ASSESSING THE ENTERPRISE INFORMATIZATION LEVEL IN DIGITAL ECONOMY CONDITIONS

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Abstract. During the Fourth Industrial Revolution, the enterprises which have begun, in due time, to introduce modern approaches to the manufacture organization, including digital technologies, obtain an essential advantage over the competitors. One of the stages of planning the changes is assessing the enterprise informatization level. Evaluating the enterprise informatization level is required for appropriate and effective choosing digital transformation technologies and approaches during the enterprise digitalization. The given assessment represents a multi-criterion problem, demanding the development of the mathematical apparatus and the principles of its use as well. The developed procedure of evaluating the level of the industrial enterprise informatization in digital economy conditions includes the procedure of organizing the assessment of the industrial enterprise informatization level and also the mathematical model of conducting an expert estimation of criteria (indicators) of the organization digitalization. The procedure of assessing the informatization level is performed by the multiplier convolution of criteria. The weights of criteria are defined by the modified T.L. Saaty’s analytic hierarchy process. Also evaluating the weights of each expert’s individual estimation and defining the error of their assessment is conducted. The approach to the proved formation of the enterprise informatization levels is developed. The given technique allows to evaluate the informatization level in some areas and to allocate those which demand the development, to forecast occurring risky situations while introducing information technologies at the industrial enterprise.

1. Introduction

The enterprise informatization is one of the basic stages of manufacture development according to the Concept of the Fourth Industrial Revolution (Industry 4.0) which is the basis for manufacture digitalization.

Defining the enterprise informatization level is the starting point while planning and realizing digital transformation. While assessing the informatization level it is possible to reveal the processes to be primarily improved by means of cross-cutting technologies, and also to develop recommendations for choosing digital transformation technologies and approaches for the specific enterprise.

The digital enterprise is an organization which uses information technologies as competitive advantage in all spheres of activities: manufacture, business processes, marketing and interaction with clients [1].

The concept of Industry 4.0 appeared in Germany in 2011 as the initiative of a group of businessmen, politicians and scientists, aiming at the increase of German enterprises’ competitiveness by the transition to digital economy. The given initiative found the response in other countries. In the Russian Federation, the National Technological Initiative, which consists of certain community and a group of measures on stimulating the development of domestic economy in digitalization direction [2], has been developed for the transition to digital economy. In his Message to the Russian Parliament on December 4th, 2014, the President of Russia Vladimir Putin designated the National Technological Initiative as one of the state policy priorities. Thus, the urgency of perfecting the existing methods and models of the manufacture organization, assessing the existing level of the industrial enterprise informatization for developing the dot measures of the organization digitalization, proves to be true.

The issues of prospects and opportunities of developing information technologies in various branches in the Russian Federation were considered and analyzed by Lonskij I.I. [3], Abdrahmanova G.I. and Kovalova G.G. [4], Odintsov V. A. [5], Akhtyrenchenko K.V. and Sorokvasha T.P. [6], Svetlakov A.G. and Glotina I.M. [7], Bereznoj A.V. and Sajgitov R.T. [8], Alekseeva O.A. and Makrova O.N. [9], Kazarin S.V. [10], Lugachev M.I. [11] and others [12-27].

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Summarizing the results of the given authors’ researches, it can be concluded that in the modern world informatization affects a number of human activities, which, in turn, influences, both positively and negatively, their development. Also, due to such wide circulating informatization, it is necessary to develop its assessment approaches.

The techniques of assessing the enterprise informatization level and features of their use were studied by such authors as Ermakova Zh.A. and Pergunova O.V. [28], Golchevskij J.V. and Maldrik A.V. [29], Shaposhnikov V.L., Artamkin A.S. and Horoshun Ch.V. [30], Kamshilov S.G. and Prokhorova L.V. [31].

Having studied the results of researches on evaluating the enterprise informatization level, it is possible to reveal the essential lacks inherent in all the techniques offered, namely the influence of subjectivity of criteria estimation by the expert group on the final result, subjectivity at the stages of the estimated criteria choice. In this connection the research objective can be defined as developing the technique of assessing the enterprise informatization level with the substantiation of the chosen criteria of the evaluation and developing the mathematical apparatus excluding the subjectivity of the experts’ estimation as much as possible.

2. Methods
The developed mathematical apparatus is put in the basis of the offered procedure for assessing the industrial enterprise informatization level in digital economy conditions (Fig. 1), describing the logic and procedure of calculating the basic criteria (indicators) of the digital enterprise.

