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Development Model of the Intellectual Property Management System

Kolodyazhnaya O.A.*
State Science and Research Experimental Institute of Technical information protection problems of Federal Service for Technical and Export Control
Voronezh, Russian Federation
e-mail olsokolik@mail.ru

Kolodyazhnaya A.A.
Saint-Petersburg State University
Saint Petersburg, Russian Federation
e-mail nastya-kolodyazhnaya@mail.ru

Anisimov Y.P.
Voronezh State Technical University
Voronezh, Russian Federation
e-mail 08-00-05@mail.ru

Selutin E.V.
Voronezh State Technical University
Voronezh, Russian Federation
e-mail zhenya-777@yandex.ru

Osipov A.A.
Voronezh State Technical University
Voronezh, Russian Federation
e-mail sanya-28@mail.ru

Arakcheev D.V.
Voronezh State Technical University
Voronezh, Russian Federation
e-mail dudarevaov@mail.ru

***Abstract* — The study reflects current issues of the intellectual property management in the socio-economic systems, which are represented by a number of research organizations. It is proved that ensuring the competitiveness of socio-economic systems in the digital environment is possible only if the conditions for their development are met. It is clarified that the development vector of intellectual property management systems is set by changing environmental factors. As a result, the need to model the development of the intellectual property management system in accordance with the changes in the conditions of external and internal interaction is revealed. The analysis of the existing development models of the social and economic systems is carried out and the restrictions for their application in modeling of the development of the intellectual property management system are revealed. The authors put forward the following examples of these limitations: the lack of sufficient information concerning the impact of digitalization of economic relations on the development of management systems and a unified system of criteria that allow to characterize the processes of development of the intellectual property management system. In order to overcome the identified shortcomings, it is proposed to model the development of the intellectual property management system based on a fuzzy set assessment of the changing parameters. An algorithm for modeling the development of the intellectual property management system in accordance with the conditions of the digital transformation of the economy is proposed. This algorithm includes: forming criteria for evaluating changes in the parameters of the developing system and determining their probabilistic forecast evaluation, introducing linguistic variables with a term set of values and their membership functions, conducting classification and analytical procedures. The simulation of the control system development research organization was obtained the fuzzy evaluation of the extent of achievement of development objectives and provides the corresponding linguistic description of the level of development of the system. The results of the study are the basis for the development of certain management decisions that contribute to the timely development of the intellectual property management system under the influence of digitalization of all spheres of economic activity.**

Keywords — management system, intellectual property, digital economy, development model, fuzzy set assessment.

I. INTRODUCTION

Intellectual property management (IP), as an economic activity, is an inevitable condition for the formation and effective functioning of the knowledge economy [1]. At the same time, the organization of management based on a system approach allows for the interconnection and interaction of all levels of management and elements of the socio-economic system in which the object of management is IP.

Currently, an important condition for maintaining the level of competitiveness of socio-economic systems is to ensure their development under the influence of environmental factors. The characteristic features of the management systems development are highlighted by Yu. P. Anisimov [2] and come down to the integration of scientific knowledge, increasing the level of standardization and automation of management processes, ensuring their dynamism. However, a significant characteristic of the modern external environment is its transformation under the influence of factors of the digital economy, which creates a new level of electronic network relations among economic entities. In turn, it is assumed that the development of the digital environment will help to realize the innovative potential of entities of science, education, business, and industry.

The provisions of the national project "Digital economy of the Russian Federation" have been developed in order to implement the digital interaction among economic entities in various fields, including IP. Accordingly, at the present time,

the entities of the research area related to the development, legal protection, use and implementation of the IP objects must objectively assess the possibilities for the development of the system management of IP in the new economic conditions [3].

As a result, the relevance of the chosen research topic is due to the availability of the managerial need to develop adaptation measures that contribute to the development of the IP management system in the context of the digital transformation of the domestic economy.

II. METHODS AND MATERIALS

Consideration of the models of socio-economic systems development proposed in the specialized literature allowed for their comparative assessment.

