



APPROACHES TO RISK FORMALIZATIONS FOR EVOLUTIONARY SYSTEMS MANAGING

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Received 19.09.2024.
Revised 11.02.2025.
Accepted 28.02.2025.

Keywords:

*Risk, Formalism, Assessing Risk,
Generalized Property, Private
Properties, Evolving System*

ABSTRACT

Risk is an interdisciplinary concept, and in some cases, it can function as a category. It is associated with human activity and reflects the impact of uncertainty on the results of activities. It can have both quantum (risk as an event) and wave (risk as a process) characteristics. To use the concept of risk constructively in management tasks, it is necessary to formalise it. Risk can be formalised in terms of three fundamental dimensions: possibility (frequency), consequences (damage) and goal achievement (quality). The pairwise combination of these properties in the formalisation of risk leads to nine formal measures: Bayesian risk (a posteriori estimation of error); risk as a measure of stability in phase space; risk as a measure of inconsistency of expert judgments; risk as a combination of probability and damage of an event; relative risk; risk as an anti-potential of development; risk as a measure of difference of states; risk as a consequence of playing with nature; risk as the difficulty of achieving a goal. A management model of an evolving system is considered, which makes it possible to combine the obtained formal risk measures in a paradigm, which provides the possibility of long-term forecasting of the behaviour of the system under study and modelling the reaction of this system to a given change in the parameters describing it and the environment external to it. As a basis for the complex joint use of the following basic ideas are proposed: a method of tracking the dynamics of the selected indicator in the phase space of states; tracking not the indicator itself, but the centre of quasi-attractors of its trajectories; construction of the area of permissible values of the indicator (the centre of quasi-attractors) in this space; if there is a target value, tracking the risk of not achieving the target and determining the frequency of motion control; tracking the causes of variability of the system under study, identifying special causes of variability; predicting the state of the system in the future by the movement of the centre of quasi-attractors. The joint application of these ideas is a method of stress testing the system under consideration to significant external and internal changes, which makes it possible to find the limits of its stability and work out scenarios for managing the system in emergency and crisis situations.



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1. INTRODUCTION

Corpuscular wave dualism (or quantum wave dualism) is a property of nature in which material microscopic objects can exhibit properties of classical waves under some conditions and properties of classical particles under other conditions. The idea of corpuscular wave dualism was used in the development of quantum mechanics to interpret phenomena observed in the microcosm in terms of classical concepts. Quantum objects are neither classical waves nor classical particles, manifesting properties of the former or the latter only depending on the conditions of the experiments performed on them. The corpuscular-wave dualism is inexplicable within the framework of classical physics and can only be interpreted in terms of quantum mechanics.

Similarly, risk is understood by different researchers as either an event or a process. This difference in perception is partly dictated by the basic theoretical background of the researcher.

For example, specialists in the field of mathematical statistics and probability theory prefer to view risk as an event, as this approach allows the use of a rich set of tools developed in this field of knowledge to describe this event in some state space and to obtain a quantitative measure for subsequent comparison of different assessments. In this approach, risk is considered in terms of the probability of occurrence of the event itself and the expected damage to the risk taker from that event. In essence, the expected loss (i.e. what the subject is willing to risk) is reduced by a fraction proportional to the probability of the risk event. The most obvious example of this approach is insurance against frequently recurring accidents (e.g. traffic accidents, common diseases, failure of technical devices and mechanisms, etc.). In this case, the researcher has representative statistics which he can process (analyse) and obtain the distributions and analytical dependencies necessary for evaluation.

This includes attempts to relate risk to uncertainty. This introduces the concept of uncertainty, rules for modelling it and ways of determining the probability associated with risk. In doing so, they define a probability space in which to work with risk. At the same time, it is often argued that both concepts, uncertainty and probability, are fundamental and therefore cannot be defined. At the heart of such axiomatic attitudes is set theory. It uses the basic notion of a set. There is no definition of a set (like any other basic concept in any theory). A set can be described informally as a set of objects that have some common properties (i.e. the concept of 'set' is expressed here by the concept of 'set'). A set is many things that we think of as one," wrote Georg Cantor.

Specialists, if I may say so, with "basic engineering training", who tend towards applied mathematical knowledge, consider risk as a process (in the limit - a

wave process), which has points of maximum and minimum impact, at which resonance phenomena (mutual strengthening or weakening) of various risk factors are possible. In this approach, risk is considered as a measure of failure to achieve the goal set by the risk subject, i.e. it is an assessment of the quality of the organisation of a purposeful process of some activity. The occurrence of a risk event requires the occurrence of a certain point in time, the so-called "Kairos".