I. The choice and substantiation of the indicators of the digital industrial enterprise are according to the concept of Industry 4.0 and the Acatech Maturity Index.

II. The Choice of criteria of assessing the industrial enterprise informatization level ($\beta_1, \beta_2, \ldots, \beta_n$).

III. Formation of the uniform criterion of evaluating the industrial enterprise informatization $\omega(x)$.

IV. Procedure of calculating aligned and normalized values of criteria ($\phi_i$).

V. Definition of weight factors of criteria by the modified T.L. Saaty’s analytic hierarchy process ($v_i^{(B)}$).

VI. Defining the index of coordination of evaluating $\lambda_{\text{IC}}$ (IC). Calculating values of the relation of coordination (RC). The analysis of the admissible level of coordination.

VII. Calculating the average consolidated estimation using group expertise ($v^{(A)}$).

VIII. Calculating the individual estimation of i expert. Defining consolidated i evaluation with the account of of the expert’s error.

IX. Defining the enterprise informatization level.

X. Developing recommendations for perfection of the mechanism and areas of digitalization of the industrial enterprise. Substantiation and choice of digitalization spheres, accounting risky environment.
Figure 1. Procedure of organisation of assessing the industrial enterprise informatization level in digital economy conditions.

The following stages represent the given procedure elements.

2.1. The choice and substantiation of the indicators of the digital industrial enterprise are according to the concept of Industry 4.0 and the Acatech Maturity Index.

As a result of the analysis of basic industrial and accompanying processes of the industrial enterprise on the basis of the Acatech Maturity Index, developed by the National Academy of Sciences and Engineering of Germany [32], the key criteria (indicators) of digital manufacture (presented in Table 1) were defined and systematized.

Table 1. Indicators of the digital industrial enterprise

| Sphere of changes (digitalization direction) | Indicators of the digital industrial enterprise |
|---------------------------------------------|------------------------------------------------|
| Organizational culture                      | Readiness for changes;                          |
|                                             | Confidence of processes and information systems;|
|                                             | Continuous professional growth;                 |
|                                             | Training and decision-making on the data basis; |
|                                             | Openness to innovations;                        |
|                                             | Recognition of errors’ advantage;               |
|                                             | Social interaction.                             |
| Material and non-material resources         | Introduction of equipment, machine tools and    |
|                                             | tools with cross-cutting technologies (artificial |
|                                             | intellect, the Internet of things, neural sets,  |
|                                             | additive technologies);                         |
|                                             | Digital systems of data gathering, processing   |
|                                             | and storage;                                   |
|                                             | Creation of digital models;                    |
|                                             | Development and training manpower;             |
|                                             | Interface on the basis of problems.             |
| Information systems                         | Data acquisition by means of gauges and         |
|                                             | activators;                                    |
|                                             | Decentralised (preliminary) processing of data  |
|                                             | gauges;                                        |
|                                             | Maintenance of digital competences;            |
|                                             | Failure-safe IT infrastructure;                |
|                                             | IT safety;                                     |
|                                             | Specialised user interface.                    |
| Organizational structure                    | Availability and information granting;         |
|                                             | Management and decision-making based on data;  |
|                                             | Motivation systems of objectives;              |
|                                             | Flexible management;                           |
|                                             | Dynamic cooperation in the network of creation  |
|                                             | of values for the customer.                    |

2.2. The Choice of criteria of assessing the industrial enterprise informatization level ($\beta_1, \beta_2, \ldots, \beta_n$). Conducting the evaluation criteria ($\beta_{\text{measured}}$).
It is supposed to choose existing indicators of digital manufacture of the specific enterprise within the limits of individual values of the organisation and also existing approaches to their measurement, as criteria for the expert estimation. The list of criteria, which, in turn, can be variative depending on the enterprise specificity, is provided.

Criteria in the offered technique are designated as follows: $\beta_1, \beta_2, \ldots, \beta_n$. They represent measured values($\beta_{measured}$). Choosing the criteria seems to be the key stage since, analyzing indicators of each criterion and using the evaluation results, it is possible to highlight the processes demanding modernization by means of cross-cutting technologies. Thus, it is possible to define the list of technologies which introduction at the specific enterprise is highly urgent. Also, depending on indicators of partial criteria, it is possible to define the processes’ informatization priority, thus, in turn, the accuracy of planning the whole organization informatization processes increases.