The classical economic theory uses the concepts of two-factor and multi-factor models for the development of socio-economic systems. Consideration of their essential characteristics and differences is given by A.V. Tatarova in [4]. The author justifies the optimal options for using models in the modern economic conditions and, taking into account some limitations of their application, offers the necessary conditions for the development of the management system to consider in the integrated information model. The model describes in detail the influence of macroeconomic factors on the sensitivity of the national economy, which necessitates the use of high-order differential equations. This fact requires providing for the development of a model for the development of the IP management system for personnel with appropriate qualifications. In addition, the use of this model to justify the development of the IP management system is limited by highly specialized features of the management object described in [5].

An alternative to the considered model is the information-logical model, which is described in [6]. According to the developer, this model can be used to manage the development of socio-economic systems. The development of the information-logical model is based on the use of the following elements: information flows and objects; functional modules that include analytical functions; information systems, methods and the information-processing mechanism. The model reflects the development of the information and communication subsystem at a sufficient level. However, according to the authors, the methodological tools of this model has a significant drawback. It consists in insufficient elaboration of inclusion in the model of issues of development of the organizational and structural component of the material, technical and personnel support required for the IP management system of the motivational stimulation subsystem.

The interesting ideas for modeling the development of socio-economic systems were proposed by the author's team under the leadership of Gromov A.I. [7]. They consist in developing a model of the socio-economic system that corresponds to the factors of development of the external environment. As one of the tasks of developing the model, we consider the factor identification of the features of the control object and the choice of the modeling methodology, in this case, simulation modeling.

Scenario modeling of the behavior of the socio-economic systems is generally recognized and quite common among economic scientists. Currently, when simulating socio-economic management systems, an empirical algorithm for estimating the probability of development of the internal and external environment of the system is widely used [8, 9]. However, it does not take into account differences in the spectral characteristics of the management objects, which can significantly affect the development vector of the socio-economic system.

The model presented in [10] is characterized by a stratified description of the system elements with an interpretation of their cause-effect dependencies. At the same time, according to the author, the preferred principle of modeling the developing socio-economic systems is the principle of stratification: certain solutions arise at the micro level , and evolutionary processes occur at the macro level.

In mathematical models, the most commonly used methods are factor modeling, simulation and statistical modeling methods, network interaction methods, subject-oriented methods [11]. A significant limitation of the use of these methods for modeling the development of the IP management system is the lack of the necessary amount of experimental data on the formation, operation and development of these systems in the context of the digital transformation of economic relations. At the same time, the impossibility of using some traditional methods of mathematical modeling is substantiated in [10].

During the examination of the IP management issues [1, 2], the authors found that there is currently no single system of criteria that characterizes the development of the IP management system in the research field and enables to model this process. As a result, the process of modeling the development of the IP management system can be carried out on the basis of selecting informative parameters in accordance with the approaches used in the existing methods of analysis of various management systems:

- the formation of a set of interrelated indicators based on the analysis of the dependencies between them;
- the formation of a set of indicators based on the expert judgment;
- the formation of a set of indicators based on the analysis of the tree of goals and objectives of the system development.

Thus, in order to overcome the above shortcomings and taking into account the specifics of assessing the development of the IP management system in research organizations, highlighted in [12], the authors developed a model that implements the possibility of fuzzy logical assessment of the development of the IP management system. The choice of a methodological tool based on the theory of fuzzy sets is related to the available source information, which does not directly determine the value of analytical dependencies characterizing the level of development of the IP management

system. The use of fuzzy multiple estimation in the process of modeling the development of the IP management system will allow for a quantitative analysis of the qualitative transformations associated with the development of the system.

The algorithm of the mathematical model for the development of the IP management system is shown in Fig. 1.