An example is the task of removing a large vessel stranded on a shoal at low tide. It is extremely costly to divert a large vessel to 'high tide' if you start at low tide, but virtually worthless if you know the tidal cycle and simply wait for the right moment. Such events are rare, and to respond appropriately requires not analysis (because there is often little to analyse) but risk synthesis. It is necessary to analyse all the known information about the place where a risk event is expected to occur, as well as about the object that may be exposed to the risk, and then to perform a risk synthesis and assess the possibility of achieving the goal (which will consist in maximum risk avoidance).

Risk synthesis is a purposeful, time-dependent process aimed at minimising or maximising some quality criterion directly related to the functions performed by the system under consideration, the type, characteristics or parameters of this system under given constraints.

In other words, depending on the totality of factors and characteristics of the risk object itself (and the risky subject), risk manifests itself in two ways.

And its analysis or assessment should be carried out considering this wave-event duality of risk assessment, without substituting one assessment tool for another. The blind transfer of probabilistic analysis to the field of risk synthesis leads to disastrous consequences (although it may provide estimates that are acceptable to the risk taker for a short planning horizon).

However, the risk of an object (process) is a value proportional to the deviation from the quality benchmark of the object (process). Quality and risk can be measured on comparable scales. In this case, the measure of risk is the threat of a change in one or more properties of an object or its environment, or the manifestation of changes associated with the emergence of undesirable processes caused by anthropogenic or natural influences.

In one way or another, the frequency of undesirable events, possible damage and quality (more precisely, its change) appear in all risk measures. This fact allows us to generalise the risk measures presented above in the form of a "matrix of risk measures" (Bochkov & Lesnykh, 2024).

2. ABOUT EVOLVING SYSTEMS

An evolutionary system is a type (class) of systems in which it is reproduced with some mutation (because of which the elements most adapted to the changed environment survive, and the least adapted ones die). One of the developers of the theory of these systems is B. Bantam. Evolutionary systems are characterized by "moving balance and dynamics of co-evolutionary interactions that cannot be foreseen in advance." Risk factors monitoring, for example is also considered as an information process. As a result, the main direction of this information process is to reduce uncertainty in risk assessment and management. The monitoring process in this context can be considered a supporting process. The uniqueness of evolutionary systems, the properties of which are in many ways are in keeping with the so-called homeostatic systems. The term was proposed by American physiologist Walter B. Cannon in 1932 proposed this term as the name for "coordinated physiological processes that support most stable states of the body" (Cannon, 1932). Hereinafter this term extended to the ability to maintain dynamically the constancy of its internal state of any open system. However, the idea of the constancy of the internal structure was formulated as early as in 1878 by the French scientist Claude Bernard.

To describe the behaviour of any system in space and time, you need to specify the initial parameters of motion, that is there must be a certain value of $x(t_0)$ - the coordinate of the material point in the phase space of states at the initial moment of time $t = t_0$, and you need to know the trajectory of motion of the material point in some phase space of states (PSS). Such a trajectory allows you to compare the real dynamics of the system in the PSS and the theoretical one obtained from the equations of motion. For example, Eskov et al. (2015) draws attention to this circumstance. As the researcher notes rightly this circumstance is the basis of the entire deterministic approach in physics and mechanics. The setting of $x(t_0)$ and the description of $x(t_k)$ in the form of equations (kinematics or dynamics) must occur exactly (this is an ideal theoretical construction within the determinism) or within the statistical functions of distribution $f(x_k)$. In general, classical dynamics states (Moon, 1980) that provided that the forces acting between the particles, as well as the initial positions and speed of the particles, are given, in principle, it is possible to predict the movement or development of the system for any desired late point in time. But the rapidly growing computational power of computers, as it turned out, far from always can predict the behaviour of even simple dynamic systems, which was called chaotic. In modern literature, the term "chaotic" is applied to such movements in deterministic physical and mathematical systems, the trajectories of which reveal a strong dependence on initial conditions.

For dissipative systems that I. R. Prigozhin studied, chaotic dynamics develop within a certain structure. This structure is not easily seen by common methods of

studying dynamics. It is necessary to study the behaviour of the system in the PSS (along the axes of which the coordinate and speed are marked). Here it can be found, for example, that chaotic motions have a new geometric property called fractal structure. I. Prigozhin said: "Unique systems are not the object of science," emphasizing the impossibility of describing the behaviour of complex systems of this type within the framework of deterministic and stochastic approaches, since such systems are completely uncertain (at any time interval T) and we cannot describe them accurately (or even approximately). They are not predictable, and this is their uniqueness. Such systems include many biosystems (including the human body), social, economic, political systems, including the Earth's biosphere. The peculiarity of the behaviour and evolution of unique systems - repeatability without repetition - has been noticed Eskov et al. (2017). The significance of this effect lies in the absence of arbitrary repetition in successive samples of any indicator characterising the behaviour of such a system, i.e. it is the absence of statistical stability in the description of homeostatic systems.

