Modeling processes of formation and development of agricultural complex using digital technologies

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Abstract. The mathematical toolkit of transformation of a multidimensional space on the basis of approximation of the generalized functions is adapted. A methodical approach to analyzing and regulating the jump-transition parameters in the conditions of extended space and time of resource integration and improving the quality of management was developed. Methods for solving the following tasks have been developed: approximations of generalized and step functions; criterial evaluation of the effect of space-time expansion and the beginning of the jump process for decision-making. The following results are obtained: the mathematical models of jump-like processes are constructed; the impact of additional management functions is interpreted; the effect of space and time expansion digital technologies is identified and determined.

1. Introduction
The integration-balanced organizational and technological management concept has been formulated earlier [1]. It justifies the development of a single methodology and the concretization of the theoretical model. The methods of modeling evolutionary and jump-like processes based on the approximation of generalized functions are mathematically grounded. Methods include assessment of static and dynamic characteristics, indices and criteria for zoning and typification of processes in agriculture that are distinguished by the innovative nature of technological and organizational processes. Also the theoretical model of spatio-temporal integration of resources and inclusion of complex objects are specified, including methods for quantitative modeling of processes for improving the quality of management. The new effect of space and time expansion for the organization of the effects of the application parameters of digital technologies and management methods corresponding to the zones and types of processes is mathematically substantiated and interpreted. The hypothesis of representation of jump-transitions of a high-tech type and innovative methods of management by a certain set of embedded approximation functions corresponding to the number of types of integrable resources and objects is formulated and confirmed.

2. The relevance of modeling the processes of formation and development of the agro-industrial complex using digital technologies
The relevance of modeling the processes of increasing the efficiency of the development of the agro-industrial complex is determined by the complexity of the plans for high-tech transformations. This follows from a long-term project to create a national platform "Digital Agriculture". The goals of the...
revolutionary leap-transition to structures and digital technologies for the development of the agro-
industrial complex, which ensure an increase in labor productivity of about 2 times, were set before
1924 [2]. The creation of a digital platform provides for the integration of technologies in a specialized
system for managing the digital interaction of objects and technology elements using the Internet of
Things methods. A review of business tools for digitalization of the agro-industrial complex with an
assessment of expert opinions in this area confirms the importance of deepening research [3]. It is
necessary to use mathematical tools for modeling business processes, adequate to the peculiarities of
creating and applying breakthrough technologies such as high-tech innovation development (HTID) in
the network of ACC elements and objects. The previously substantiated concept and methodological
approaches (including in the article by A.A. Alabugin of this collection of conference materials) made
it possible to expand the composition of digital business analytics models. It is proposed to implement
an approach to modeling using the model of generalized functions. The necessity and complexity of
their special approximation led to the choice of a complex type of Data Science toolkit. An analytical
representation of such a mathematical model facilitates the adaptation of existing algorithms for
modeling processes. The simulation results are necessary for organizing the development of projects
and computer programs that are necessary for making decisions readable by an electronic device [1]. It
is advisable to use the capabilities of Machine Learning for modeling and examination of projects in
the technology of artificial intelligence neural networks. The use of such tools makes it possible in real
time for several days (not months, as before) the implementation of measures for the preparation of
production of innovative technologies and products. The results of multivariate and multicriteria
analysis make it possible to avoid even testing prototypes of equipment. The need to model the
processes of the formation of the agro-industrial complex in the paradigm of industrial development,
taking into account the key factors of the development of territories to increase labor productivity is
confirmed by many studies [4-7].

It is proved that the quality of control of an acceptable level in the regulation of the objectives of
objects is achievable in the elimination of the paradox of compression of space and time of jump
processes for making the necessary decisions. The paradox is observed in the period of theoretically
instantaneous, and practically during a short duration of time. The requirements for accelerating
transformations are also associated with taking into account its innovative differences in business
development [8]. At the same time, the importance of agile manufacturing resources, common in the
agro-industrial complex, is growing [9]. This determines the need to expand the composition of
personnel competencies and the need to use the resources of education and science in it [10-12].