2.3. Formation of the uniform criterion of evaluating the industrial enterprise informatization $\omega(x)$.

The general level of the industrial enterprise informatization is offered to be made by the results of calculation of the integrated criterion of evaluation.

Within the limits of solving the given multi-criterion problem, and also taking into account the investigated elements’ features, it is offered to use the method of multiplicative convolution of criteria. Therefore, calculating the uniform criterion of informatization evaluation is supposed to be made according to the formula:

$$\omega(x) = \beta_1(x)^{v_1(B)} \times \beta_2(x)^{v_2(B)} \times \ldots \times \beta_n(x)^{v_n(B)}$$

Where $\omega(x)$ is the integrated criterion, $\beta_n$ - normalized value of the criterion, $v_j(B)$ – the criterion weight.

2.4. Procedure of calculating aligned and normalized values of criteria ($\varphi_n$).

We use the following two formulae. The choice depends on the negative or positive influence on the specific process rendered by more value of the given partial criterion:

$$\varphi = \frac{\beta_{measured} - \beta_{min}}{\beta_{max} - \beta_{min}}, \quad (1)$$

$$\varphi = \frac{\beta_{max} - \beta_{measured}}{\beta_{max} - \beta_{min}}. \quad (2)$$

For presentation of the calculated aligned and normalized values, it is offered to demonstrate them in Table 2.

| No | Criterion | Normalized and aligned value |
|----|-----------|------------------------------|
| 1  | $\beta_1$ | $\varphi_1$                  |
| 2  | $\beta_2$ | $\varphi_2$                  |
| ...| ...       | ...                          |
| n  | $\beta_n$ | $\varphi_n$                  |
2.5. Definition of weight factors of criteria by the modified T.L. Saaty’s analytic hierarchy process ($V_j^{(B)}$).

With a view of defining the degree of the received criteria importance, and also for accounting the influence of each of them on the integrated one, we will calculate the weight factors of the criteria. Therefore, it is offered to use the modified T.L. Saaty’s analytic hierarchy process [33].

For pair comparison of the criteria, using the evaluation scale, which consists of numerical indicators from 1 to 5 and their return values (Tab. 3), is supposed. These values display degrees of superiority of one criterion over another. In case the considered criterion is less important, other return values are used, namely 1, 1/2 … 1/5.

Table 3. Scale of relative importance.

| Relative importance intensity | Definition | Explanation |
|------------------------------|------------|-------------|
| 0                            | Not compared | The expert finds them difficult to compare |
| 1                            | Identical importance | Equal degree of importance of i and j criteria |
| 3                            | Not essential degree of importance | i criterion is insignificantly more important than j criterion |
| 5                            | Essential degree of importance | i criterion essentially is more important than j criterion |
| 2.4                          | Intermediate values between two next values of the scale | The situation when the conciliatory proposal is necessary, 2 - i criterion has weak advantage before j criterion, 4 - i criterion has appreciable advantage before j criterion |

Return values resulted above numbers

If i criterion at comparison with j criterion is attributed with one of numbers resulted above, j criterion at comparison with i criterion is attributed with the return value

Comparison procedure consists in filling matrixes by the experts. The experts are required to fill only the top part of the matrix (above the main diagonal), as the bottom part of the matrix is filled with return values.

Further the typical matrix of pair comparisons (Tab. 4) is presented.

Table 4. Matrix of pair comparisons.

|     | $w_1$ | $w_2$ | $w_i$ |
|-----|-------|-------|-------|
| $w_1$ | 1     | $a_{12}$ | $a_{1i}$ |
| $w_2$ | $a_{21}$ | 1     | $a_{2i}$ |
| ...   | ...   | ...   | ...   |
| $w_j$ | $a_{j1}$ | $a_{j2}$ | 1     |

2.6. Defining the index of coordination of assessing $\lambda_{pi}$ (IC). Calculating values of the relation of coordination (RC). The analysis of the admissible level of coordination.
In order to process the received matrixes, defining the index of coordination (IC) which reflects the presence of logic relation between the evaluated indicators is necessary. 

For its calculating it is required to define maximum own value of the matrix and its dimension. IC is defined according to the formula [34]:

\[ IC = \frac{\lambda_{\text{max}}}{n-1}, \]  

(3)

Where \( \lambda_{\text{max}} \) - maximum own value of the matrix, \( n \) – the matrix dimension.