The beginning of the evolution (development) of the observed system we considering the displacement as defined as permissible limits of deviations in the position of the centers of quasi-attractors of the same object (system) during Δt . At the same time, the quasi-attractor is some area of PSS in which the observed state of the system is set (that is, this state is not determined with a specific point, but some centroid of the cluster of points characterizing the stable (constant) state of the system). At the same time, however, there is a problem of determining the measure of such constancy, that is, at what values of the change in the parameters of the quasi-attractor it can be considered that the observed system is in stationary mode.

Management, as a concept, means study, accurate calculation, fixation and control. The strategy and tactics of management are determined not by analysis, but by the synthesis of information. The study includes the synthesis of information. The management task must be uniquely defined in an algorithm containing an accurate calculation of the time and place of each action. The goal of the management is to transfer the system by making some movement from the current state to the desired state.

3. TRAJECTORY ANALYSIS IN PHASE SPACE OF STATE

In Bernshtein, 2017, Bochkov (2019) note that any measurements of the kinematic characteristics of unique (in the sense of I. Prigozhin) systems in the general case can occur in some kind of phase space of states (PSS), the simplest of which can include three coordinates of the measurement of the system state vector - the state vector in the form of $x = x(t) = (x_1, x_2, x_3)^T$. In such PSS for

any unique system, $x_1(t)$ is the real coordinate of the material point, $x_2 = \frac{dx}{dt} = v(t)$ is the speed and $x_3 = \frac{dx_2}{dt} = a(t)$ is the acceleration of the movement of both the physical material point and the system as a whole. The evolution of the system, as a rule, is aimed at some kind of final state. But this state is not given by a point in the PSS, but by some area of the phase space, which is defined as a quasi-attractor (QA). This QA can be precisely defined, if only artificially and specifically set external management actions. Thus, evolution for the studied class of systems is partially manageable. At the same time, it is necessary to calculate the volumes of QA, the coordinates of their centers, as well as the speeds of these centers in the PSS. In other words, we are talking about the kinematics of the system, about the features of its movement in the PSS. At the same time, as the authors of the effect note, it is always necessary to keep in mind the possibility and reality of the x coordinates going beyond the limits of 3σ , 9σ and even 20σ .

The main conclusion obtained by the authors is the absence of a unique system of conditions under which one could talk about some kind of similarity of two of any states. And if we talk more narrowly - about some (even short) stable state in the segment Δt of their state vector in the PSS. In other words, the concept of stationary mode in terms of "state vector" and "PSS" offers the identification of similarity (conformity) of systems, objects, processes. The motion of the state vector occurs within QA, that is, the limited volumes of the PSS. For such a special movement (evolution), the concepts of such speed and acceleration of movement are introduced.

As the main criteria for the non-zero speed of the QA center and the criteria for a significant or insignificant change in the volume of the QA, it is proposed to consider the product of variation scales. The movement of the QA center is calculated in a co-ordinate manner and, if there is a displacement over all coordinates by a value that exceeds the sum of halves of the initial variation scale, then we can talk about significant changes in the system. At the same time these displacements should occur at all coordinates of the entire PSS. In general, it is necessary to consider the co-ordinate radii. Exceeding the sum of these radii at all coordinates for the real distance between the centers of the initial and final QA, signifies a significant displacement of the center of the quasi-attractor during Δt . If this is observed in individual coordinates, then it is proposed to talk about the beginning of a significant displacement of the QA in the PSS.

Thus, the positions of the centers of the QA of the same object (system) are compared during Δt by the distances of displacement of the centers of the initial of the quasi-attractor (QA1) and the final quasi-attract (QA2). The authors introduced two units of measurement. The first, minimum (or initial) unit when the center QA2 goes left

or right beyond the variation range Δx_i^1 for QA1. The second, maximum (real) conditional unit when $z = \frac{R_i^*}{R_i} \geq 1$ (R_i^* is real, and R_i is the minimum distance between the centers QA1 and QA2) and when $R_i^* \geq r_i^1 + r_i^2$ ($r_i^1 = \frac{\Delta x_i^1}{2}$, $r_i^2 = \frac{\Delta x_i^2}{2}$ is the co-ordinate radius QA1 and QA2, respectively). In general, if $R_i = R_i^*$, then such distance acts as the unit of measurement of the displacement itself (is estimated by $z \geq 1$). At the same time, you can introduce the concept of the average speed of this displacement. In general, according to the authors, the stationary mode will be characterized by such system parameters when there are no significant changes in the QA parameters.

In this case similar arguments were used: in the framework of the so-called trajectory analysis (Bochkov, 2017), it is proposed to represent the intensity of change in the specific value of the selected indicator by the time function $y(t)$. Its analogue in physics is instantaneous speed. Then, for any period $[t_1, t_2]$, the value of the indicator will be defined as $\int_{t_1}^{t_2} y(t)dt$. Three periods are taken as the basis, in the limit case: I_0 - the specific value of the indicator expected (declared, but not actual) for the current period; I_{-1} - specific value of the indicator for the previous period (actual) and I_{-2} - specific value of the indicator two periods ago (from the current).