3. Scientific novelty. Modeling of processes of improving the quality of management in digital
technology of resource integration in the agro-industrial complex
The results of modeling the processes of improving the quality of management and innovation in a
number of sectors of the economy are known in the areas of green innovation on sustainability
performance, taking into account the risks and opportunities for the progress of digitalization [13, 14].
It is advisable to use the proposals of the relevant researchers to follow the paradigm of high-tech
development of industries [15,16]. The previously substantiated concept and methodology determine
the accounting in modeling the educational resources of universities [10] and the experience of using
the Total Quality Management in the context of Industry 4.0 [11]. Modeling improving innovation
efficiency of emerging economies [12] was used by us at the stage of modernizing digital technology
in the agro-industrial complex.

To analyze the process of jump-transition organization, we will highlight the area of 1 evolutionary
formation of additional functions and the area 2 of creation of the Center's management structures
(Figure 1) [13]. In the ranges of 0.15 ... 0 and 0...0.15 changes in factors can be represented by a leap-
the transition to high technology or a new organizational method. Such transitions are not effective
enough in the Cycle 2, using only the basic standard management functions of individual objects in the
absence of integration of their resources and cooperation in the complex.
The increase in the integration space of possible resources (corresponding to the W1 constituent of the spatial direction of the theoretical model) necessitates the analysis of parameters of the jump-transition. This will allow us to investigate the possibilities of reducing the influence of the paradoxes of the zero extension of the transition time and the unpredictability of the behavior of non-closed systems (Laplace) [14]. Indeed, time and material resources are needed for organizational and technological changes (setting goals, planning and implementing management decisions, plans or projects). This led to the development of mathematically grounded methods of “extending the time interval” for the implementation of short-term technological and organizational solutions of the jump-like types [15]. We showed that a noticeable value of the expansion is achieved by approximating the increasing number of nested functions in the range $A = (9,10,11)$. Here we have the planar representation of the effect of space-time expansion is given in Cycle 1 of the processes of the jump-transition from conditions of imbalance of goals to Cycle 2 of the processes of other type (1):

$$H_g(x) = 0.5(1 + \sin(A(A(A(A(A(A(x)))))))));$$

$$H_{10}(x) = 0.5(1 + \sin(A(A(A(A(A(A(x)))))))));$$

$$H_{11}(x) = 0.5(1 + \sin(A(A(A(A(A(A(x))))))))),$$

where $A(x) = \frac{\pi}{2} \sin x$.

**Figure 1.** The representation of the static estimate of the effect of the space-time expansion of the jump-transition in agriculture complex.

The thickness of the lines in the figure increases as the number of approximating functions increases, interpreting the increase in the integration of resources and the effectiveness of innovation factors. At $A=18$, the approximation corresponds to the maximum approximation of the delta-function (vertical line in Figure 1).

The static representation of processes is sufficient for estimates at the current time of the planned period with small factors. In particular, the management of the objects of the complex may be interested in the results of the integration and convergence effects of its coordination Center. It is advisable to quantify the reduction in the imbalance of goals of efficiency ($H$) and innovation during the time ($\delta$) in the Cycle 2 in comparison with Cycle 1. This can be established by the ratio of areas of the interaction zone of complex objects bounded by dashed lines. Moreover, $S_{c1}$ corresponds to zone 1 of the implementation of medium-technological processes on the basis of the application of evolutionarily added control functions, and $S_{c2}$ corresponds to zone 3 of evolutionary changes in management structures during the formation of the Center. Such areas representing the processes and results in the space of the regions of impact of functions and control structures in the cycles are proposed to be evaluated in accordance with Figure 2. However, they do not reflect the dynamics of processes. The static criteria for improving the quality of management in the final increments are as follows (2):
\[ |H_i(x) \cdot x_{c2}| \geq |H_i(x) \cdot x_{c1}|; \frac{H_i(x) \cdot x_{c22}}{H_i(x) \cdot x_{c21}} \geq 1. \] (2)

Obviously, the inadequacy of static estimates characterizes mainly the zones of the processes of evolutionary development. The zone of the detected short-term jump-jump effect (in the range of 0.05 ... 0.05) should be investigated on the basis of estimates of dynamic processes under strong perturbations in terms of intensity and velocity of factor influences.

The new ways of improving the quality of control for the jump development of complex systems are defined in this way, we propose to call the effect of a conditional "stretching" of the time for making decisions and regulating the dynamics of processes in the space of resource integration and cooperation of complex objects. An increase in the effect of integration of these types of resources with an increase in the number of nested functions from 9 to 11 is established. This confirms the hypothesis of a more efficient HTID of jump-like type with an improvement in the quality of managing the integration of a certain number of resource types of these objects in the extended cooperative space in the complex.