For correct checking the coordination of corresponding matrixes it is also necessary to define IC of casual matrixes of the given type (the casual index of coordination - CI).

Therefore, casual matrixes of the same dimension are generated.

The received values are specified in Table 5.

Table 5. CI at the evaluation scale from 1 to 5.

|   | 1    | 2    | 3    | 4    | 5    |
|---|------|------|------|------|------|
|   | 0.000| 0.000| 0.211| 0.423| 0.464|

Further, it is required to define the threshold value of the admissible coordination of the matrix made at the scale 1:5.

Therefore, it is necessary to analyze the admissible level of the matrixes’ coordination by modelling which consists in the analysis of values of the relation of coordination (RC) of the matrix at various deviations of the expert estimations from those corresponding to the matrix completely co-ordinated [35]:

\[ RC = \frac{IC}{ct}, \]  

(4)

By modelling a certain value, which corresponds to maximum RC for the matrixes differing from the ideal one at change of any variable at one step, is defined. When RC of the matrix of the expert estimation becomes more than the threshold value established, it is required either to spend a new interview with the expert or not to take into account the given questionnaire while defining the result of group examination. Other matrixes can be used for calculating the weights of criteria. For every line of the matrix we define \( \chi_j \) [36]:

\[ \chi_j = \left( \prod_{j=1}^{n} a_{ji} \right)^{\frac{1}{n}}, \]

Where \( a_{ji} \) - j criterion assessment at comparison with i criterion in the matrix of the expert estimation, \( n \) - an order of evaluation matrix.

Further, calculating the weights [37] is made:

\[ v_j = \frac{\chi_j}{\sum_{j=1}^{n} \chi_j}. \]

2.7. Calculating the average consolidated estimation using group expertise (\( V^{(A)} \)).

In order to obtain the average consolidated estimation using group expertise, we offer to use the method allowing to evaluate taking in the account experts’ different competence.

After obtaining all sets of criteria assessment from m respondents, for each j criterion the average value of estimation, made by all experts, is calculated by the expected value. The vector characterising the set of the expected value of assessments for each of n criteria (36) is:
Where \( \overline{y_j} \) - the average evaluation of j criterion, obtained by using the expected value.

2.8. Calculating the individual estimation of i expert. Defining consolidated i evaluation with the account of the expert’s error.

On the basis of calculated deviations of individual estimations from the average evaluation, we calculate \( w^{(i)} \) – the weight of individual estimations of i expert. Thereby it is possible to obtain the consolidated evaluation considering errors of experts’ estimations:

\[
\overline{y_j} = \frac{1}{m} \sum_{i=1}^{m} y^{(i)} = \left( \frac{1}{m} \sum_{i=1}^{m} y_1^{(i)}, ..., \frac{1}{m} \sum_{i=1}^{m} y_n^{(i)} \right) = \left( \overline{y_1^{(i)}}, ..., \overline{y_n^{(i)}} \right),
\]

2.9. Defining the enterprise informatization level.

At the given stage, defining the considered enterprise informatization level is conducted. This requires obtaining the relation of the calculated integrated criterion to the integrated criterion at perfect conditions. Therefore, percentage parity, which is required to be correlated with the established percentage parities for each level, is obtained.

Table 6. Levels of manufacture informatization

| Level | Level description | Percentage parity |
|-------|-------------------|------------------|
| 0     | Complete absence of information technologies | 0 |
| 1     | Beginning of IC creation | 0.2 |
| 2     | Repeating processes established | 0.4 |
| 3     | Models of repeating processes used | 0.6 |
| 4     | Processes measured and controlled | 0.8 |
| 5     | IC optimized | 1 |

2.10. Developing recommendations for perfection of the mechanism and areas of digitalization of the industrial enterprise. Substantiation and choice of digitalization spheres, accounting risky environment.

The given stage is offered to be realized by forming the roadmap formation of digitalization which includes stage-by-stage planning the digitalization of processes in the organization depending on the priority of introducing digital technologies in the corresponding process. The priority can be defined through determining the organization informatization level, since, during the given research, it is possible to reveal the organization processes’ “weak spots” and to optimize them by introducing digital technologies. Also the priority depends on how efficient the introduction of one or another technology will be, since cross-cutting technologies are capable to influence a set of processes simultaneously.

