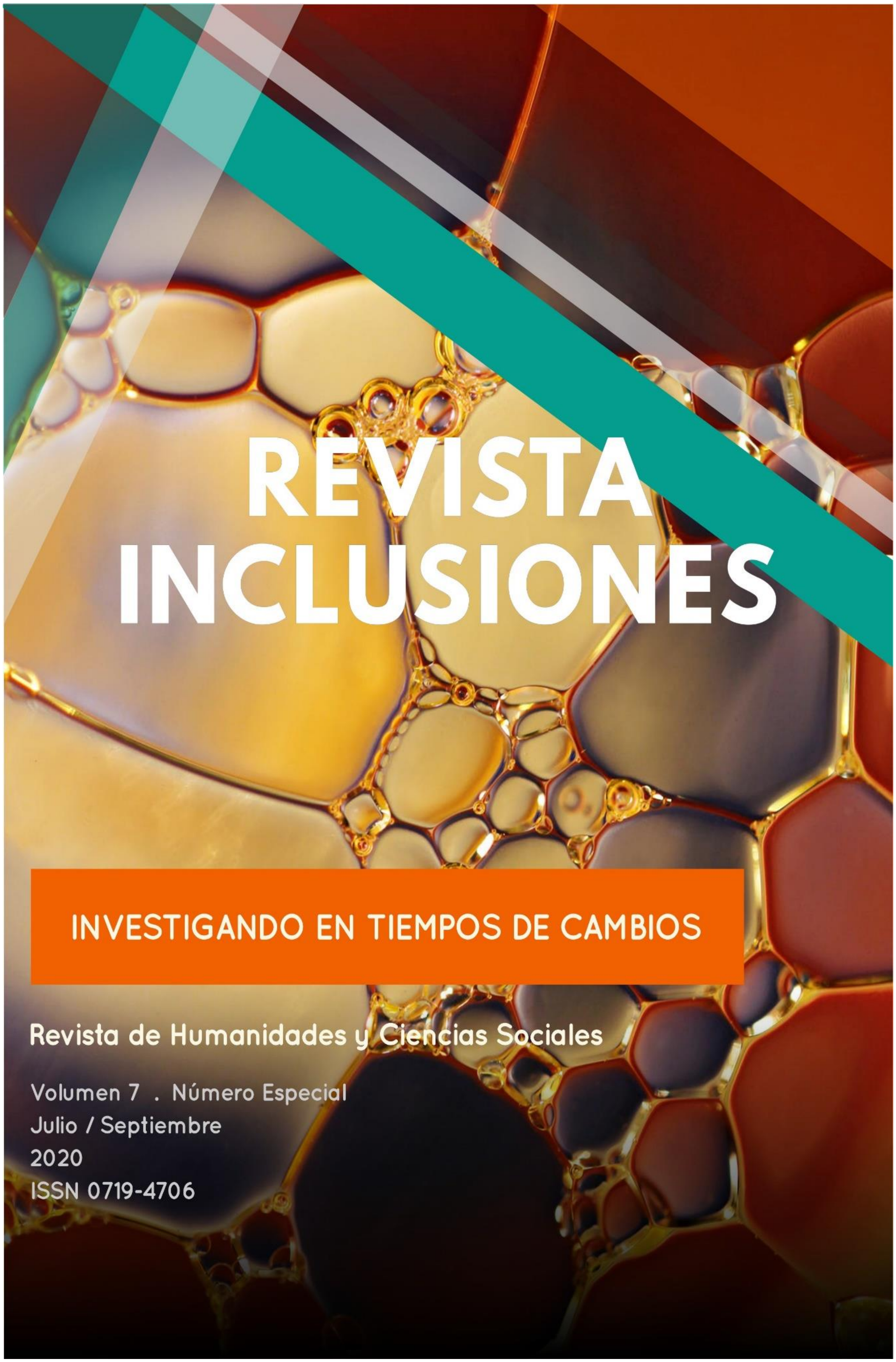

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MODELS OF LOSSES OF WORKABILITY OF SOCIO-ECONOMIC SYSTEMS

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Abstract

In the process of transformation of the socio-economic system, the sustainability of the system is particularly relevant. Under the influence of internal and external threats, the sustainability of the socio-economic system may be impaired. This probably could lead to a complete loss of the entire system. The aim of the study is mathematical and graphical modeling of the loss of efficiency of socio-economic systems. To achieve this goal, the following tasks were solved: a mathematical model of the loss of efficiency of the socio-economic system is presented; a graphical interpretation of the model of the loss of efficiency of the socio-economic system is presented. According to the results of modeling the loss of working capacity of the socio-economic system, two equations were obtained. The equations described the loss of working capacity of the socio-economic system when exposed to any variable regime of factors. A graphical interpretation was also presented. Mathematical and graphical modeling of the working capacity of a socio-economic system allows, in the conditions of transformation of a socio-economic system, to determine with mathematical precisión the moments of failure and the complete loss of system performance. This is the fundamental basis for making decisions about maintaining system stability.