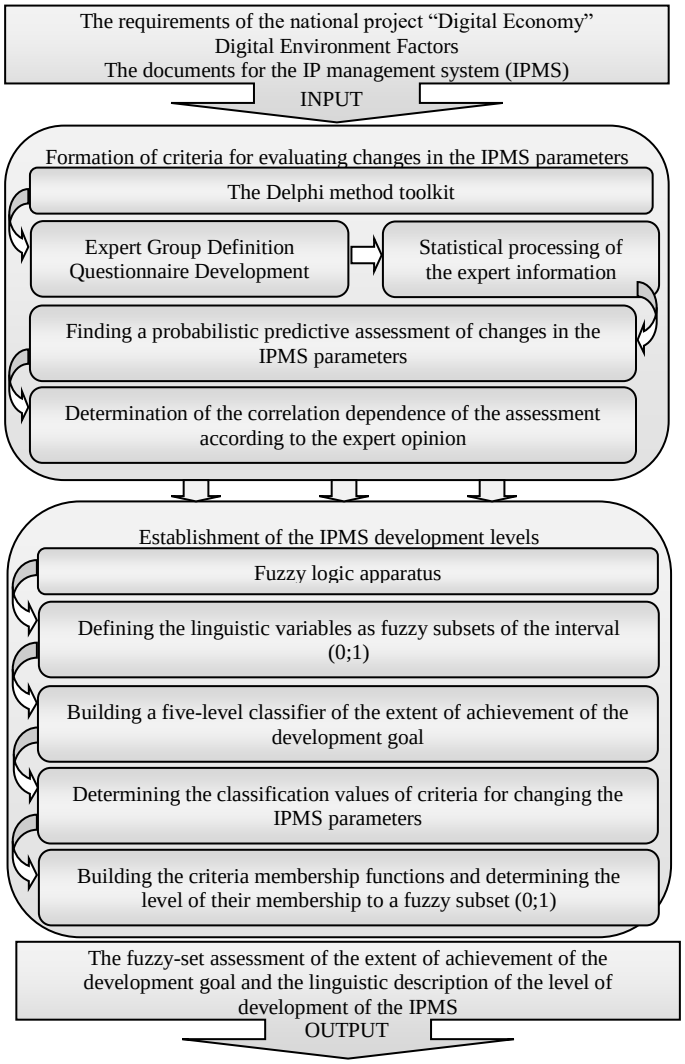

Fig. 1. An algorithm for modeling the development of the IP management system

The conceptual basis of this algorithm is the use by experts of linguistic variables characterized by a certain term-set of values, and membership functions of these variables to some fuzzy subset. The trapezoidal view of the membership function is used in the model, the upper base of it corresponds to the analyst's confidence of the correctness of the classification, and the lower base specifies certain values of the fuzzy subset from the interval (0, 1) [13, 14].

The linguistic variables used in the model characterize the level of development of the IP management system (Y), determined by the degree of achievement of the development goals (C) with the indicator (c), and the parameters of the system during its development (P), the change of which affects the extent of achievement of the goals.

The implementation of the developed model algorithm was carried out on the basis of justification of criteria that, according to the authors, significantly characterize the qualitative signs of changes of the parameters of the system during its development and demonstrate:

- the compliance of the system's functional capabilities and structural parameters to IP management tasks in the digital economy;
- the sufficiency of information support for solving IP management tasks in an external digital environment;
- the compliance of material and technical support with the requirements of digitization of interaction of the subjects in the field of IP;
- the changing the level of communication links in order to solve internal and external tasks of IP management and compliance with the degree of qualification of the management [15].

Thus, in justifying the criteria, the requirements for their compliance with the goals and objectives of the development of the IP management system in the digital economy were met. The criteria that characterize the parameters of the developing IP management system represent an assessment of their change in the following form:

1. The functional parameter, the changes relate to the optimization of the functional subsystem in accordance with the tasks of digital transformation of the economy. The change evaluation criterion (P_1) reflects the overall level and sufficiency of connections for forming the internal digital space and performing functions of external interaction with the digital environment.

2. The structural parameter, the changes relate to the optimization of the organizational management structure in accordance with the development objectives. The change assessment criterion (P2) reflects the level of standardized requirements for the IP management, taking into account the development of new functions, and the adequacy of the functional relationship.

