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THE CONCEPT OF ANALYSIS THE FUNCTIONAL SUSTAINABILITY OF THE ORGANIZATIONAL SYSTEM

Abstract. *The support system concept is described as a solution for ensuring the functional stability of the organizational system and approaching the mathematical model of functional stability. Several ways of reconfiguring connections between system elements are described to ensure the functional stability of the system in cases where the system's functioning is at risk due to the violation or absence of some system elements. The formulation of the problem of sustainable functioning of the organizational system is given. Some areas of human activity and subject areas in which the concept proposed in this work can be applied are considered. Schemes of the organizational system are proposed, illustrating various options for the performance of functions by the elements of the organizational system. A model of nominal resource needs in a full-time situation is proposed. A model of replacing functions performed by some element in a regular situation is also provided. Situations were also considered when some elements of the organizational system could not perform their functions for various reasons, requiring reconfiguration. Some heuristics are introduced to define decision-making situations that arise during the functioning of the organizational system.*

Keywords: organizational system; functional stability; system elements; reconfiguration; staff situation; nominal resource requirements; heuristics

Introduction

The world around us is not only changing at an incredible speed, but the speed of these changes is increasing. This forces those responsible for the functioning of organizational systems to make decisions quickly and maintain the quality of such decisions. Since there are more and more factors when making decisions, it becomes impractical to rely on intuition in most cases. Each solution requires pre-processed and consolidated data, which is justified and adequately corresponds to the decision-making situation. Today, sustainability research is a popular area of scientific research. The topic of stability of organizational systems is the subject of economic studies [1; 2] and mathematical schools of various directions [3; 4].

Problem statement

Let some set of indices of functions, the execution of which must be ensured by the elements of the organizational system, be given. We will assume that there will be n such functions. Let us denote the set of all functions performed by the system as $A = \{a_1, ...a_n\}$, $J = \{1,...,n\}$. Note that the number of functions of a complex system can be hundreds and thousands of units. The functions performed by different elements of the system are not duplicated, that is, $n = \sum_{i \in J} n_i$ – each function in the system is unique: $A^{i_1} \cap A^{i_2} = \varnothing, i_1, i_2 \in J$, where is an empty set [5].

It is clear that functions from the set A can be performed by elements of the organizational system with different levels of quality. The peculiarity of the concept proposed in this work is that the quality of performance of functions by various elements of the system is determined on an ordinal scale. The relationship between functions and the sequence of their execution is given by a binary relation B, which is a subset of the Cartesian product $A \times A$. The binary relation is built taking into account the sequence of functioning of some organizational system and reflects the logic of solving the problems facing the system and its elements [6, 7]. Moreover, the performance of each function of the system is provided by some element of the system $e^i, i \in I = \{1,...,k\}$ and can be performed by some other element $e^j, i \neq j,\ i, j \in I,$ – in the general case with different degrees of quality – that is, redundancy is embedded in the system [8; 9].

Data and methodology

Recently, more and more attention has been paid not only to the development and growth of the quality of the functioning of the organizational system but also to such an important indicator as functional stability. We can usefully define functional stability as the ability of an organizational system to absorb stress, recover critical functionality, and thrive in altered circumstances. Resilience is essential today because the business environment is becoming more aggressive, dynamic, and unpredictable. The theory of functional stability has been successfully developed over the past three decades to ensure response to such decision-making situations and to determine the sustainable functioning of complex systems [10; 11].

The concept of ensuring the functional stability of an organizational system can be applied to a wide variety of systems [12]. This can be a military unit, a business organization, or some complex mechanism, such as an entire country's IT infrastructure or energy infrastructure. Also, it is assumed that it is not functionally homogeneous. Because in a functionally homogeneous system, the process level is much simpler, and this will be just one of the variants of a non-homogeneous system.

The model of nominal resource needs in the regular situation

The nominal resource needs, in particular, the cost and time of performing the function, are such values that are acquired when the function of ensuring the operation of the organizational system is performed in regular mode - when it is performed by an element of the system that performs the function according to the a priori approved regular schedule. It is better to perform it no system element is capable of this function. Additional parameters may be specified for specific applied tasks of ensuring the reliable functioning of the organizational system, but we will not consider them in this work [13]. Also, the creation of organizational systems is connected with the development of competence methods [14 – 17].

In the process of functioning in natural conditions, the situation described in the statement of the problem may differ significantly from the idealized one. In case of temporary or long-term failure of a system element, the system does not perform all the functions that this element should perform. To fulfill them, deciding on the redistribution of functions or their replacement is necessary. Moreover, as mentioned above, information about the quality of the performance of functions by various elements of the organizational system is provided by an expert in ordinal scales - for example, in the form of a ranking of the perfection of the performance of each specific function by various elements of the system.