Keywords

Workability – Sustainability of the socio-economic system – Mathematical and graphical modeling

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Introduction

Relevance

The transformation of socio-economic systems is a multifaceted and dynamically developing phenomenon throughout humanity since the moment when economic relations between people appeared and the social connection between them strengthened. Determination and rethinking of previously known facts and dogmas, the definition of processes and trends that have a significant impact on the transformation of socio-economic systems in the process of evolution of economic thought have undergone many changes. In the process of transformation of the socio-economic system, the sustainability of the system is particularly relevant.

Studies of the transformation of socio-economic systems are affected in the works of foreign and Russian scientists[1]. Security studies are also devoted to a number of scientists[2]. The studies of scientists[3] are also devoted to the fundamentals of the theory of reliability testing and safety of complex systems.

Under the influence of internal and external threats, the sustainability of the socio-economic system may be impaired, which probably could lead to a complete loss of the entire system. At the same time, the study of modeling the workability of socio-economic systems is particularly relevant in the context of transformation.

The purpose of the study - mathematical and graphical modeling of the loss of efficiency of the socio-economic system.

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Method

As is known, there is no strict notion of a “system resource”. In this connection, an intuitive concept of a resource and its measures ξ,, on the basis of which the theory of resource consumption is built, is introduced. In this case, under the resource we will conditionally take the characteristics of the functioning of the socio-economic system (hereinafter SES).

As such characteristics can be selected: state vector of system parameters; change of the vector of phase coordinates; vector of perturbations of environmental parameters; moments of failure of elements (blocks, units) of the system, etc. Failure moments will be the main cause of loss of performance, which is influenced by many causes and factors. Therefore, we will investigate events related to the loss of system performance due to failures occurring in it.

Denote the moments of failures of the socio-economic system as ξ_i for $i = 0$, n -1. If the system produces some kind of impact in the failure mode ξ_i during the time τ, $\tau < \xi_i$, then the duration of its operation will decrease and become equal to $\xi_I - \tau$ for $\tau = 0$, n-1. We will “change” the moments of failures in T_0 fractions (mean time to failure).

In this case, the following condition is true:

$$M\xi_0 = 1 \qquad (1)$$

The value of τ can be considered as a characteristic of the loss of efficiency of a given socio-economic system. Let us fix an arbitrary value $0 \leq \tau \leq t$ and define the characteristic of the loss of efficiency of the system’s functioning on the time interval $[\tau, t]$. Denote

$$q(\tau; t; \xi_i) = \begin{cases} 0, if\ \tau > \xi_i \\ \tau, if\ \xi_i > \tau, \qquad \xi_i < \tau \\ t - \tau, if \xi_i > \tau \end{cases}$$

Let us average the function $q(\tau; t; \xi_i)$ depending on the random variable ξ_i. Then, we obtain $M_q(\tau; t; \xi_i) = Q(\tau; t; \xi_i)$ which is a generalized characteristic of the loss of efficiency of the system’s performance in the time interval $[\tau, t]$ under the influence of SES in the i mode ξ_i. To determine the index $Q(\tau; t; \xi_i)$, it is necessary to know the distribution function.

$$F_i(t) = P(\xi_I < t), i = \overline{0, n, n-1}.$$

In practice, as a rule, such information is unknown. Therefore, instead of $Q(\tau;t;\xi_i)$, we will choose other characteristics $L(\tau;t;\xi_i)$, which should be closely related to $Q(\tau;t;\xi_i)$, being some operator, i.e. $L(\xi_i) = AQ(\xi_i)$, $i = \overline{0, n, n-1}$. However, not all, we will assume that the function $L(\tau; t; \xi_i)$ (where ξ_i is some acceptable mode of influence on the SES) satisfies the following conditions.

