^H_{it} \ge 0,\ i = \overline{1, I},\ t = \overline{1, T}$$
$$x_{it} - V_{it} b^B_{it} \le 0,\ i = \overline{1, I},\ t = \overline{1, T}$$
$$0 \le V_{it} \le 1,\ i = \overline{1, I},$$
$$x_{it} \ge 0,\ i = \overline{1, I},\ t = \overline{1, T}$$

Secondly, restrictions on the time funds of groups of equipment used:

selection of the best option for innovative modernization of the production subsystem of a

$Y_{jrt} \geq 0$,

Thirdly, restrictions on the production area:

$$\sum_{j}\sum_{r} s_{jr}\, y_{jrt} - S \leq 0,$$

Fourth, restrictions on additional investment.

To calculate the effectiveness of innovative modernization of the production subsystem of a research and production enterprise, the following models were used.:

First, the difference of results (R_t) and costs (Z_t) was determined for the year t of the innovative modernization of the production subsystem of a research-and-production enterprise:

$(R_t - Z_t) = \sum V_{it}\, x_{it}\, C_{it} - \sum m_i x_{it} - \sum d_j\, f_{jt}\, y_{jt} - S\psi - (S - P)\, \Pi - b\, Q$

Secondly, total investments (MK_t) in year t were calculated in the project of innovative modernization of the production subsystem of a research and production enterprise:

$$MK_t = K_t^{TI} + (\sum\sum y_{jrt}\, q_{jrt})_t + P\psi,$$

and also the integral value of investments was calculated for the entire life cycle (T) of the project of innovative modernization of the production subsystem of a research and production enterprise:

The non-negative value of net present value was chosen as the criterion for the optimality of the strategy of innovative modernization of the production subsystem of a research and production enterprise (NPV).

If there are several options ($v = 1\ldots.., V$) of the innovation modernization strategy, the best option is chosen according to the max NPV_v, criterion, provided that $NPV_v \geq 0$.

3.3 Development of Cross-Platform Software for Innovative Modernization

The formed set of economic and mathematical models is the basis of software for automated selection of the best option for innovative modernization of the production subsystem of a research and production enterprise. The software allows for the search of potentially acceptable options, their comparison by the optimality criterion (taking into account the established system of restrictions) and the subsystem, the Listed and Content classes perform an important functional load. These classes are implemented in software to eliminate code duplication [8].

research and production enterprise. Essential features of the software are, firstly, its cross-platform, and secondly, the presence of a convenient user interface.

Using the knowledge of working group specialists, a high-level Java programming language was chosen to solve the problem [6, 7]. It is taken into account that software written in the Java language can function on different platforms (Windows, Linux, MacOS, and so on). This is achieved by having a Java Virtual Machine (JVM). The software is implemented in IntelliJ IDEA multi-functional integrated development environment. This environment has a number of significant advantages, firstly, it allows you to create a graphical user-friendly interface, secondly, it allows you to implement an intuitive automatic filling, and thirdly, it has modern debugging tools.

The program is written using the JavaFX platform, which has extensive functionality, allowing you to design unified applications with a graphical user interface. The software user interface is developed using the SceneBuilder program, which has the ability to generate fxml files with a formal description of the user interface.

The developed software has a rather complicated architecture. This architecture encompasses a number of structural elements. In particular, a model that includes domain classes. An important element of the software is the controller. This software architecture element is used to associate a model and a view. Another no less significant element of the architecture is the representation itself. This element provides a convenient user interface in the software architecture. The architecture of the software application along with the UML class diagram of the model covers the description of a number of other classes of the model. These classes are classes such as Listed, Content, Project, ProductInnovation, ProcessInnovation, GroupElements, ProjectChecker, and Parser.

The Listed class characterizes the element in the list and can belong to any list (for example, innovative modernization options, product or process innovations, groups of technological innovation elements, etc.). Content class means an element that contains data. In the developed software that allows the research and production enterprise to choose the best option for the innovative modernization of its production
automated selection of the best option from a set of alternative solutions.

The classes ProductInnovation, ProcessInnovation, and GroupElements denote an editable entity. These classes in the created software act as heirs of the abstract Content class. The entity that allows you to get information about whether the innovation modernization option satisfies the constraints specified in the mathematical model is the ProjectChecker class.

When a research and production enterprise used software designed to solve the problem of choosing the best option for innovative modernization of the production subsystem, it became necessary to design a user interface. The created user interface contains a set of windows reflecting the algorithms for the introduction and adjustment of source data for innovative production modernization subsystem options considered by a research and production enterprise. This applies to filling and editing the list of projects (innovative modernization options), product and process innovations.

In addition, the user interface allows you to notify the user about errors that occurred when using the software of an innovative modernization of the production subsystem of a research and production enterprise. In this case, a window with detailed error information is displayed on the computer screen. The analysis of these errors is an important source of replenishment of knowledge about mathematical and informational support for solving the problem of innovative modernization of the production subsystem of a research and production enterprise.

4 Conclusion

The report proposed a model of the intellectual space, reflecting the mechanisms of knowledge representation about the processes of innovative modernization. The systematization of knowledge in such subject areas as mathematical modeling, innovation and project management, organizational design was carried out. In order to systematize knowledge in the field of project management, a database of foreign and Russian information systems on the market has been created, which are used to solve problems of

However, the software products included in the knowledge base do not fully reflect the design, technological and organizational specifics of innovative modernization, as well as the specifics of the formation of investment capital. The analysis showed that a significant drawback of the software systems included in the database is the low level of detail of the economic and mathematical models that form the basis of the software product.

Based on the use of individual knowledge of the participants of the established working group, the requirements for economic and mathematical models are described, which describe the strategy of innovative modernization of the production subsystem of a research and production enterprise. First, a reflection of the real dynamics of the market needs in the product innovations created. Secondly, the presence in the models of a wide range of variables that characterize the innovative system of a research and production enterprise, its investment resources, as well as restrictions on factors of production.

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