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CRITERIAL ASSESSMENT OF RELIABILITY OF FUNCTIONING OF THE ENTERPRISE MANAGEMENT SYSTEM

КРИТЕРІАЛЬНА ОЦІНКА НАДІЙНОСТІ ФУНКЦІОНУВАННЯ СИСТЕМИ УПРАВЛІННЯ ПІДПРИЄМСТВОМ

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Захарченко В.І, Бондаренко К.О. Критеріальна оцінка надійності функціонування системи управління підприємством. Науково-методична стаття.
На основі економіко-математичного моделювання запропонована критеріальна оцінка надійності функціонування системи управління промисловим підприємством. У поняття надійності системи управління включена безвідмовність, тобто своєчасне безпомилкове виконання управлінських операцій і можлива кореляція процесу несвоєчасного виконання технологічних операцій. Вважається, що в системі управління у кожний момент часу вхідні елементи технології виконуються незалежно один від одного. Аналогічно так і управлінські операції також виконуються незалежно одна від одної, а їх невиконання носить випадковий характер. Операції управління об'єднані в окремі групи-елементи технології. Вважається, що виправлення помилок відбувається одночасно з виконанням інших управлінських операцій та функціонуванням відповідних елементів технології управління. Також були проаналізовані три основні моделі управління – цільового, функціонального, лінійного, – які на практиці звичайно зустрічаються як їх синтез.
Ключові слова: надійність, система, управління, модель, ймовірність, критерій, функція, ефективність, аналіз, ціль

Zakharchenko V.I., Bondarenko K.O. Criterial Assessment of Functioning Reliability of an Enterprise Management System. Scientific and methodological article.
On the basis of economic and mathematical modeling, an initial assessment of the functioning reliability of an industrial enterprise management system is proposed. The reliability concept of the control system includes faultlessness, that is, timely error-free execution of management operations and the process correlation of untimely execution of technological operations is possible. It is believed that in the control system at each moment of time the input elements of the technology are performed independently of each other. Similarly, management operations are also performed independently of each other, and their failure to perform is accidental. Management operations are combined into separate groups of technology elements. It is believed that the errors correction occurs simultaneously with other management operations implementation and the corresponding elements functioning of management technology. There also were analyzed three main management models – target, functional, linear – which in practice are usually found as their synthesis.
Keywords: reliability, system, control, model, probability, criterion, function, efficiency, analysis, goal

Most administrative enterprises use a management system that has already been developed, while making efforts to adapt it to the new economic environment and business conditions that are constantly changing. Newly established enterprises usually independently create management systems by the analogy with existing production facilities or, in extreme cases, use the consultants' services – i.e. specialists in the field of management. As a result, recently there has been a fundamental change in approaches to the problem of formation and further analysis of management systems reliability and efficiency. Prior to the beginning of economic reform in the planned socialist economy conditions, each production amalgamation applied the management systems developed by the main organizations in the corresponding branch of industry. Thus, there was a set of standard control systems, which were slightly supplemented due to the local and technological features of production. Therefore, the company management did not need to analyze the management system reliability and efficiency, it was initially considered reliable and efficient. The enterprise managers only had to use the management decisions apparatus given to them and the management system ready mechanism. The management technology issues and, accordingly, reliability and efficiency, in turn, were dealt by industry and major research institutes. Nowadays the situation in the national economy is complicated by its crisis. The various ministries actions are linked to a holistic goal - to move from an eating economy to a development economy, to create policies that increase jobs, raise wages, and create a climate in which new capacities are created. The average depreciation of fixed assets in Ukraine is 60%. According to the government, almost 50 billion US dollars are needed to reach the level of 45-50% investment in the next 5-10 years. And if one reaches 35-38% (employment rate in Belarus, Slovakia, etc.), one needs twice as much. There is a striking difference between Ukraine and its neighbours in the production level per capita employed. In Ukraine, per employee in 1991 prices, production is 20 thousand US dollars per year. In Moldova it is less, and in all others – is 35-60 thousand US dollars. Because the economies are more modern there. The percentage of high-tech goods and services in Ukrainian exports is 17%. Everything else is raw material. In the processing industry, the high technology percentage is 3%. Our economy is now detechnologized.

