Modeling of the management strategy of the research process on the basis of a digital model

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Abstract. An important problem of efficiency growth of scientific and technological development by means of a centralized management of the research process is analyzed. The digital modeling of scientific problem solution was studied as an efficient tool of a precise, targeted management of the scientific search. It was shown that one of the priority goals of digitalization consists in a significantly exact and operational numerous calculation of forecasted results under the conditions of innovative development on the basis of use of factors which in reality reflect the conditions and means of system functioning. The theoretical justification of the strategy of a scientific problem modeling is provided. On the basis of the analysis of retrospective information of results of previous research with the help of a multi factor correlation and regressive analysis the digital modeling was carried out which allows creating the management strategy of a scientific problem solution. An example of optimization of the scientific search management strategy based on matrix transformations is given.

1. Introduction
Science is the most efficient sphere of capital investments. The world experience shows that the profit from capital investments into the science makes up 200 % [1]. Every year the expenditures on R&D in the world grow. For the last 50 years the volume of new knowledge grew about two or three times and at the same time the amount of the information reflecting the results of research grew eight or ten times and the volume of funds which are allocated for R&D increased more than 100 times. For example, in the USA the share of the expenditures in the Gross Domestic Product in 2018 made up 2.74 %, in 1950 this ratio was 1 %. China in 2018 spent 2.12 % of its GDP on science and in 1996 this ratio was 0.6 %. Russia has the 34th rank in the world with 1.1% of expenditures on R&D [2–5].

The research shows that neither the gross expenditures for R&D, nor the expenditures for R&D calculated per a researcher do not give any country the result which can provide the “leading positions in the world science”. The volumes of the accumulated investments into R&D, development of scientific schools and R&D experience can be an indicator of these processes. These factors explain, for instance, the leading positions of scientists from Great Britain (70 Nobel Prize Winners) which spends money volumes on R&D comparable with Russia [5]. Science has become a specific human activity. The global organizations sneaked into the scientific institutions. A system of administration and management of science appeared [1, 6–9]. The problem consists in the incompliance of the existing management system of scientific research with the requirements of scientific and...
technological development.

2. The analysis of conceptual foundations of strategy development of the research process

The opinion of specialists of the institute of management problems of the Russian Academy of Sciences is the following: “When we speak about the science management, we should understand that the R&D are the most important management process. Without a literate management of scientific research it is impossible to construct a new digital economy” [6].

The goals of efficiency growth of funds allocated for R&D are connected with the rationing of the work of scientific workers what allows justifying the planning of research and the expenditures on them. The work time standards are one of the most important stimuli and must be found in the foundation of the encouragement system of an efficient work of scientific workers. However the question of rationing of scientific and research work in the scientific community still remains open and disputable as it is possible to assess objectively the justification of the established ratios only taking into account its specific traits [10–12]. The presidium of the Russian Academy of Sciences plans the solution of problems connected with the development of suggestions for criteria development and growth of efficiency of the Russian science [13].

The solution of a set of goals which are connected with the efficiency growth of R&D determined the development of the corresponding standard. The Standard in the clause 4.4 provides “the choice of direction of research with the goal of determination of an optimal variant of research direction on the basis of condition analysis of the problems under analysis including the results of patent research and comparative analysis of variants of possible solutions taking into account the results of forecasted research which were carried out in analogous problems” [14]. Judging from the wording of the focal point of the All Union State Standard it is extremely difficult to determine with a sufficient exactness the optimal variant of research direction.

According to the opinion of the specialists, today an important problem is not only and not so much the use of a computer as a tool of research as the use of informational technologies for the efficiency growth of scientific activity management. New technologies can become a serious support in such areas as planning and the analysis of results of scientific activity [15].

Since 2008 in the Saint Petersburg State University, the informational and analytical system of the R&D maintenance has been working. The information about all current scientific projects which are being implemented by researchers and subdivision of the university is put into this database. The registration in this system is obligatory for all scientific projects. With the help of this system the following tasks are completed. They are: the planning of scientific and research work; record of results of scientific and research activity; analysis and forecast of the activity results; management of scientific research [16].