3. The information parameter, the changes relate to reducing the level of information uncertainty and increasing the level of information security. The change assessment criterion (P3) reflects the extent of readiness of information support to solve management tasks in the context of the external digital relationships.

4. The communication parameter, the changes relate to ensuring the necessary level of sufficiency of external and internal communication links to solve IP management tasks. The change evaluation criterion (P4) reflects the level of responsiveness of the management information and the level of feedback.

5. The material and technical parameter, the changes relate to ensuring the use of digital technologies and applying the capabilities of the digital economy in the field of IP management. The change evaluation criterion (P5) reflects the

level of automation and the technological effectiveness of management work that corresponds to the conditions of transition to the digital relationships.

6. The motivational parameter, the changes relate to maintaining the level of interest of scientific, technical and managerial personnel in improving the effectiveness of the IP management system. The change evaluation criterion (P6) reflects the level of allowances for the extent of personal development and high performance.

7. The personnel parameter, the changes relate to improving the skill level of management personnel, corresponding to the functions and tasks of the management system development in the digital transformation of the economy. The change assessment criterion (P7) reflects the level of qualification and digital literacy of the staff.

III. RESULTS

The results of the implementation of the algorithm presented in figure 1 were obtained by the authors in the course of modeling the development of the IP management system according to the conditions to the development of the digital economy.

The object of research in this paper is the IP management system of a research Institute that has multi-disciplinary scientific schools, has a developed infrastructure, and has a production and experimental base. The information basis of the study was the documents regulating the activities of IP management, statistical reporting forms, as well as the results of interviewing scientific and technical workers and employees of the managerial apparatus.

The use of this information in the course of modeling the development of an IP management system will ensure the identification and disclosure of its essential properties that are manifested in the development process and reflect its difference from any other management system.

In accordance with the described modeling algorithm, the parameters of the management system were identified, and a significant change of the parameters elements determines one or another degree of achievement of development goals. The possible values of the management system parameters were obtained based on the processing of expert questionnaire data. The experts were the most competent scientific and technical personnel, and managerial staff operating in the field of IP management. The Delphi method was defined as a methodological tool for processing expert opinions.

The expediency of using this method is based on the opinion of scientists-economists, presented in [14] and containing a justification for the effectiveness of its application in the absence of reliable information about the behavior of the object of research under the influence of external factors.

In the process of practical implementation of the Delphi method, a probabilistic forecast estimate of changes of the system parameters was given, provided that its potential was used, and the correlation dependence of this estimate on the significance of the experts ' opinion was established. The obtained results are presented in table I.

In this model, the authors made an assumption about the equivalence (ri) of criteria that characterize the degree of achievement of the development goals of the management system through changing parameters, which corresponds to the expression:

$$r_i = \frac{1}{\sum_{i=1}^{7} P_i} \quad (1)$$

where P_j is the criterion for evaluating the change in the I-parameter.

TABLE I. THE VALUES OF THE CONTROL SYSTEM PARAMETERS

The system parameters criteria and their values						
P_1	P_2	P_3	P_4	P_5	P_6	P_7
0,324	0,612	0,342	0,140	0,175	0,115	0,426

For the purpose of practical use of the model, the gradations of the linguistic variables Y, C, P were adopted, as shown in table II:

TABLE II. LINGUISTIC VARIABLE VALUES

Level of management system development	**Degree of achievement of development goals**	**Control system parameters**
fuzzy subset		
Y_1 – extremely unfavorable development	C_1 – extremely insignificant	k_1 – low level of the P_j criterion
Y_2 – adverse development	C_2 – insignificant	k_2 – level of the P_j criterion is below average
Y_3 – relatively stable development	C_3 – average	k_3 – average level of the P_j criterion
Y_4 – sustainable development	C_4 – significant	k_4 – level of the P_j criterion is above average
Y_5 – marginal development	C_5 – marginal	k_5 – high level of P_j criteria

Due to the justification that the level of development of the management system depends on the indicator of the degree of achievement of the goal, it is necessary to transform the set C into a fuzzy subset. This procedure was carried out using a standard five-level classifier, in which the range of values of the indicator of the degree of achievement of the goal is set with an internal step of 0.10 and a boundary step of 0.15 and subject to the conditions $0 \le c \le 1$. The results of the conversion are shown in table III.