Analysis of recent researches and publications

The following scientists made a significant contribution to the study of issues related to the functioning reliability of management systems of industrial enterprises and Ukraine's industrial complex in general: A. Voronin [1], V. Gerasymchuk [2], A. Kolosov [6], Yu. Levchenko [7], Yu. Lysenko and his colleagues [8], I. Novakivsky [9], Vas. Osipov [10], O. Salikhova [11], O. Trut [12], S. Filyppova and V. Saadzhan [13], K. Shubravska [14]. Thus, S. Filyppova and V. Saadzhan conducted a thorough analysis of economic factors that influence the decision-making of Ukrainian industrial enterprises [13, p. 50-51]. Yu. Lysenko and A. Madykh understand the economic systems reliability as the probability of plan implementation with fluctuations in internal and external factors [8, p. 129]. A. Kolosov defines the stability paradigm in enterprise management – as the ability to maintain the status, despite the external forces influence - is unacceptable for an enterprise operating in conditions of severe resource constraints [6, p. 60-61]. He adds: "All other sustainability paradigms to some extent relate to the enterprise activities, allowing the possibility of maintaining sustainability through management intervention" [6, c. 60]. O. Trut warns: "…that domestic researchers practically do not cover the issue of effective using the management resources to increase the organization effectiveness, the adequate formation to modern market realities management systems, appropriate apparatus development and performance management mechanism" [12, p. 362].

I. Novakivsky insists: "Changing the system-forming system of enterprise management is directly based on the new identified principles, generalized accumulated empirical material, application of improved analysis methods, measurement, evaluation and modeling and development on their basis of evolution, self-organization and self-government of complex systems and their adaptation for domestic enterprises." [9, p. 112]. A. Voronin suggests: "The main place in the analysis and justification of economic decisions is possible to use an integrated indicator of producing economic efficiency, which reflects the joint action result of individual indicators that characterize different efficiency aspect" [1, p. 30]. V. Osipov, based on the analysis of domestic and foreign scientific papers, reveals the indicators system essence for the comprehensive assessment formation of the enterprise economic and financial activities [10, p. 21]. K. Shubravska insists on considering the reliability of any economic system mainly in connection with the analysis of its equilibrium states [14, p. 38]. Yu. Levchenko adheres to a similar viewpoint. [7, p. 56]. V. Gerasymchuk notes: "Problems in the management practice are justified mainly by the fact that in the process of making managerial decisions, managers see a certain problem, which is separated from many other aspects of an enterprise" [2, p. 14]. O. Salikhova researching the concept of smart specialization and linking it with the concepts of technology, innovation and industrialization through its common goal – to increase productivity and ensure sustainable economic growth, pays attention to the fact that..."the new government needs to update the preparation of the Strategy taking into account recently adopted by the EU documents on industrial modernization based on reasonable specialization " [11, p. 69].

Unsolved aspects of the problem

In examining the enterprise management systems reliability in an unstable economic environment, all issues will be directed towards the practical recommendations development, they will be either unproductive or reduced to a selection of trivial advice by an outside observer, or, on the other hand, a narrow expert, not applicable and reflecting a subjective view, is proposed, if not linked to analysis, to modern ideas about an enterprise within the economic theory framework. It is necessary to apply an integrated view of the enterprise, which is reflected in its goals system, which may consist of the following components: meeting the individuals' needs in the enterprise; improving the enterprise structure, its adaptation to internal and external changes; building and maintaining capacity for future development; external requirements satisfaction to the enterprise and the requirements representation to external environment [5, p. 22]. It requires a system of qualitative and quantitative criteria. In the research paper we will dwell on the latter one formation – quantitative.

The main part

In modern conditions, the efficiency and reliability analysis of the management system is a part of the problems range solved by each of the enterprises, as well as the owner [4, p. 60]. Theoretically, there are three main models of enterprise management system, in practice, their synthesis is usually found with a certain model dominance as the main one.

1. Let's consider the model focused on target management which includes the organization and coordination of the enterprise activities divisions for the achievement purpose by them of the results which provide the final goals performance. In general, it consists the normative documents system regulating management objectives, indicators and criteria, the general structure of the management system, special functions, tasks, management procedure, managerial decisions implementation, i.e. technology.