Let denote the E – set of permissible modes of action on the system, which consists of E and all variable modes composed of the initial modes $\boldsymbol{i} \in \boldsymbol{E}$. Let the quality of functioning of a certain system be characterized by two parameters x_1 and x_2. Our task is to establish the functional dependence $\psi(x_1, x_2)$ between them. Suppose that there are n systems and each of them has the remoteness to obtain quantitative estimates of the parameters x_1 and x_2, i.e. get information (x '1 и x '2), where x'1 and x'2 are the values of the parameters x1, x2 of the i-th system (product), respectively, where i = 1, n. If, withinthe measurement error, the points x ', x ' lie on the curve described by the equation $\psi(x_1, x_2) = 0$, then between the parameters x_1 and x_2 there is a functional dependence $\psi(x_1, x_2) = 0$ (Fig. 1), otherwise, it is not.

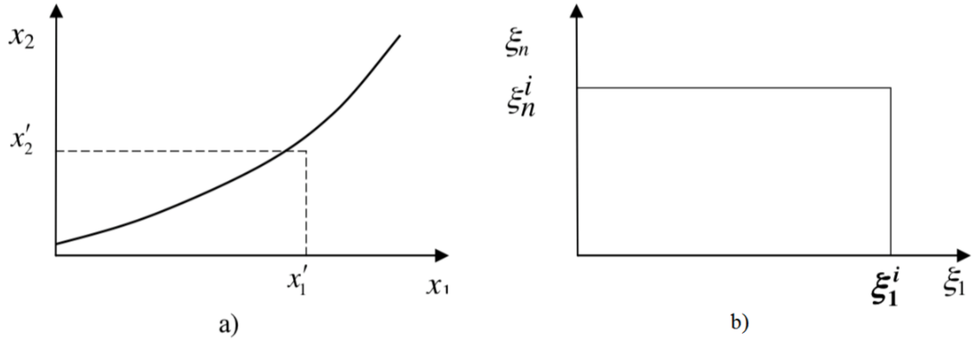


Figure 1

Dependencies Of Observable And Simultaneously Unobservable Parameters

The presented approach is the main (dominant) in physics, chemistry, biology and of other fields of science. With intensive impacts on the SES, this methodology is unsuitable. In the system under study, it is impossible to measure the failure times $\xi_0(\omega_0)$. With the impact on the i-th SES with socio-economic parameters ω_0 in mode ξ_1, you can determine the time of failure $\xi_1 i$ (ω_0). However, at the same time, the SES will change its original properties (parameters ω_0) and it will be impossible to restore the state $\xi_0(\omega_0)$ for it. Thus, after acting on the SES, you can get the value of one coordinate of the random vector $(\xi_0(\omega_0), \xi_i(\omega_0))$. A similar situation occurs when the i-th SES operates in the impact mode ξ_1. As a result, we will determine the failure moment $\xi_1(\omega_0)$, and the second component of the random vector $(\xi_1(\omega_0), \xi_0(\omega_0))$ will be unknown. The parameters $\xi_1(\omega_0)$ and $\xi_0(\omega_0)$ are called simultaneously observable.

Consider the additivity condition. For any $\theta \in (\tau, t)$, the equality

$$L(\tau, t; \xi) = (L(\tau, t; \xi) + L(\theta, t;\ \xi),$$

this implies a more general relationship

$$L(\theta_1, \theta_n; \xi) = \sum_{i=2}^{n} L(\theta_{i-1}-, \theta_i; \xi); \xi \epsilon \bar{E} \qquad (2)$$

$$i = 2$$

at any $\theta_1 \leq \theta_2 \leq \ldots \leq \theta_n$

The Markov condition is as follows.

Function $L(\tau, t; \xi)$ depends on the size of the developed resource in the past $L(\tau, t; \xi)$ during time t and does not depend on how this resource is developed and in what mode (it is possible purposeful aggressive influence on the system). In a formalized representation, this condition can be written as follows:

If $L(0,\theta;\xi_2) = L(0,\tau;\xi_1), mo\ L(\theta,\theta+t;\xi) = L(\tau,\tau+t;\ \xi), \xi\epsilon\bar{E}$

For the convenience of subsequent research, it is advisable to make the following conversion.