The results of table III contain the classification levels of the variable C_j, $j = \overrightarrow{1,5}$, which will be the basis for a linguistic description of the degree of achievement of the goal, and accordingly the level of development of the IP management system.

Further, in accordance with the algorithmic actions of constructing a mathematical model, it is necessary to determine the classification values of the criteria for changing the parameters of the system during its development. For this purpose, we use trapezoidal numbers of the form (a, b, c, d)

that characterize the criteria membership functions to some fuzzy subset of k_j, $j = \overrightarrow{1,5}$.

TABLE III. CLASSIFICATION OF THE DEGREE OF ACHIEVEMENT OF DEVELOPMENT GOALS

Variable	Interval values	Membership function
C_1	$0 \le c \le 0,15$	1
C_1		$\mu_1 = 10 \times (0,25 - c)$
C_2		$\mu_2 = 1 - \mu_5$
C_2	$0,25 \le c \le 0,35$	1
C_2		$\mu_2 = 10 \times (0,45 - c)$
C_3		$\mu_3 = 1 - \mu_4$
C_3	$0,45 \le c \le 0,55$	1
C_3		$\mu_3 = 10 \times (0,65 - c)$
C_4		$\mu_4 = 1 - \mu_3$
C_4	$0,65 \le c \le 0,75$	1
C_4		$\mu_4 = 10 \times (0,85 - c)$
C_5		$\mu_5 = 1 - \mu_2$
C_5	$0,85 \le c \le 1$	1

The experts estimated the classification level of any parameter of the system according to the following principle: the subjective opinion regarding the differentiation of parameters of the subsequent classification levels was expressed in the use of a numerical series (a, b, c, d) (c, d, …).

Based on the obtained classification of criteria values, the authors constructed membership functions $\mu_k(\Pi_i)$ using the Matlab Toolbox Fuzzy Logic tool package. The results of constructing membership functions for the criteria for evaluating changes in the functional and structural parameters of the system are shown in Fig. 2 and 3, respectively. Similarly, membership functions were constructed for the other five criteria characterizing changes of the management system parameters during its development.

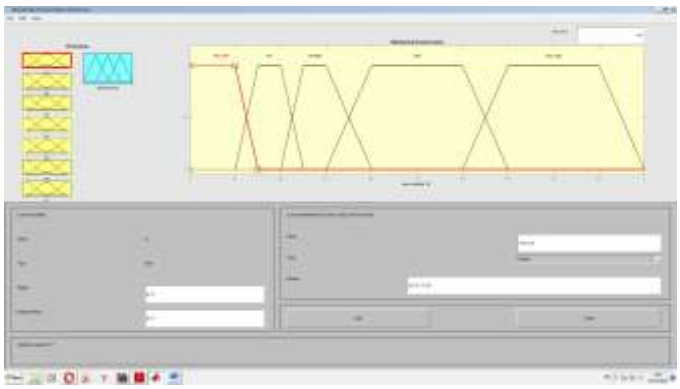

Fig. 2. The membership function $\mu_k(\Pi_1)$.

As a result of constructing the membership function, it became possible to determine the membership level of the values of P_i, $\left(i = \overrightarrow{1,7}\right)$, a fuzzy subset of k_j, $\left(j = \overrightarrow{1,5}\right)$, which is presented in table IV.