2. The management system purpose is determined based on the main purpose of the enterprise, established by the owner and management. The goal achievement degree, i.e. the management system efficiency, is assessed by quantitative criteria, which are traditionally based on indicators of producing the economic efficiency. Let's analyze the model of the control system focused on functional management. It is the specialized management activities implementation that have been developed as the result of the management work division. Its essence is to distinguish a set of separate types of management work. Each functional subsystem is characterized by the management activities specialization, management objectives, the specific functions composition and management tasks for each individual function and their distribution by management. The functions composition, their distribution between departments are specific to each enterprise. The functional management purpose is also set in accordance with the enterprise main objectives, defined by the owner and management of the enterprise.
3. Let's consider a model that focuses on linear management, which is mainly the head's managerial activity, in the process of which he/she exercises the right to make final decisions in relation to his subordinate units and employees with full focus on his/her responsibilities.

   The organizational basis for such a management system construction and operation is:
   - provisions on the relevant structural units and their heads;
   - job descriptions

Any enterprise, originally created for production activities aimed at manufacturing products and providing production nature services, as the developed business faces the problem of diversification and growth, which provides the company with greater financial and economic stability in fierce competitive conditions and to some extent it is difficult to predict fluctuations in market enviroment. This corresponds to one of the most general survival principles of an enterprise of any profile: the enterprise has to continuously develop, invest a significant part of its financial resources in the production development and expansion. Stopping development, stagnation will inevitably lead the enterprise to economic collapse and its liquidation as a business entity. In the general case, the management system, which is quite ideal according to the previous periods criteria, may not correspond to the enterprise dynamic growth during its transition to the next level of production development or diversification. Thus, the task of assessing the management system reliability and efficiency, its ability to really reflect the business capital status, to implement in a timely manner and without distortion of management decisions becomes particularly important in market relations.

Quantitative criteria are needed to assess the operations and actions effectiveness of the industrial enterprise management system. Criteria are specific values that are considered as the system properties. In the general case, there may be many. Therefore, the more fully one needs to evaluate the system, the more its properties are needed to be considered and studied, the more difficult the criterion can be. Such an approach involves "constructing" criteria, in which there is a problem of "criteria selection criteria". In practice, when analyzing the management system effectiveness, the criteria are decomposed, i.e. they are built in a hierarchical tree, where the links meet certain rules. Usually administration evaluates the enterprise functioning as a whole, for which only one coefficient is calculated: in the numerator the profit, and in the denominator the total expenses amount. The found result is compared with the past periods indicators and the same indicators of other similar enterprises in the industry. On the basis of the conducted analysis the general estimation of all the enterprise constituent divisions and systems activities is given. Meanwhile, a properly functioning management system creates most of the effect in the field of production and sales. It is confirmed in practice. Therefore, it is not enough to determine its work effectiveness on a small group of parameters or coefficients as the savings result by reducing individual cost items. Such approaches are imperfect and do not allow even a rough assessment of the management system quality and efficiency. In general, the synthesis and analysis theory of efficiency criteria is still insufficiently developed, so the criteria choice is justified by various private or heuristic considerations.

Any really existing management system of the enterprise, regardless of its size and activity nature, is a complex system that includes a set of similar technological elements. Each element corresponds to a set of specific actions – i.e. management operations. The organized relationships complexity between these elements and operations necessitates the need to take into account the specific features of systems research in the enterprise management system analysis and evaluation.

Firstly, the system characteristics are not a simple sum of parts properties . It may also be able to acquire new properties that arise from the interrelationships between its elements.

Secondly, a complex, real-world management system is presented as a simplified study object, focused on solving a specific problem, leaving only the most important properties and relationships of system elements.

Thirdly, the management system is constantly functioning in conjunction with the external environment, which has a significant impact on the results of the enterprise. It is an open system and is in continuous interaction with others similar to itself. Finally, it is a subsystem of a more general higher-level economic system.

According to the abovementioned, a number of methods are used to analyze the enterprise management system efficiency and reliability. From them it is possible to allocate the following ones, i. e. basic.
- According to statistical and economic indicators.
- According to financial indicators of economic activity.
- Based on the audit results.