A possible variant of the creation of working strategies in the Russian Federation on the basis of forecasting are studied and the Presidium of the Russian Academy of Sciences points out that “In the world there exist about 20 models of the economic development but their results vary. It is important to come to a consensus and to adjust all the parameters which are used at the creation of these models. The methodic basis of mathematic modeling is not justified. That’s why the mathematic models give various results. The problem consists in the absence of the tools for the decision making. 99 % of Russian strategies cannot be realized as they do not contain quantitative assessments which are presented in forecasts” [17].

To unambiguously determine the priority direction of the research process and its automation, digital models are needed that can reasonably justify the research strategy, taking into account not only quantitative, but also qualitative parameters.

The goal of research is the develop of the model of a unambiguous definition of the management strategy of the research process at the solution of a scientific objective under the conditions of the innovative development taking into account the real conditions on the basis of a digital model [18].

The objectives are:

1. To study the opportunity of quantitative assessment for the justification of the choice of the
strategy for a scientific task solution on the basis of a digital model.

2. To develop the strategy of a scientific task’s completion on the basis of a digital model.

3. To solve the task of management strategy optimization of scientific search.

3. Example of the strategy determination
   of a scientific problem solution on the basis of a digital model

One of the first stages of the fulfillment of a research work is the analysis of the results of the research that has been accomplished earlier. In the result of such an analysis the factors $x$ are identified which influence the target indicator $Y$. In a general case the challenge consists in the achievement of a desirable result of a target indicator by means of the influence on the factors to achieve. As a rule it is spoken about the search of an extreme point (maximum, minimum). For instance, it can be the increase of the carrying capacity of the road surface or, for instance, the reduction of the accident rate on highways [19]. The statistical information about the materials of research which reflect the values of factors and target indicators which were obtained by a number of researchers with the help of multi-factor correlation and regression analysis can be presented with the help of a function of type:

$$ Y = C_0 \prod_{i=1}^{n} x_i^{\alpha_i}. $$

Here $Y$ – target indicator; $x_i$, $i=1,n$ factors influencing $Y$; $\alpha_i$, $i=1,n$ - index of power which characterizes the “input” of $x_i$ into $Y$; $C_0$ – coefficient [20]. Let us analyze for instance the digital model:

$$ Y=1.231 \ x_1^{1.331} \ x_2^{1.502} \ x_3^{0.432} \ x_4^{0.231} \ x_5^{0.753}. $$

(1)

It is worth emphasizing that the obtained digital model, for instance (1), describes the hyper surface of a specifically studied process what gives the opportunity of realization on this surface of various operations which are connected with the optimization of the strategy of the solution of a specific scientific problem. In order to visualize the solution of the problem let us limit with a three dimensional model which includes the factors $x_1$ and $x_2$ as the factors having the biggest influence on $Y$. Let us use the simplified digital model of the research process $Y=1.231 \ x_1^{1.331} \ x_2^{1.502}$ by means of attributing of various values for $x_1$ and $x_2$ and we will get the calculated values of $Y$. The obtained values allow constructing a three dimensional graphical model, for instance, figure 1, illustrating the surface of the process under analysis with the help of which the search of management strategies can be carried out, for instance, of a maximum $Y$. The curves $1Y$ and $2Y$ are isouquant curves which connect the calculated points with the similar values of target indices.

![Figure 1. Visualization of management strategy](image_url)
The curve $2Y$ connects the calculated points with the similar numerous values of a target indicator, the value of which it is necessary to achieve in the result of scientific research. As we can see from figure 1 and the same value $2Y$ can be achieved by an eternal set of the combination of factors $x_1$ and $x_2$. For instance, the level of the target indicator $1Y$ obtained in the result of research is characterized by its projections $A_1$, $A_2$ and $A_3$. For the achievement of the target indicator $2Y$ from point $A$ an eternal set of variants exists. Let us take three variants, for instance $B$, $C$ and $D$. Every point is characterized by projections $B_i$, $B_2$, $B_3$, $C_i$, $C_2$, $C_3$, $D_i$, $D_2$, $D_3$ and $Bx_i$, $Bx_2$, $Cx_i$, $Cx_2$, $Dx_i$, $Dx_2$, which determine the parameters of the factors at the achievement of the target indicator $2Y$. As we can see in Figure 1, the achievement of the target indicator $2Y$ is accompanied by various combinations of factor values.