Formally, you can write these three integrals as:

$$\int_0^1 y(t)dt = I_0; \int_{-1}^0 y(t)dt = I_{-1}; \int_{-2}^{-1} y(t)dt = I_{-2}. \quad (1)$$

Further for each compared system (or considered variants of one system), the trajectory of changing of its "capacity" $y(t)$ is drawn. In the simplest case, the law of changing the values of $y(t)$ has the form of a uniformly accelerating (uniformly slowing) movement:

$$y(t) = y_0 + v \cdot t + a \cdot \frac{t^2}{2}, \quad (2)$$

where y_0 - assessment of the specific value of the indicator at the beginning of measurements in the current period; v is the average accumulation speed $y(t)$; a is the average acceleration (speed of change of value v).

If $v > 0$ this means that (according to assessments of I_0 , I_{-1} , I_{-2}) the specific change in the value of the goal indicator increases; if, on the contrary, $v < 0$, then falls; if $v = 0$, then it is maintained at the same level during the considered three periods. Similarly, the acceleration indicator a is interpreted: the value $a > 0$ means that the system "on take-off" - the speed of change in the value of the goal indicator at the end of the analyzed three-stage period grows faster than the average; the value $a < 0$ may mean that although the speed of change of the goal value is increasing, the speed increase is decreasing. Nine

conditional control areas with characteristic value v and a are possible (Fig. 1). The purpose of the management in this case is to direct the trajectory of the QA centers of the system to the area in which the best conditions for achieving the development goal are provided.

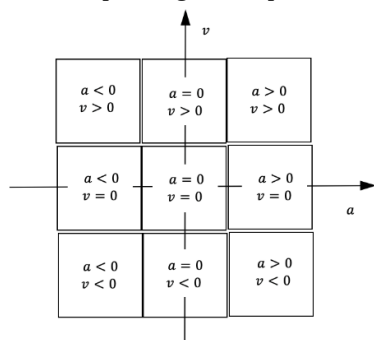


Figure 1. Characteristic areas of speed and acceleration values of assessed indicator in phase space of states

Formally we can get a correspondence between the three values of y_0 , v , a and the three values of I_0 , I_{-1} , I_{-2} . Substituting expression for $y(t)$ in integrals of I_0 , I_{-1} , I_{-2} we will receive, respectively:

$$\begin{aligned} I_0 &= y_0 + \frac{v}{2} + \frac{a}{6}; \\ I_{-1} &= y_0 - \frac{v}{2} + \frac{a}{6}; \\ I_{-2} &= y_0 - \frac{3v}{2} + \frac{7a}{6}. \end{aligned}$$

Solving three equations with three unknowns, we find the values of y_0 , v , a :

$$\begin{cases} y_0 = \frac{2I_0 + 5I_{-1} - I_{-2}}{6}; \\ v = I_0 - I_{-1}; \\ a = I_0 - 2I_{-1} + I_{-2}. \end{cases} \quad (3)$$

The values of y_0 , v , a vary from system to system and make sense of "average" assessments of their trajectory over the three considered periods. Since these indicators smooth out "seasonal" and other diffusion factors, it is better to normalize them. When displaying common characteristics, group indicators are interesting above all others, and then the relative position of the values of each system relative to the group indicator. Thus, two such indicators have been introduced.

The first is the relative acceleration factor (q_a), calculated as the ratio of the sum of the change in the value of the goal indicator in the current (I_0) and previous period (I_{-2}) to the change in the value of the goal indicator in the previous period (I_{-1}). Changes in the value of the goal for the previous period (I_{-1}) are selected since this is the closest of the confirmed assessments

$$q_a = \frac{I_0}{I_{-1}} + \frac{I_{-2}}{I_{-1}} = \frac{a}{I_{-1}} + 2. \quad (4)$$

It is seen to be that q_a - a measure of "failure" in changing the value of the goal indicator into the previous (I_{-1}) ($q_a \gg 2$) or current (I_0) ($q_a \ll 2$) periods. That is indirectly factor q_a is a factor for assessment of trend instability (with large deviations from 2) and, conversely, a trend stability indicator for values of q_a close to 2. A priori, it can be considered that the instability of the q_a and the downward trend are "suspicious," since they are associated with the "reorganization" of the system and clarification is required: if the system in its new state is a successor to the capabilities of its predecessor. In addition, a steady "fall" ($q_a \cong 2$) with a negative trend is not exactly what it is needed for development, it is important to know the meaning of the second factor.