— According to the operational control indicators.
— According to the time criteria of management operations.
— According to the quantitative reliability criteria of the control system [4, p. 61].

The first three allow you to evaluate the system for long time periods and influence the enterprise strategy and management decisions of global orders. The next three are used in operational management and have a significant impact on the efficiency of the enterprise economic activity. Their analysis within the production cycle allows to optimize quantitative indicators at the next stages of production and sales, as well as to create optimal conditions for capital movements within the enterprise economic field.

The concept of the enterprise management system reliability will include faultlessness, i.e. timely error-free execution of management operations, and the correction possibility, that is the ability to correct failures or timely non-performed technological management operations. We will assume that in the control system at any time the technology elements that are part of it, are performed independently from each other, similarly, and management operations are also performed independently from each other, and their non-compliance is random. Let's consider the mathematical modeling of the overall reliability of such a system [3, p. 250].

Let's suppose that the management system includes management operations. The reliability of each is a function $P_{ij}(t)$, then its non-fulfillment probability has the form $q_{ij}(t) = 1 - P_{ij}(t)$, where $i = 1, 2, \dots, n$, $j = 1, 2, \dots, m$. P_ij (t), (t) = 1-P_ij (t),

As management operations are grouped into separate groups – elements of technology

X_i, let's consider events A_i, consisting in the fact that in this element for time *t* all operations were performed with the specified reliability. The system reliability in this case is calculated by the ratio:

$$P(t) = P(A_1 A_2 \dots A_n) = 1 - P\left(\overline{A_1} \cup A_2 \cup \dots \cup \overline{A_n}\right) =$$
$$1 - \sum_i P(A_i) + \sum_{i<k} P(\overline{A}_\iota A_k) - \sum_{i \le k \le l} P(\overline{A_\iota A_k A_l}) + \cdots + (-1)^{n+1} P(\overline{A_1 A_2} \dots \overline{A_n}). \quad (1)$$

Here $\overline{A}_\iota$– is an event , which is the opposite of the event $\overline{A}_\iota$, i –

$$P(\overline{A_\iota A_k} \dots \overline{A_n}) = q_{ij} q_{kj}(t) * q_{lj}(t). \quad (2)$$

Thus, the obtained correspondence allows to calculate the reliability of the system as a whole.

Let's determine the system reliability in which errors are eliminated over a finite period of time. Let's suppose that there is a known law of time distribution $F_i(t)$ without failure of the i-th control technology element, and $G_i(t)$ – is the law of time distribution of accidental errors correction. The probability density of these laws $f_i(t)$ and $g_i(t)$ we will define as continuous functions with known average T_{i1} and T_{i2} variances σ_{i1}^2 σ_{i2}^2.

We will assume that error correction occurs during the performance of other management operations and the relevant elements operation of management technology. In this approach, the flow of system failures and errors can be represented as the sum of successive processes with a finite recovery time. Their readiness factors $k_n(t)$ will determine the system functioning probability without failures at time *t*. Let's consider single random functions:

$$v_{ij}(t) = \begin{cases} 1 \\ 0, \end{cases} \quad (3)$$

Where $v_{ij}(t) = 1$, if the management operation x_{ij} is completed at the moment t; $v_{ij}(t) = 0$, when in the management operation x_{ij} at the moment t the disruption is allowed.

Then the function $v_i(t)$ can be set as:

$$v_i(t) = \frac{\sum_{j=1}^{m_i} v_{ij}}{m_i}. \quad (4)$$

Therefore for the system:

$$v(t) = \frac{\sum_{i=1}^{m} v_i(t)}{n}, \quad (5)$$

as the functions $v_i(t)$are independent , then:

$$k_\tau = M\big(v(t)\big) = \frac{\sum_{i=1}^{n} M(v_i(t))}{n} = \frac{\sum_{i=1}^{n} k_{ri}(t)}{n}, \tag{6}$$

Where $k_{ri}(t)$ – is the readiness coefficient of i-th technology element. With increasing time, the flow of failures and recovery tends to stationary, and the readiness factor of the system can be written as:

$$k_r = \frac{1}{r}\sum_{i=1}^{n} \frac{T_{1i}}{T_{1i}+T_{2i}}. \tag{7}$$

If we further assume that the system operates in stationary mode, then its other reliability characteristics are for the following reasons. Let's suppose that at time *t* there was restoring the error-free operation of the control system. Let's establish the probability that the system will function flawlessly over time τ, for which purpose events are introduced: $A(\Delta t,\tau)$ – on the site $(t-\Delta t, t)$ there was a failure, and on a site $(t, t+\Delta t)$ the system works flawlessly; $A(\Delta t)$ – on the site $(t-\Delta t, t)$ the fault was rebuilt.