Let's build a matrix of all possible functions performed by each element of the organizational system:

$$A^i = (a_i^0, a_i^1), \qquad (1)$$

where $a_i^0 = \left(a_{ij}^0, j = 1,...,n_i\right), i \in I -$ the vector of basic functions of the $i -$ th system element,

$a_i^1 = \left(a_{is}^1, c_{is}, s \neq j \in \{1,...,n_i\}, s = \{1,...,\nu_i\}\right), i \in I -$ the matrix of adjacent functions of the $i -$ th system element,

$c_{is}, s \neq j \in \{1,...,n_i\}, s = \{1,...,\nu_i\}, i \in I -$ the rank of the quality of performance of a $s -$ th related function by an $i -$ th element of the system in a ranking given by experts, which is built on the set of all elements that can, in principle, perform this function.

Each function of ensuring high-quality and safe functioning of the organizational system from (1) a set of functions $A = \{a_1,...a_n\}$ is characterized by two parameters: $c_i^0 -$ the nominal price of execution or the need for a resource, $i \in I$, $t_i^0 -$ nominal execution time of the function, $i \in I$. Each element of the organizational system in regular mode performs the functions defined for it by the staff list from the set (1) and has limited opportunities to perform the entire subset of its functions:

$$\sum_{a_i^j \in A^j} c_i^j = C^j, j \in J = \{1,...,n_i\}. \qquad (2)$$

Note that restrictions may be imposed for some tasks for $\forall j, j \in J$

$$\sum_{a_i^j \in A^j} t_i^j = T, \qquad (3)$$

when resource limits are set for each system element or group of elements according to the task execution time.

When approaching these limits, the quality of ensuring the functioning of any element of the organizational system reasonably decreases.

Constraint (2) is the cost of performing tasks by an element of the organizational system, and constraint (3) is a time constraint - an analog of the monthly norms of the duration of working hours in the functioning of organizations. When performing regulatory tasks determined by the nominal tactical and technical characteristics of the organizational security system, the resource needs of the system and its elements (2)-(3) are constant, and the quality of task performance by all subsystems and the system as a whole is one hundred percent. In practice, ensuring such a situation requires the use of significant resources. The nominal tactical and technical characteristics of the system for ensuring the functioning of the organizational system are characterized by the need for various resources, the most important of which in many organizations are:

$$\sum_{i=1}^{n} c_i^{0i} = C^0 \text{ – system activity budget;}$$

$\sum_{i=1}^{n} t_i^{0i} = T^0$ – total time required to system functions.

Schemes of performance of functions by the organizational system

To adequately assess the quality of the functioning of the organizational system and ensure the quality functioning of this system, a mathematical model should be built, and an intellectual system should be created to support the functioning of the organizational system. The main entities in the intelligent system are: roles and executors. Executors are some persons performing roles. At a certain level of abstraction, the system can be considered an executor, and its top-level functions as roles in a more global system. For example, let's describe a simple organizational system. In some companies, three people work and perform five functions. One person can perform several functions, as well as one function can be performed by several people. In Figure 1, functional responsibilities are indicated by gray arrows. White arrows represent side skills not used on the job and not part of their functional responsibilities but could be used in case of necessity.

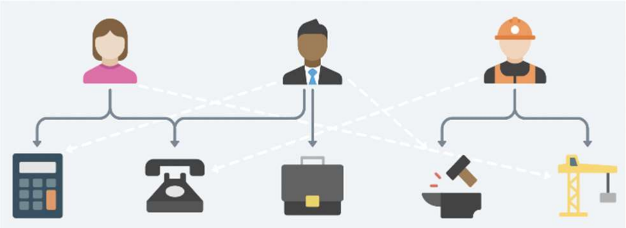

Figure 1 – Diagram of an organizational system in which 3 elements perform 5 functions

Let's say one of the performers dropped out for a while for any reason. In the case of the activity of a large organization, there are always employees who, at every current moment: are on sick leave, are on vacation, sent on a business trip, absent for unknown reasons, holidays were officially issued, dismissed from work for various reasons, violate labor discipline, absent due to force majeure, undergo adaptation and, therefore do not perform their functions with sufficient quality, involved in conflict situations, demotivated employees, etc.

In this case, the functional stability of the system will be in danger since not all system functions are performed as needed. The primary way to ensure functional stability is system reconfiguration. We will define this action, which is one of the essential components of ensuring the functional stability of the organizational system [18].