The second factor (q_v) shows the relative growth speed of the system goal over the last two periods:

$$q_v = \frac{I_0}{I_{-1}} = \frac{v}{I_{-1}} + 1. \quad (5)$$

This indicator naturally correlates with the first indicator as part of it. Its adequacy is somewhat weaker.

To visualize a change in the possible value of factors depending on changes in the state of the system, it is useful to move from indicators q_a and q_v through affine transformations to a pair of related normalized indicators - F_a and F_{va} , which specify a geometric image that is called a "goal."

The first factor F_a is obtained by simply normalizing the factor q_a

$$F_a = \frac{q_a - c_a}{L_a}, \quad (-1 \leq F_a \leq 1), \quad (6)$$

where c_a is the center of the goal along the abscissa axis, and L_a is the size of half the side of the section square.

The second normalized factor F_{va} is obtained by a linear combination of acceleration factors q_a and speed q_v :

$$F_{va} = \frac{q_a - c_a - \mu \times (q_v - c_v)}{L_{va}}, \quad (-1 \leq F_{va} \leq 1). \quad (7)$$

The effect that the speed grows with increasing acceleration is considered by the fact that this "additive" is subtracted with a coefficient $\mu > 0$, which is determined, like constants c_a, c_v, L_a, L_{va} , based on the analysis of group data. Geometrically, the position of the square goal ($F_a \times F_{va}$) with a size of $[-1, +1] \times [-1, +1]$ on the plane of factors q_a (abscissa) and q_v (ordinate) will appear as parallelogram ABCD (Fig. 2). Point A corresponds to point $\{F_a = -1; F_{va} = +1\}$. Point B corresponds to point $\{F_a = -1; F_{va} = -1\}$. Point C

corresponds to point $\{F_a = +1; F_{va} = -1\}$. Point D corresponds to point $\{F_a = +1; F_{va} = +1\}$.

Since the transformations are affine, it is obvious that the center of the goal with coordinates $(c_a; c_v)$ - the point of intersection of the diagonals corresponds to the center of the square goal, the coordinates $\{F_a = 0; F_{va} = 0\}$. In Fig. 2, it is shown that the value of the coefficient $\mu > 0$ is equal to the tangent of the tilting angle of the side (DA) to the axis of the ordinates.

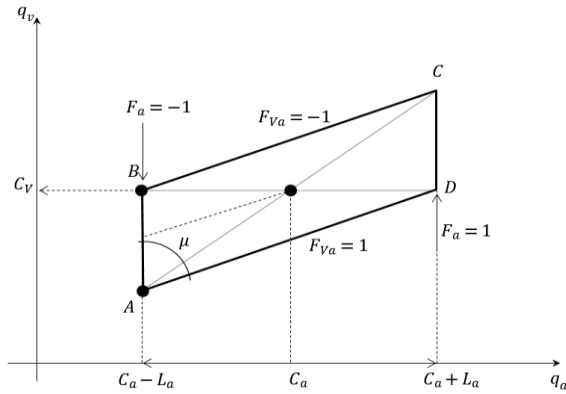


Figure 2. Appearance and main parameters of "goal" in phase space of states

According to the group analysis, the size and tilting of the goal were determined using a modified method of reference vectors.

Knowing the "reference" trajectory passing through the center of the goal, it is possible to assess in percentage terms the level of "marginal nonoptimality" of the trajectories of the system ψ in the form of "overload" or "underload" to the standard if it was given the opportunity to implement the "optimal development scenario" in the current period

$$\psi = \frac{I_0 - I_0^*}{I_0^*}. \quad (8)$$

Closer than this relative value (in percent), the system will not approach the optimum. Calculating the values of deviations of the system trajectory from the optimum in the current period δ_0 and assessing the optimal "expected" deviation δ_0^+ in the future period (from the assumption that it is not necessary to "shift" the goal)

$$\begin{aligned} \delta_0 &= \frac{I_{-2}}{I_{-1}} - \Theta^*; \\ \delta_0^+ &= \frac{I_{-1}}{I_0} - \Theta^* \end{aligned} \quad (9)$$

it is possible to develop the indicator of "progress" of the system ξ in the form of the difference of the above-stated assessments rated through logistic curves. The type of logistic curves should be selected from the considerations that remaining a "leader" is also progress, and a slight

improvement in the "outsider" is better not to consider significant progress.

In general, to determine the belonging of the point characterizing the current position of the system to the parallelogram (or any polygonal curve), limiting the area of stable trajectories of movement on the PSS, it is enough to calculate the Cauchy integral and compare it with the value of the function at the point under test. If they match, the point lies in the contour line. According to Cauchy's integral theorem, if the point does not lie in the contour line, that is, the sub-integral formula does not reduce to infinity anywhere, then the integral is zero (Sveshnikov & Tikhonov, 1967). Thus, it is enough to check the equality of the integral to zero: equal to zero - a point is outside the contour line, different from zero - a point is in the contour line.