Reduce the dimension of the function $L(0,\ t;\ \xi)$,by entering the rate of loss of the system performance as a result of aggressive impact on it

$$\mu(t,\xi) = \frac{L\ (0,t,\xi)}{dt}$$

Then the function $L(\tau,\ t;\ \xi)$ can be represented as

$$L(\tau,t;\ \xi) = \int_{\tau}^{1} \mu(t,\xi)dt.$$

Instead of the moments of failure ξ, we will use the characteristic $\upsilon(\xi)$, according to which we believe that the SES is inoperative. The characteristic $\upsilon(\xi)$ has the dimension t and is a random variable.

Denote $H(t,\xi) = P(v(\xi) < t)$ as a distribution function. Consider the equation describing the process of loss of system (products). Let's pretend that

$$ML(0,\upsilon;\xi) = 1\forall\xi_i\epsilon E. \qquad (3)$$

If

$$ML(0,\upsilon;\xi_i) = c_i > 0, c_i \neq 1, i = \overline{0, n-1},$$

then, instead of $L(0,\theta;\xi_i)$, we introduce another characteristic of system loss - $L(0,\theta;\xi_i)\ /\ c_i$ which will satisfy condition (3). An additional limitation is that the normalization (3) is valid not only for $\xi_i \in E$, but also for all other possible modes of influence on the system, i.e.

$$ML(0,\upsilon;\ \xi_i) = \int_0^{+\infty} L(0,\upsilon;\xi_i)dH\ (\upsilon,\xi) = 1\forall\xi\epsilon\bar{E}. \qquad (4)$$

We assume that the loss of system performance implies a dynamic or potential (static) hazard. We use the method proposed in [1]:

$$L(0,\upsilon;\xi) = L(0,\upsilon;\xi_0) with\ 0 \leq \upsilon \leq t_1 \qquad (5)$$

If $t_1 \leq \upsilon \leq t_2$, then this means that the SES has a more rigid mode ξ_1. The duration of this mode is determined from the equality

$$L\ (0,\tau_1;\xi_1) = L(0,t;\xi_0)\ (6)$$

Using the properties of additivity and Markov property, we determine the loss of system performance in the interval $[0, \eta]$. We first note that $\eta -$ is a rule for the termination of the system, depending on the moments of failure of elements (units) of the system and their distribution functions, which is uniquely determined by the rate of loss of efficiency $\eta(t, \xi)$ (condition (2)). Thus, the total loss of working capacity of the socio-economic system on the interval $[0, \eta]$ will be defined as

$$L(0,\upsilon;\xi) = L(0,\tau_1;\xi_1) + L(\tau,\upsilon;\ \xi_1) = L(0,\upsilon - t_1 + \tau_1;\xi_0) when\ t_1 \le \upsilon \le t_2 \tag{7}$$

Fig. 2 illustratively shows the modes of impact on the SES in its operation.

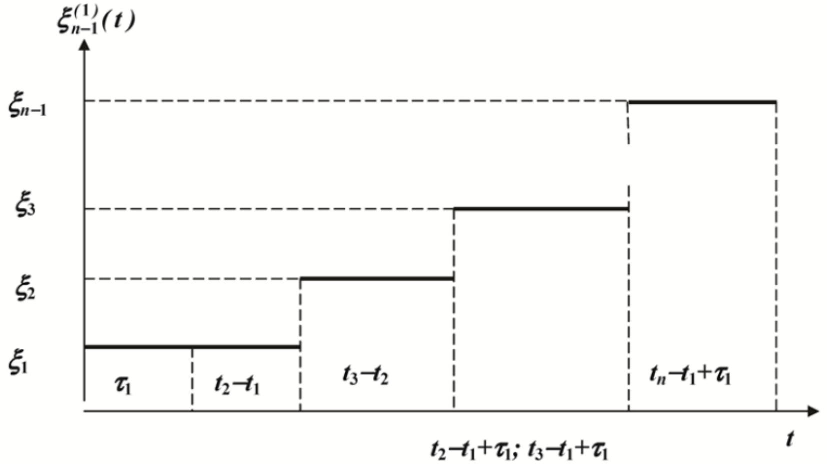


Figure 2
Transformed Impact On Ses With N – 1 Steps

Similarly, we do when $\upsilon\in[t_2, t_3]$. The first stage of the mode of influence on the system (product) $\xi_n^{(1)}{}_{-1}(t)$ is replaced by the equivalent of the loss of working capacity in the mode 2. Duration of exposure τ_2 is equal to

$$L(0,t_2 - t_1 + \tau_1;\xi_1) = L(0,\tau_2;\xi_2) \tag{8}$$

Again, using conditions (1) and (2), we write the total loss of performance on the time interval $[0, \upsilon]$ in the form

$$L\big(0,\upsilon;\hat{\xi}\big) = L(0,\tau_2;\xi_2) + L\big(\tau_2 - t_1 + \tau_{1,}\ \upsilon - t_1 + \tau_2;\xi_2\ \big) = L(0,\upsilon - t_2 + \tau_2;\xi_2)$$
$$at\ t_2 \le \upsilon \le t_3 \tag{9}$$