It is possible to take into account the risky environment after determining the list of the cross-cutting technologies planned to be realized at the specific enterprise since it depends on their characteristics, e.g., on the scope of changes occurring while introducing the technologies, on material inputs demanded, etc.

3. Results and Discussion

At present the question of conducting digital transformation of organizations, especially large industrial enterprises, is a pressing one for developed countries, including the Russian Federation. In that regard, developing models and algorithms of digital transformation realization is of great scientific and practical value.
The question of conducting the estimation of the level of the organization readiness to implement this transformation is also important, that directly depends on the existing level of using information technologies while realizing all the processes. In the given research the authors offer the approach to determining the given level as the first stage of conducting digital transformation of the organisation.

As a result of the research conducted it is possible to define the objective level of the industrial enterprise informatization in numerical expression by means of mathematical methods. It is also possible to determine the spheres which demand development and to calculate and forecast risks at digitalization of the industrial enterprise. The processes, which demand the deepest revision using cross-cutting technologies, are recommended to be considered as particularly exposed to risks. It will allow to develop recommendations for managing digitalization for the considered organization.

As a result of determining the enterprise informatization level the following results are obtained:
1. Priority cross-cutting technologies for the specific organization is defined.
2. The level of informatization of the organization processes is defined due to which it is possible to prioritize the processes’ digitalization.
3. Accuracy of planning the realization of digital transformation of the organization increases.
4. Owing to the data received during determining the organization informatization level, it is possible to evaluate the risks of digital transformation with higher accuracy.

4. Conclusions
During the research, the following basic scientific results are obtained:
1. The indicators of the digital industrial enterprise are developed.
2. The procedure of organizing the assessment of the industrial enterprise informatization level in conditions of digital economy is developed.
3. The mathematical apparatus for evaluating the enterprise informatization level is developed.
4. The basic possible levels of the industrial enterprise informatization are defined.