It is important to understand that the described "goal" model considers the trajectories of indicators of a goaled system without considering "diffusion" components. It is only the basic element for increasing the sets and indicators for a valid branched system for monitoring the behaviour of a developing system when it moves to its goal value. It is expected that assessments of the current state and especially assessments of "progress" on different indicators will partially contradict each other. In this case, you will need to treat indexes and indicators as elements of decision logic, make an analog-digital conversion of indicators into logical variables, and build a "new" logic for eliminating contradictions.

4. CASE STUDY

As an example of using the approach described above, let us consider the unique system that appeared at the beginning of last year and exists to date - the current pandemic of coronavirus infection caused by coronavirus SARS-CoV-2. The outbreak was first recorded in Wuhan, China, in December 2019 (Huang et al., 2020). The outbreak was declared an international public health emergency by the World Health Organization on the 30th January 2020 and on the 11th March - a pandemic. The pandemic COVID-19 caused serious socio-economic consequences, including the largest global recession after the Great Depression and mass famine, affecting about 265 million people. This led to the postponement or cancellation of many sporting, religious, political and cultural events, and the widespread shortage of supplies was aggravated by panic purchases. Emissions of pollutants and greenhouse gases have decreased. Schools, universities and colleges were closed either nationally or locally in 172 countries, affecting approximately 98.5 per cent of the world's school and student population. Misinformation about the virus spread through social networks and the media.

Attempts to describe the spread of the pandemic of COVID-19 with methods of mathematical modeling and Big Data analysis practically have no clear effect up to

date. Models describe well-known data, but forecasts have extremely low accuracy (Huang et al., 2020; Khakharia et al., 2020; Niazkar & Niazkar, 2020).

Let us consider the behavior of the unique evolutionary system COVID-19 in the proposed paradigm. As the indicator describing this unique system, we take the indicator of the growth of infected people over time. The goal of the management is to move the values of the selected indicator in phase space into the area of zero values of speed and acceleration of changes in its values. The indicator of the correctness of the efforts made during the "life" of the system under consideration is mainly negative values of the coordinates of the phase space, which indicate a slowdown in the movement of the system up to its complete "stop."

In this context, a very significant comparison of the behavior of the described system in different countries against the background of measures taken by the government and epidemiological services is very illustrative. Fig. 3 shows the trajectory of the movement of the system in the People's Republic of China from the beginning of the pandemic to 17.02.2020 when it began to die away markedly. The efforts made by the government led to the transition of the values of the indicator characterizing the system to the field of negative values, that is, contributed to the localization and slowdown of the spread of the infection within the country.

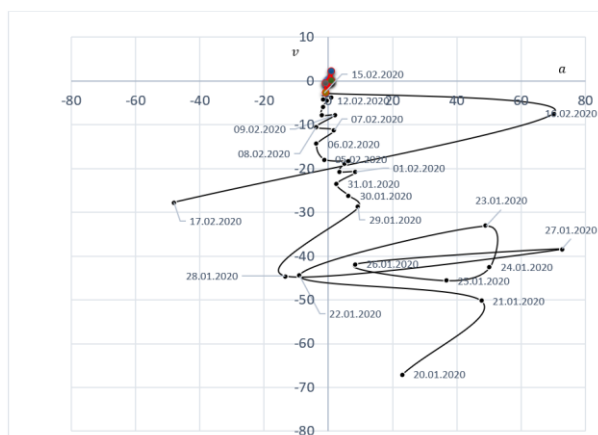


Figure 4. Trajectory in the phase space of states of change in the indicator of increase in COVID-19 infection in China

According to the statistical data published 19.11.2020, the economy of the People's Republic of China the first in the world won back all losses caused by COVID-19 pandemic.

A similar picture was also obtained for Russian Federation. With the detailed analysis that we will leave outside the present study, it is possible to determine the dates of events that caused the acceleration (slowdown) of the disease spread throughout the country. The diagram shows that government measures to restrain the

infection, which are more liberal than efforts in China, have resulted in a highly time-stretched oscillatory process, close to enough low positive indicators of acceleration at a moderate speed of movement of the indicator in phase space.

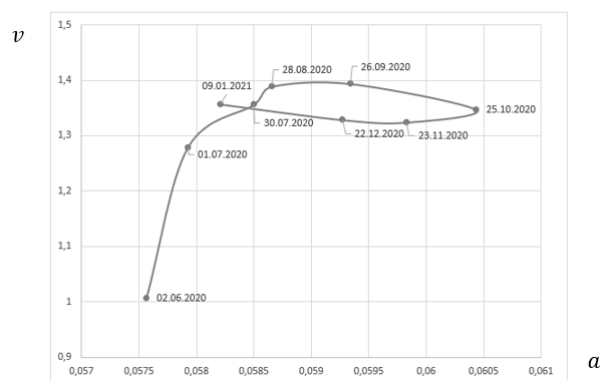


Figure 5. The movement of the center of the quasi-attractor of the growth of COVID-19 infection in Russia in the phase space of states (lunar cycle, with forgetting)

The periods of the steady oscillatory state of the system were determined by the Shewhart charts.