The mentioned probability has the form:

$$P(\tau) = \lim_{\Delta t\to 0} P\left(\frac{A(\Delta t,\tau)}{A(\Delta t)}\right) = \lim_{\Delta t\to 0} \frac{P(A(\Delta t,\tau))}{P(A(\Delta t))}. \tag{8}$$

Ignoring the events, the probability of which was small compared to Δt, we can consider the event $A(\Delta t,\tau)$ as the sum of ordinary events:

$$A(\Delta t,\tau) = A_1(\Delta t,\tau) + A_2(\Delta t,\tau) + \cdots + A_n(\Delta t,\tau) = \sum_{i=1}^{n} A_i(\Delta t,\tau). \tag{9}$$

Here the event $A_i(\Delta t,\tau)$ is that in the i-th element of $(t-\Delta t, t)$ and on the interval control technology there're was a failure correction in the time interval c $(t, t+\Delta t)$ it functions flawlessly, other elements are executed flawlessly in the interval $(t, t+\Delta t)$. The probability of such an event is calculated by the ratio:

$$P\big(A_i(\Delta t,\tau)\big) = \frac{1-F_i(\tau)}{T_{1i}+T_{2i}} \prod_{s\neq i} \frac{\int_\tau^\infty (1-F_s(x))dx}{T_{1s}+T_{2s}} \Delta t + 0(\Delta t). \tag{10}$$

$$P\big(A(\Delta t,\tau)\big) = \sum_{i=1}^{n} P(A_i(\Delta t,\tau)). \tag{11}$$

Taking into account that the event $A(\Delta t) = A(\Delta t, 0)$, we will get:

$$P\big(A(\Delta t)\big) = \sum_{i=1}^{n} \frac{\Delta t}{T_{1i}} \prod_{s=1}^{n} \frac{T_{1s}}{T_{1s}+T_{2s}} + 0(\Delta t). \tag{12}$$

While moving to the limit when $\Delta t \to 0$, the final type of the required probability is recorded:

$$P(\tau) = \lim_{\Delta t\to 0} \frac{P(A(\Delta t,\tau))}{P(A(\Delta t))} = \frac{\sum_{i=1}^{n} \frac{1-F_i(\tau)}{T_{1i}} \prod_{s\neq i} \frac{1}{T_{1s}} \int_\tau^\infty (1-F_s(x))dx}{\sum_{i=1}^{n} (T_{1i})^{-1}}. \tag{13}$$

Let's enter the notation:

$$\widetilde{F_s}(\tau) = \frac{1}{T_{1s}} \int_0^\tau \big(1-F_s(x)\big)dx. \tag{14}$$

It characterizes the i-th element fulfillment without failures over time τ. Let's find the probability density distribution of the specified function:

$$\varphi_s(\tau) = \frac{d}{d\tau}\widetilde{F_s}(\tau) = \frac{1-F_s(\tau)}{T_{1s}}. \tag{15}$$

Let us assume that $\sum_{i=1}^{n}\frac{1}{T_{1i}}=\frac{1}{T_0}$, then T_0 – is the average time between adjacent system failures with instant error correction. The desired probability is gaining momentum:

$$P(\tau)=T_0\sum_{i=1}^{n}\varphi_i(\tau)\prod_{s\neq i}\left(1-\widetilde{F}_s(\tau)\right)=-T_0\frac{d}{d\tau}\left(\prod_{s=1}^{n}(1-\widetilde{F}_s(\tau))\right). \quad (16)$$

Let's set the average duration of the control system without failures:

$$T_1=\int_0^{\infty}P(\tau)d\tau=-T_0\prod_{s=1}^{n}(1-\widetilde{F}_s(\tau))\Big|_0^{\infty}=T_0. \quad (17)$$

As the result, $T_1=T_0=(\sum_{i=1}^{n}(T_{1i})^{-1})^{-1}$.