References
[1] Digital Enterprise Forum: Electronic resource. Available online: http://www.digenforum.ru/banks/ (reference date: 29.09.2019)
[2] National Technological Initiative: Electronic resource. Available online: http://www.nti2035.ru/nti/ (reference date: 29.09.2019)
[3] Lonskij I I 2015 Informatization and society evolution Perspectives of Science and Education 2 (14) 29-35
[4] Abdrahamanova G I and Kovaleva G G 2009 Tendencies of developing information and communication technologies Forsyte 4 44-55
[5] Odinotsov V A 2009 Organization features of using computer technologies in management of public health services Person Ecology 11 37-42
[6] Akhtyrchenko K V and Sorokvasha TP 2003 Methods and technologies of reengineering of IS Proceedings of System Programming Institute of Russian Academy of Sciences 4 141-162
[7] Svetlakov A G and Glotina I M 2018 Influence of information space on economic safety of the region Regional Economy 2 474-482
[8] Bereznoj A V and Saigitov R T 2016 «Digital revolution» and innovative business models in public health services: global trends and Russian realities Bulletin of Russian Academy of Medical Sciences 3 200-213
[9] Alekseeva O A and Makhrrova O N 2009 Level of informatization of house economy in Russia Economic Science of Modern Russia 2 (45) 117-127
[10] Kazarin S V 2013 Level of the region informatization: system of indicators and analysis of branch variation (example of the Samara Region) Management of Economic Systems: Electronic Journal 12 (60). Available online: https://cyberleninka.ru/article/n/uroven-informatizatsii-regiona-sistema-pokazateley-i-analiz-otraslevoy-variatsii-na-primer-samarskoy-oblasti (reference date: 29.09.2019)
[11] Lugachev M I 2017 Information revolutions, economics and economic education Bulletin of Moscow University. Series 6. Economics 4 142-160
[12] Arkhipova M Yu and Sirotin V P 2019 Regional aspects of developing information-communication and digital technologies in Russia Economy of Region 15 (3) 670-683
[13] Astashov A M and Oshkina L M 2014 Role of information technologies of designing in reforming civil engineering education Integration of Education 4 (77) 116-123
[14] Ashmarova O V and Fedulova E A 2016 Automated management information systems at food enterprises Food Processing: Techniques and technology 41 (2) 170-176
[15] Protchenko A N 2014 Education in society’s informatization Integration of Education 3 (76) 77-82
[16] Illin I, Levina A, Abran A and Iliashenko O 2017 Measurement of enterprise architecture (EA) from an IT perspective Research gaps and measurement avenues. ACM International Conference Proceeding Series, F131936 232-243
[17] Borremans A D, Zaychenko I M and Iliashenko O Yu 2018 Digital economy. IT strategy of the company development MATEC Web of Conferences 170 paper N 01034
[18] Anisiforov A B and Dubgorn A S 2017 Organization of enterprise architecture information monitoring 2920-2930
[19] Kovalenko I I, Sokolitsyn A S and Sokolitsyna N A 2018 The Enterprise's Automated Management Stability System Taking into Account its Life Cycle Stage paper N 8524966 357-360
[20] Fedyakova N N 2016 Improving management information systems at a higher educational institution Integration of Education 2 (20) 198-210
[21] Sorgner A 2017 The Automation of Jobs: A Threat for Employment or a Source of New Entrepreneurial Opportunities? Foresight and STI Governance 11 (3) 37-48 DOI: 10.17323/2500-2597.2017.3.37.48
[22] Krause I 2019 Coworking Space: A Window to the Future of Work? Foresight and STI Governance 13 (2) 52-60 DOI: 10.17323/2500-2597.2019.2.52.60
[23] Maslennikov M I 2017 Technological innovations and their impact on the economy Economy of Region 4 1221-1235
[24] Dezhina I, Ponomarev A and Frolov A 2015 Advanced Manufacturing Technologies in Russia: Outlines of a New Policy Foresight-Russia 9 (1) 20-31 DOI: 10.17323/1995-459x.2015.1.20.31
[25] Anisiforov A, Dubgorn A and Lepekhin A 2019 Organizational and economic changes in the development of enterprise architecture E3S Web of Conferences 110 paper N 02051.
[26] Lyovina A, Kalyazina S, Sinelnikov M and Poljanskih A 2019 Conceptual model of IT-infrastructure for production company: Target vision and development approach. Proceedings of the 33rd International Business Information Management Association Conference, IBIMA: Education Excellence and Innovation Management through Vision 2020
[27] Illin I, Capo D and Lepekhin A 2019 Developing Smart Factory Architecture Model Proceedings of the 33rd International Business Information Management Association Conference, IBIMA: Education Excellence and Innovation Management through Vision 2020
[28] Ermakova Zh A and Pergunova O V 2014 Utilization of information-communication technologies in management of industrial enterprises (methodological tools of efficiency evaluation) Management Issues: Electronic Journal 6 (12). Available online: https://cyberleninka.ru/article/n/ispolzovanie-informatsionno-kommunikatsionnyh-tehnologiy-v-upravlении-na-predpriyatiih-promyshlennosti-metodicheskiy (reference date: 29.09.2019)
[29] Golchevskij J V and Maldrak A V 2013 Five steps on the way to effective informatization of the enterprise Applied Computer Science 3 (45) 23-35
[30] Shaposhnikov V L, Artamkin A S and Horoshun Ch V 2018 Model of diagnostics of the company's informatization for criteria evaluation of its level Bulletin of Russian University of Cooperation 1 (31) 84-90
[31] Kamshilov S G and Prokhorova L V 2014 Methods of assessing the information security of business processes at enterprises Bulletin of Chelyabinsk State University. Management 2 (331) 41-43
[32] Industry 4.0 and the Acatech Maturity Index. Management of digital transformation of companies: Electronic resource. Available online: http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Publikationen/Projektberichte/acutech_STUDIE_rus_Maturity_Index_WEB.pdf (reference date: 29.09.2019)
[33] Tikhomirova A N and Sidorenko E V 2012 Variation of hierarchy analysis method T. Saaty for the reckoning of criteria weights for innovative project estimation Modern Problems of Science and Education: Electronic Journal 2. Available online: https://www.science-education.ru/en/article/view?id=6009 (reference date: 29.09.2019).

[34] Guseva A I, Tikhomirova A N and Sidorenko E V 2010 Modelling the decision-making process using characterizing management Software Products and Systems 1 131-135

[35] Sidorenko E V and Tikhomirova A N 2010 Visualization tools and representations of financial indicators interrelations in expert support system of administrative decisions making process Audit and Finance Analysis 2 354-357

[36] Sidorenko E V 2011 Three-factorial model of the analysis of alternative in the decision-making process Audit and Finance Analysis 1 294-299

[37] Sidorenko E V and Tikhomirova A N 2012 Optimization of process of conducting the scientific-technical expertise of projects in area of nano-biomedical technologies Nanotech 1 (29) 26-28