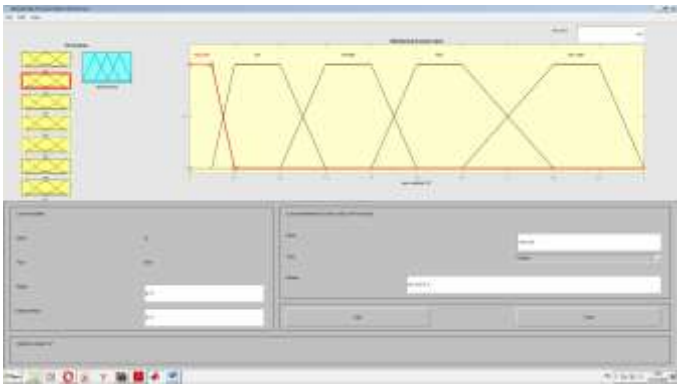

Fig. 3. The membership function $\mu_k(\Pi_2)$.

TABLE IV. THE CLASSIFICATION OF THE MEMBERSHIP LEVEL OF VALUES

The performance	$k_1(P_i)$	$k_2(P_i)$	$k_3(P_i)$	$k_4(P_i)$	$k_5(P_i)$
P_1	0	0	0,767	0,233	0
P_2	0	0	0	0,9	0,1
P_3	0	0	1	0	0
P_4	1	0	0	0	0
P_5	0	1	0	0	0
P_6	0	1	0	0	0
P_7	0	0	0,5	0,5	0
$\sum P_i$	1	2	2,267	1,633	0,1

Thus, all the preparatory algorithmic actions have been performed, which will allow us to determine the degree of achievement of the system development goals in the context of digitalization of the economy as an indicator of the level of development of the IP management system. The double convolution formula is used for this [16]:

$$c = \sum_{j=1}^{5} c_j \sum_{i=1}^{7} r_i k_{ij}, \qquad (2)$$

where c_j is the average value of the indicator of the degree of achievement of goals, determined by the principle of equidistant nodal points of the membership functions in accordance with the expression:

$$c_j = 0,9 - 0,2 \times (j-1), \quad j = \overrightarrow{1,5}; \qquad (3)$$

r_i is the level of the criteria significance for evaluating the parameter changes;

k_{ij} is the result of the classifying system parameters by fuzzy subsets corresponding to the expression:

$$K_{ij} = \mu_{k_j}(\Pi_i), \quad i = \overrightarrow{1,7}; \quad j = \overrightarrow{1,5}. \qquad (4)$$

These analytical expressions determine the weights of fuzzy subsets of k in assessing the extent of achievement of goals and in assessing the level of development of the system.

As a result of the calculations, we get a quantitative assessment of the degree of achievement of the development goals of the IP management system, represented by the expression:

$$c = \frac{1}{7} \times \begin{pmatrix} 1 \times 0,9 + 0,7 \times 2 + 0,5 \times 2,267 + \\ 0,3 \times 1,633 + 0,1 \times 0,1 \end{pmatrix} = 0,562 \quad (5)$$

The resulting fuzzy assessment is classified according to the linguistic description of the degree of achievement of the goal presented in table III.

As a result of the simulation of the development of the IP management system in the digital economy, it was determined that the value of the degree of achievement of the goal corresponds to the average rank, so that the IP management system has a relatively stable development. Accordingly, to make managerial decisions to ensure the development of the IP management system, it is necessary to provide the level of development of parameters specified in the model that characterize changes of the system according to changes in the external conditions of its functioning.

IV. CONCLUSION

In order to effectively form the knowledge economy and increase the level of competitiveness of domestic developments, the relevance of ensuring the timely development of the IP management system under the influence of the digital transformation of all spheres of economic activity was revealed. As a result, the authors justified the feasibility of developing the model for the development of the IP management system.

As a result of the research, the algorithm for mathematical modeling of the development of the IP management system was developed. The procedure of the algorithmic actions contains a toolbox that allows to simulate the relatively stable development of the IP management system in the absence of sufficient information about the functioning of socio-economic systems under the influence of the digital environment.

As a result of the simulation, it was concluded that managerial decision-making for the development of system IP management is necessary to ensure the development level of parameters describing the system change according to the change of the external conditions of its functioning.

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