Evaluation of the criteria for integration and convergence of trajectories of the indicator-property of HTID on the indicators of regulation of the number of nested functions and positive synergism of the interaction of objects is possible on the basis of the first derivatives of the functions (2) that determine successive approximations \( \frac{dH_9(x)}{dx} \), \( \frac{dH_{10}(x)}{dx} \) and \( \frac{dH_{11}(x)}{dx} \) for the function in the given space-time interval (minimal in the range of 0.05...0.05, the maximum in the range of 0.15...0.15). This corresponds to an increase in the speed of implementation of management decisions on the development of facilities with the increasing number and diversity of integrable resources (Figure 2).

Manifestations of new properties of the "mechanics" of the organizational behavior of a complex system (named by analogy with quantum mechanics) can be more fully depicted in a three-dimensional space. The properties of flexibility of space and time have been discovered in the measurements of the interrelationships of complex objects. We have the need to increase their number and diversify the integrable resources cause an increase in the multifactority and complexity of functional and probabilistic impacts on the studied property indicators of the dynamics of processes.

Figure 2. The cycles of dynamic effects of space-time expansion are the resources of the efficiency of the complex of objects.

The height of the approximation peak (amplitude) can be determined by differentiating the approximating functions of the considered sequence \( H_n(x) = 0.5(1 + f_n(x)) \):
\[ \frac{dH_n(x)}{dx} = \frac{\pi^{n-1}}{2^n} \prod_{k=1}^{n-1} \cos \left( \frac{\pi}{2} f_{k}(x) \right) \cdot \cos x. \]  

Substituting the resulting expression for the derivatives \( x=0 \), taking into account the parity of the delta-functions, we find the maximum value \( A_n \) (4):

\[ A_n = \frac{\pi^{n-1}}{2^n}. \] 

This value is achievable in zone 2 of realization of structural-revolutionary processes such as HTID. The criterion for the zone of the equilibrium state of the system is the values of the approximating functions in the neighborhood of the point \( x=0 \).

4. Practical significance

Managed expansion of the space and time of decision making increases the possibility of reducing the uncertainty of organizational behavior in an open complex system of complex objects. This increases the period of time for the application of additional functions and indicators of their integration-balancing impact on the regulation of the imbalance of efficiency goals and the innovative nature of the development of the complex's facilities. The Center for coordination of their actions ensures the quality of managerial decisions, which makes it possible to increase the predetermination of trajectories even of the jump development.

We have justified the zones of correspondence to the conditions of stable convergence of trajectories when integrating resources with the number of embedded functions 9, 10 and 11 in statics (by the criterion of formula (2) for small perturbations. In dynamics (according to criterion (9) with significant influences of HTID factors in the effect zone, the maximum and stable value of the indicator-property of the system in the evaluation of formula (4) is achieved. To estimate the beginning of the HTID jump process in the range of the effect, we propose the following procedure: determination of the rates of increase of the exponent-property by the formula (4) of the approximations with the number of nested functions 9, 10, 11; calculation of the derivatives with respect to directions of the vectors of these functions at the same time in the ranges of preparation of managerial decisions (-0.15 ... 0) and their implementation (0 ... 0.15); the construction of tangent ray vectors to the graphs of the dependencies of the functions 9, 10, 11 at the points \( x=0 \) and corresponding to these moments; the definition of the points of bifurcations of the vector fields of these functions (shaded in Figure 2). In practice, the criterion means the equality of relative increments of actual performance indicators and innovation in development at the time of their evaluation. The result of their control at the Center should be the decision to start joint actions of the project participants of the HTID complex.

5. Conclusion

Thus, the following scientific and practical results were obtained and reflected in the paper:

1. Proposals on the new application of mathematical tools for transforming multidimensional space and approximation of generalized functions in static and dynamic processes differ in the possibilities of modeling jump technological development and organizational behavior. Earlier this was possible only in technical systems [16]. The quantitative criteria and quality indicators of management are substantiated, which estimate the static and dynamic parameters of beginning of the jump and the rate of change.

2. Application of research results will improve the quality of management of innovative development of objects of the complex. It is achieved on the basis of expanding the space and time of regulatory impacts of quality indicators of the application of new functions of resource integration of improving the development efficiency of the complex. The addition of mathematical and organizational tools contributes to the improvement of the accuracy of analytical assessments and the
effectiveness of integration-balancing management decisions on the factors of innovation in development using digital technologies.

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