After replacing the first stage in $\hat{\xi}_{n-2}^{(1)}$ with the equivalent one according to (9), we obtain the variable mode of influence on the SES as $\hat{\xi}_{n-2}^{(2)}$(t) with *n* – 2 steps.

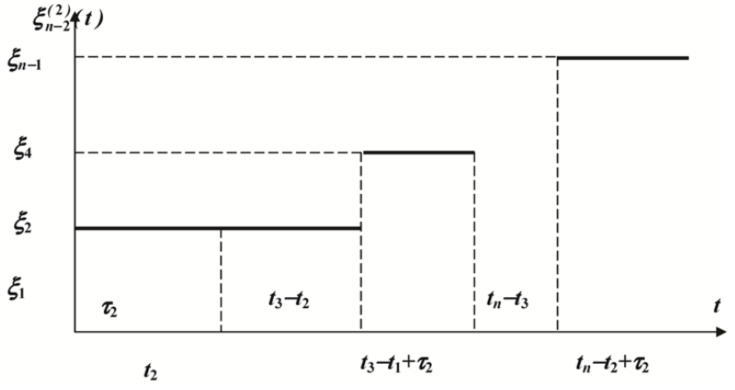


Figure 3
Illustration of The Variable Mode Of Exposure As$\hat{\xi}^{(2)}_{n-2}$

Based on (1 - 3), the method of mathematical induction can be used to obtain an expression for $L(0,v;\hat{\xi})$ for any $v\epsilon(t_j,t_{j+1}), j=\overline{0,n-1,}\, t_n+\infty$:

$$L(0,v;\hat{\xi}) = \sum_{k=1}^{j} L(\tau_k, t_k - t_k + \tau_k; \xi_k) + L(t_j, v - t_j + \tau; \xi_J). \qquad (10)$$

The $t_j$values are determined from recurrent expressions.

$$L(0,\tau_i;\xi_{i+1}) = L(0, t_i - t_{i-1} - \tau_{i-1,}; \xi_{i-1}) \text{ at i } = 0,1,\dots,\tau_0 = t_0 = 0 \qquad (11)$$

We introduce a function

$$\psi(t,\bar{\xi}) = \begin{cases} 0,0 \le t < t_1 \\ \tau_1, t_1 \le t < t_2 \\ \dots\dots\dots\dots \end{cases}$$

$$\psi(t,\bar{\xi}) = \begin{cases} 0,0 \le t < t_1 \\ t_1, t_1 \le t < t_2 \\ \dots\dots\dots\dots \end{cases}$$

$$P(t,\bar{\xi}) = G(t,\bar{\xi}) - \psi(t,\bar{\xi}) + t$$

Then (10) and (11) can be represented as:

$$L(0,v;\hat{\xi}) = \int_0^v \mu(P(t,\hat{\xi}),\xi_1)dt = L(0,P(v,\bar{\xi});\ \bar{\xi}_t). \qquad (12)$$

Here ξ_t means the mode $\xi \in E$, in which the SES was functioning at the moment of time t.