For the data array for the period from 07.03.2020 to 09.01.2021, the coordinates of the attractor center were calculated, formed on the phase plane by the movement of the indicator over equal intervals of time - 29 days (the so-called "lunar" cycle) for two characteristic cases - with the "forgetting" of previous data, when the center coordinates were calculated each time for a set of 29 points without taking into account past attractors (Fig. 6) and with accumulation, when the center coordinates were calculated each time with the addition of the following 29 points to the initial data set (Fig. 7). Both diagrams confirm the tendency to dying the process, and the diagram of the center of the quasi-attractor of the increase in COVID-19 infection in Russia in the phase space of states (lunar cycle, with accumulation) is an almost straight line. The length of the segments connecting the equal intervals of the "life" of the system gradually decreases. Considering that the goal state of the system is the transfer of the coordinates of the indicator describing it into the field of negative values, it is possible, on conditions that the emerging tendency keeps, to predict the beginning of the pandemic slowdown in Russia.

This state will correspond to the intersection point of the line in Fig. 8 of the v axis (that is, when $\alpha = 0$). While keeping the tendency, this moment should correspond to the beginning of May 2021 (approximately, 05.05.2021).

More accurate calculations within the framework of this work were not carried out, they can, if desired, be carried out by everyone on their own.

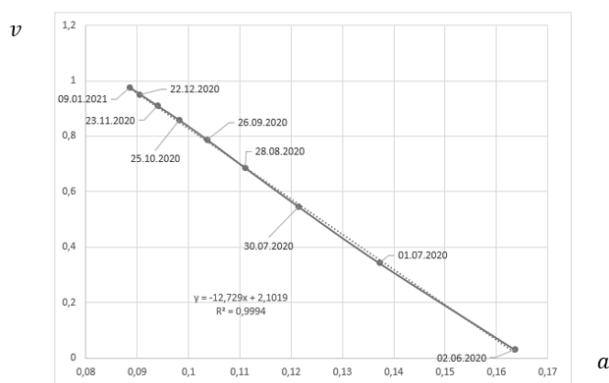


Figure 9. The movement of the center of the quasi-attractor of the growth of COVID-19 infection in Russia in the phase space of states (lunar cycle, with accumulation)

Comparing the data processed by the proposed method in different environments (in the case of the spread of the virus - in different countries) you can find interesting intermediate conclusions. For example, we will analyze the results of calculations for Russia and China (Fig. 10-11).

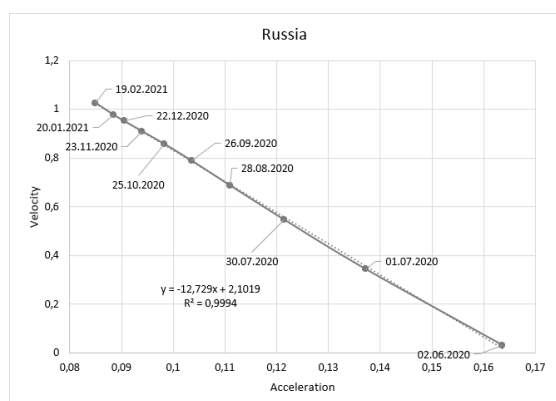


Figure 12. Comparison of the movement of the center of the quasi-attractor of the increase in COVID-19 infection in Russia in the phase space of states (lunar cycle, with accumulation)

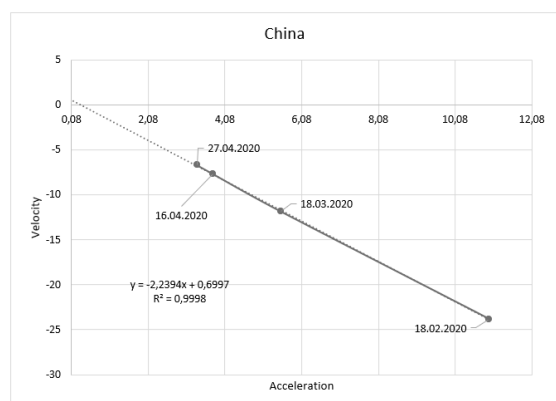


Figure 13. Comparison of the movement of the center of the quasi-attractor of the increase in COVID-19 infection in China in the phase space of states (lunar cycle, with accumulation)