As we can see in Figure 1 the achievement of the target indicator $2Y$ is accompanied by various combinations of factors. For example, $OC_{x_1}<OD_{x_1}$, but $OC_{x_2}>OD_{x_2}$. Consequently, in the existing system under analysis the achievement of $2Y$ can be obtained by means of various values of $x_1$ and $x_2$. In dependence on real conditions (economic, technical, organizational and others) the corresponding values of $x_1$ and $x_2$ are selected. From the mathematical point of view the optimal variant is $AB$ as $AB$ is a perpendicular from the point $A$ to overlying isoquant to a tangency in point $B$ and is the shortest distance between the isoquants.

The exemplification of the development strategy of a scientific problem solution in progress can be seen well in Figure 2 in projections with numerical marks. The variants of management strategy can be presented by an infinite set.

Let us analyze three of them. For example, the variant $A_1D_1E_1$ at constant values of the factor $x_1$ and a constant growth of $x_2$ finally provides the achievement of a goal $N$.

Analogously the strategy can develop in directions $A_1F_1G_1$. However the direction in $A_1B_1C_1$ obviously and convincingly prove that an efficient strategy has another direction by means of the movement in the shortest distance between the isoquants. It is worth mentioning that a digital model which is being implemented in the projections with indices also reflects qualitative characteristics of a strategy. For example, on the basis of the distance between the isoquants in the same scale at two various strategies it is possible to calculate indirectly the time costs for their realization. The smaller the distance between them, the surface of the digital model has greater steepness and the more intense the influence of factors on the target indicator.
Figure 3. Visualization of consequences of the deviation from an optimal strategy

It is worth exemplifying the consequences from the deviation of the chosen management strategy. For example, in Figure 3 the operational management \( A_1E_1D_1 \) keeps the direction of the strategy but the dislocation takes place as a result of a significant reduction of the value of factor \( x_1 \) what we can see in the parameters \( E_{x_1} \) and \( E_{x_2} \). The implementation of the management strategy will not lead to the achievement of the target indicator which is shown in point \( N \). After the achievement of the index \( 3Y_1 \) despite a further growth of factors \( x_1 \) and \( x_2 \) (\( H_{x_1} \) and \( H_{x_2} \)), the value of a target indicator will reduce what is seen in the position of point \( H_1 \).

The visualization of the strategy on the basis of a three dimensional graphical model can not be found a complete enough as here only two factors \( x_1 \) and \( x_2 \) of the function (1) out of five are used. For a more detailed determination of the strategy it is indispensible to analyze other combinations of factors.

It is worth mentioning that the direction of the strategy in \( A_1B_1C_1 \) (Fig. 2 and 3) is determined not only by the shortest distance between the isoquants but also by the real conditions of use of factors’ combination which should be optimal.

4. Conclusions

It is proved that on the basis of the digital model it is possible to construct the trajectory of management strategy of a scientific search what will create the prerequisites for the automation of the research activity, for a significant efficiency growth of scientific and technological development. The digitalization is a tool in the management of the scientific search which supposes the use of all management functions: planning, organization, record and control. The digital model is formed on the basis of the set of data types and transformation rules which determine the set of rules of its construction and as a subtype of the general class of the transformation of basic models. The use of a digital model is showed which is formed on the basis of the set of statistical information which reflects various retrospective results of researches of the correlation of target indicators and factors. The visualization of a digital model allows exemplifying the construction of variants of management strategy of a problem’s solution and determining an optimal variant as the shortest distance between the isoquants of the surface which is described by a digital model. The prerequisite of the model exactness is the information redundancy in respect to the model of a single object. It is proved that one of the first order digitalization goals consists in a considerably precise and prompt numerical calculation of the forecasted results of the scientific search under the conditions of the innovative development, on the basis of the use of the factors which reflect in reality the conditions and means of the scientific problem solution. On the basis of the retrospective information of the results of previous
research with the help of multi factor correlation and regression analysis the digital modeling was carried out which allows creating the management strategy of a scientific problem solution.