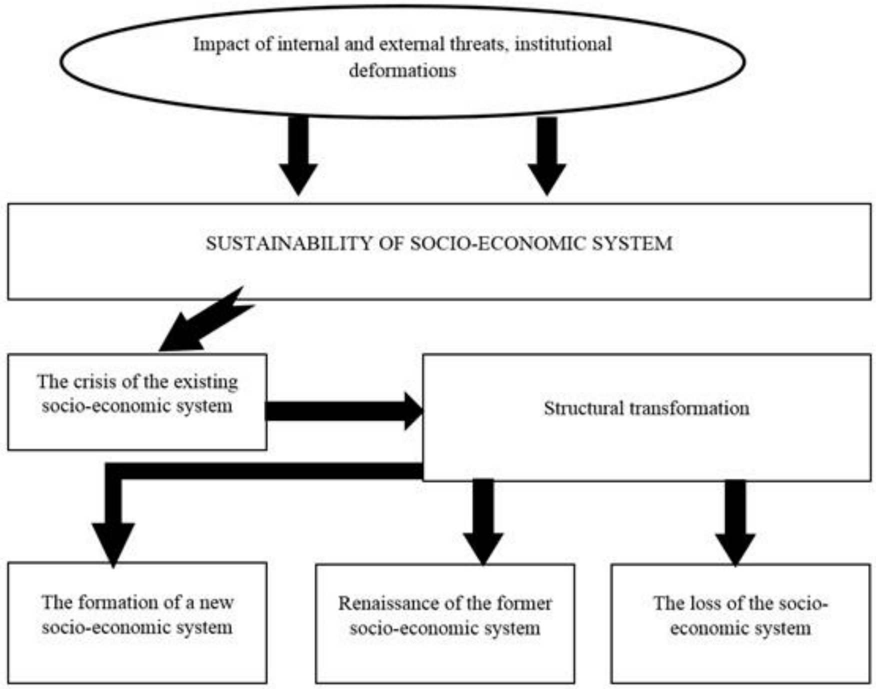
After replacing in (4) the characteristics of $L(0, u; x)$ on the right-hand side of (12), we obtain two equations describing the process of loss of the system's performance when exposed to any variable mode of factors

$$\int_0^\infty dH(\nu,\hat{\xi})\int_0^\upsilon \mu(P(t,\bar{\xi}_t)dt = 1,$$

$$\int_0^\nu L(0,P(\nu,\bar{\xi}),\bar{\xi})dH(\nu,\hat{\xi}) = 1$$

Results and discussion

Graphically, the transformation of the socio-economic system can be illustrated by mapping in Figure 4.



Source: Supplemented by The Authors
Figure 4
Graphic Interpretation of The Loss Of Efficiency Of The Socio-Economic System

Figure 4 illustrates the process of transformation of socio-economic systems. The influence of internal and external threats, institutional deformations leads to the violation of the stability of the socio-economic system in the context of transformation. The crisis of the existing economic system forms a structural deformation, which ultimately leads to two consequences:

1) the formation of a new economic system in which a different socio-economic structure is formed, which differs significantly from the previous one.

2) the renaissance of the former economic system, in which the former socio-economic structure remains. At the same time, somewhat is deformed.

Structural transformation is clearly described through the example of a gradual approach, which focuses on the intensity of institutional interaction (see Figure 5).

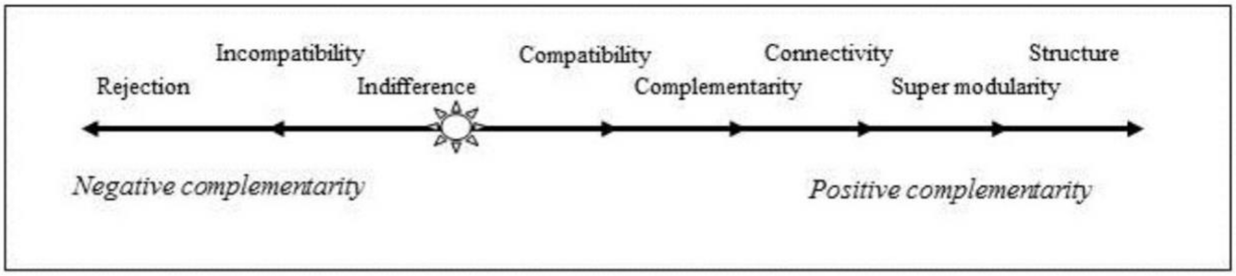


Figure 5
Scale Of Measurement Of Institutional Complementarity In Sign And Intensity[4]

Thus, the impact on the system, depending on its strength, can have completely different consequences. If system fluctuations are not strong enough, strong tendencies to return to the old state, structure or behavior may arise in the system. If the fluctuations are very strong, the system may collapse or the process of forming a new structure and changing the state, behavior and / or composition of the system will start[5].

Conclusion

Mathematical and graphical modeling of the working capacity of a socio-economic system allows, in the conditions of transformation of a socio-economic system, to determine with mathematical precision the moments of failure and the complete loss of system performance, which is the fundamental principle of maintaining the stability of the system as a whole.

Further research should be directed to the transformation of the modeling of the health of the socio-economic system in the context of transformation.

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