It follows that the average operating time of the system without failures is the same as for instant error correction [8, p. 130].

Let's determine the average system recovering time T_2 taking into account that:

$$k_\tau=\frac{T_1}{T_1+T_2}, \text{тоді } T_2=T_1\frac{1-k_\tau}{k_\tau}. \quad (18)$$

If the number of management operations in the management system is large and their share in the failures and recovery flow is very small, then the probability $P(\tau)$ can be represented in a simplified form:

$$P(\tau)\approx e^{-\frac{\tau}{T_1}}. \quad (19)$$

The system operation probability without failures in the interval $(t,t+\Delta t)$: can be found from the ratio

$$k_\tau p(\tau)\approx k_\tau e^{-\frac{\tau}{T_1}}. \quad (20)$$

In the case when the operating time of the control system without failures is subject to the indicative law:

$$F_i(t)=1-e^{-\lambda it}, \quad (21)$$

and the error correction time is distributed arbitrarily, we can find not only the average operating time of the system without failures and error correction, as well as analytical dependences of their distribution laws. If we assume that the system periods without interruption are subject to th indicative law $F(t)=1-e^{-\lambda t}$ and independent from the error correction periods, distributed by arbitrary law$\widetilde{F}(t)$, то $\lambda=\sum_{i=1}^{n}\lambda_i$.

The system readiness coefficient in this case will look like:

$$k_\tau(t)=e^{-\lambda t}+\int_0^{t}e^{-\lambda(t-x)}h(x)dx, \quad (22)$$

where $h(x)=\sum_{i=1}^{\infty}\Psi_i(x)$ – is the density of system recovery moments.

This is, as above mentioned, the quantitative criterion content for assessing the operations and actions effectiveness of an industrial enterprise management system.

Conclusions

The research paper analyzes three main generalized models of an industrial enterprise management system - target, functional and linear management. Applying any of them in the conditions of developing market relations requires assessing the management system reliability and efficiency, its ability to really reflect the enterprise capital status. It requires, first of all, quantitative criteria.

Using the economic and mathematical modeling apparatus for assessing the enterprise management system reliability is substantiated. The concept of the enterprise management system reliability also includes system failure, i.e. timely error-free execution of management operations and possible corrections. There are several management operations in the managerial system, either of which is carried out with a high probability. Management operations are grouped into separate groups - the technology elements. The dependences obtained in the work allow to calculate the reliability of the system as a whole. The study was prepared for publication within the R&D «Competition Secret Service as a Guide Security Management by Innovative-Investment Development of Enterprises of Strategic Meaning for a National Economy and Safety of the State» (R&D № 0119U002005).

Abstract

Any objectively existing enterprise management system, regardless of its size and activity nature, is a complex system that includes a set of similar technological elements. Each element corresponds to a set of specific actions – control operations. The organized relationships complexity between these elements and operations predetermines the need to take into account the specific features of system studies in the process of analyzing and evaluating the enterprise management system.

In order to assess the effectiveness of an industrial enterprise management system operations and actions, quantitative criteria are needed, the specific values of which are considered or the system properties.

On the basis of economic and mathematical modeling, an initial assessing the reliability of an industrial enterprise management system functioning is proposed. The concept of the control system reliability includes faultleness, that is, timely error-free execution of management operations and the process correlation of technological operations untimely execution is possible. It is believed that in the control system at each moment of time the technology input elements are performed independently of each other. Similarly, managerial operations are also performed independently of each other, and their failure to perform is accidental. Management operations are combined into separate groups - i.e. technology elements. It is believed that the errors correction occurs simultaneously with the other management operations implementation and corresponding elements functioning of the management technology. Three main management models were analyzed – i.e. target, functional, linear – which in practice are usually found as their synthesis.

The research paper identifies three main models of the enterprise management system. In practice, they are usually synthesized with a certain predominance of one model after the main one: a model focused on target management, which includes the activities organization and coordination of the company divisions; functional management model is specialized management activities implementation; the model focused on line management is mainly the head's managerial activity.

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