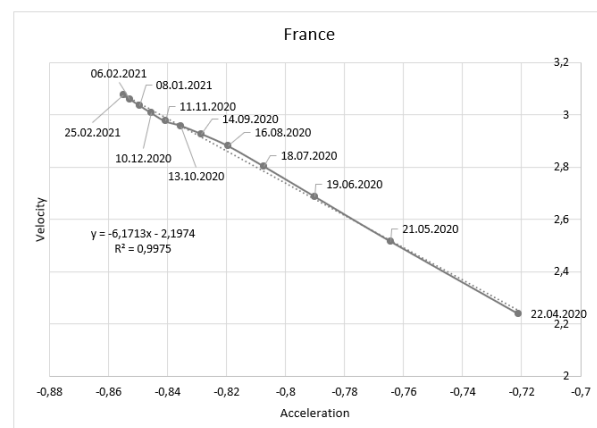


Figure 14. Comparison of the movement of the center of the quasi-attractor of the increase in COVID-19 infection in France in the phase space of states (lunar cycle, with accumulation)

In these cases, we deal with slow movement - speed falls over time. At least two very interesting conclusions can be drawn from the comparison of diagrams.

China acted more decisively and effectively in the fight against the epidemic, because the "system" was managed around negative speeds by reducing acceleration to zero values. Russia (like most countries of the world) "stretches out the pleasure," reducing acceleration to zero, but speed slowly grows... And, most likely, it will begin to fall after reaching the zero-acceleration value and its moving to the negative area.

The movements of the center of quasi-attractor clusters for Russia, China and France are approximated by the straight line. It can be assumed that this confirms the applicability of the method to the description of equal in nature phenomena, though occurring in different external conditions and under different external influences.

Acceleration - the rate of speed change - should decrease if we want to stop the system (i.e., stop the infection). That is what happens. Only in China the outbreak was sharp - hence the high (modulo) initial values of speed and acceleration, and then the sharp "collapse" of the process by introducing restrictive measures reduced acceleration, that led to the decrease in the speed of spread. Up to date, statistics on China there are about 83 thousand diseased people and 4.6 thousand deaths. Today we have more than 4 million diseased people and almost 83 thousand deaths. This is the price for more "liberal" measures of struggle. Only in Moscow, which is comparable in population to Wuhan (12 million), and 4 times more populated in density (4934.13 per 1400.3 people/sq. km) figures differ from all-Chinese by an order of magnitude (diseased people - 966 thousand, dead - 14.7 thousand people).

Data on changes in indicators provide a very clear idea of the effectiveness of management! In China, the fall in acceleration occurred in less than 3 months by factor of

4. The absolute values are large, but the negative speed indicates a sharp slowdown in the process (the speed fell by factor of 5). In Russia, the drop in acceleration by 2 times occurred in almost 12 months, and the speed increased by 10 times (hence the much greater number of cases and deaths). But the absolute values for Russia are low. For example, in France, a drop of 1.19 times also occurred in 12 months, the speed increased by 1.37 times, but the number of cases and deaths over the same period is greater (3 million 746 thousand cases, 85.7 thousand deaths, respectively), because the absolute speed values are higher.

5. CONCLUSIONS

The model considered and the very method of analysing the behaviour of unique evolutionary systems can be used quite widely. Almost any complex technical or economic system in the process of functioning and in its development goes through stages that are perceived by the external and internal observer as chaos.

In general, there may be two possible search directions. The first tendency is to try to use an unconventional mathematical apparatus to build a model that considers all the features of the object and is suitable for realization. This approach supposes the description of an action algorithm in the language of statements of the type "if (conditions, laws, characteristics), then the consequence (for example, qualify the company for one or another type of work or refuse it)." This approach clearly includes the imitation of some cause-and-effect relations and the fixation in machine codes of certain rules of action. These are mainly "white box" models, in which the "production

process" is fixed step by step. When analysing retrospective cases, the place where the error occurred is clearly visible in the monitoring system: this is either inaccurate initial data or this is an incorrect rule for making decisions, which the expert proposed, etc. But this approach is not productive in processing heterogeneous multidimensional flows of information - for decision making, algorithms must be adapted - it is constant reengineering, constant work on the provision of services, constant "demand" of experts to confirm that old rules are suitable (may be not optimally) for each new case. Therefore, the massive failures of implementing diagnostic systems in practice (Bochkov, 2017).

The second tendency is to build not an object model, but an object management model. In other words, it is not the object itself that is modelled, but the human operator in the process of managing the object. Naturally, it is worth modelling only a qualified operator who is well acquainted with all the features of managing this object and successfully manages it "manually." The task of such kind is reduced to the need for building the "grey box" model that tests the inputs and outputs of some imitator of real business processes. Unlike the "black box" (for example, sentiment analysis), it is a partially transparent model in which elements of the decision structure are visible and it is possible to interfere in the configuration process.

The proposed approach relates to the second tendency. The main thing that it allows is that it provides the possibility of long-term prediction of the behaviour of the studied unique evolutionary system and modelling the reaction of this system to one or another change in the parameters describing it.

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