References

[1] Ryzhakova A V and Manakhov S V 2013 Assessment of the effectiveness of research work in a university Bulletin of the Russian University of Economics G.V. Plekhanov 12 32

[2] Ranking of countries in terms of research and development costs 2019 Institute for Statistical Studies and Economics of Knowledge, Higher School of Economics Retrieved from: https://www.vestifinance.ru/articles/104411?page=10. Accessed 18.07.2019.

[3] R&D Financing in Russia 2019 Retrieved from: https://helpiks.org/3-21533.html. Accessed 22.07.2019

[4] The national economy of the USSR in 1990 (Moscow), pp 9, 307

[5] Podosokorskiy N I 2019 In terms of spending on science as a percentage of GDP, Russia ranked 35th in the world Retrieved from: https://philologist.livejournal.com/9605867.html. Accessed 22.07.2019

[6] Scientific and Practical Conference 2017 “Problems of R&D Management – 2017” Institute of Management Problems named after V.A. Trapeznikov of the Russian Academy of Sciences Retrieved from: http://www.sib-science.info/ru/conferences/fano-gov-v-0112017. Accessed 18.07.2019.

[7] Shchedrovitskiy G P 2019 Science Search Strategy. Forum Fund named after Shchedrovitsky G P Retrieved from: entries/archive/friendshuserinfo. Accessed 18.07.2019.

[8] Dzyun T 1983 Theory of science Translated from the Japanese (Moscow: Nauka Publ.) 192 p

[9] Riehl Alois Adolf 2011 The theory of science and metaphysics from the point of view of philosophical criticism (Moscow: “Librokom” Publ.) 448 p

[10] Feoktistova O A 2014 Rationing of research work: methodological approaches Internet J. “Science of Science” 5(24) Retrieved from: http://naukovedenie.ru.

[11] Kushnir A B 2010 Features of creative work in matters of rationing Bull. of the Res. Instit. of Labor. 23(34) 64–6

[12] Feoktistova O A 2014 Research Cost Planning: A Design Approach Research Financial Institute Financial magazine 1

[13] The meeting of the Presidium of the RAS and members of the Academy 25 June 2019 Retrieved from: https://scientificrussia.ru/articles/vak-ekspertiza-otsenka-deyatelnosti-nauchny-sovety-i-drugie-temy?utm_source=pulse_mail_ru&utm_referrer=https%3A%2F%2Fpulse.mail.ru. Accessed 03.05.2019

[14] GOST 15.101-98 Procedure for the implementation of scientific research

[15] Emelyanov A I 2019 10 theses on automation of science management Retrieved from: https://habr.com/ru/post/123102/. Accessed 03.05.2019

[16] Information and analytical system for supporting research Retrieved from: http://philosophy.spbu.ru/3597. Accessed 03.06.2019.

[17] Mathematical modeling of the Russian economy Meeting of the Presidium of the Russian Academy of Sciences 11 June 2019 Retrieved from: https://scientificrussia.ru/articles/matematichesko-modelirovanie-ekonomiki-rossii?utm_source=pulse_mail_ru&utm_referrer=https%3A%2F%2Fpulse.mail.ru. Accessed 05.06.2019.

[18] Borovik V S, Borovik V V and Prokopenko Yu E 2013 Model for managing the implementation of the new technology based on the production function Economic analysis: theory and practice 42(345) 25–30

[19] Silyanov V V and Domke E R 2016 Transport and operational qualities of roads and city streets (Moscow: Academy), 352 p

[20] Borovik V S and Lukin V A 1995 Justification of measures to ensure traffic safety Car roads 3–4 12–3