Reconfiguration is the implementation of an automatic or automated restructuring of the structure of the performance of functions of the organizational system and the exchange of information between system elements or a change in the functioning algorithm to achieve the most excellent efficiency in the performance of the purpose of functioning on the available working resources of the system. That is, when some elements of the organizational system fail, the functions they perform begin to be performed by other elements. At the same time, such redistribution is not carried out spontaneously but by evaluating various options for exchange, weighing possible consequences, considering restrictions on the ability of elements to carry out additional loads, etc.

To ensure functional stability, we will need a backup plan. We could use different strategies to mitigate the risk. One way is to use the side skills of the personnel to cover the absent person's duties. In Figure 2, red arrows represent side skills that were not used before and are now temporarily involved.

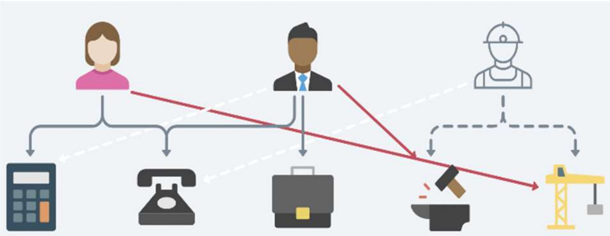

Figure 2 – Diagram of the use of reserve competences of two elements of the organizational system in case of absence of the third element of the system

Another way to fulfill the job is to ask employees who already perform the work to do overtime for a while. In Figure 3, the double arrow represents that the person will do twice as much work on the function. Sometimes, we could do nothing and leave the function without an executor. As shown in the figure, the left function. Such a decision is the prerogative of the decision-maker, who bears full responsibility.

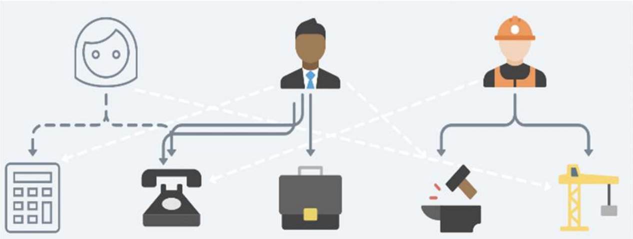

Figure 3 – Illustration of making a decision to refuse to perform one of the functions by the organizational system in the event that one of the elements of the organizational system is missing

The main criterion in this case is the quality of performance of regulatory functions of the organizational system. It is clear that, in this case, a criterion of the quality of performance of a set of functions by the system should be introduced. Depending on the values of this criterion, the decision-maker has the opportunity to make a well-considered decision regarding the choice of an option for the functioning of the organizational system.

Each approach to the formation of options for the functioning of the organizational system with a deviation from the normative provision of the performance of the system's functionality has pros and cons. For each strategy, the value of the performance quality criterion should be calculated. Thus, the manager will have the opportunity to choose among the options proposed and evaluated by the intelligent system, which allows the functioning of the organizational system in a compromised way.

In some decision-making situations, prolonged overtime of organizational system elements can lead to burnout. In other situations, the right employees may be underworked, and the additional workload will not negatively affect their motivation. In some cases, the functions of the missing elements of the organizational system may not be performed for a specific time, not impair the quality of functioning, and not affect the overall stability of the system.

In each of these decision-making situations, aspects of subjectivity play a vital role. Therefore, all factors that depend on the quality of the functioning of the elements of the organizational system and the organizational system as a whole must be adequately modeled and taken into account accordingly. To ensure such modeling, it is suggested to use decision-making models in ordinal scales. Also, in some cases, we needed a backup plan. The role may be critical, but employees need help backing up a colleague in an emergency. The case is shown in Figure 4. This situation is critical. As a rule, it indicates insufficient elaboration by experts of the organizationnal system, failure to consider all interrelationships between the elements of this system, inadequate formalization of the organizational system, etc.

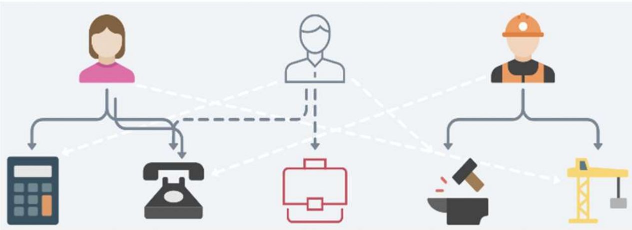

Figure 4 – Illustration of the forced non-fulfillment of one of the functions of the system in the event of the absence of one of the elements and the absence of options for duplicating this function by other elements of the organizational system

To prevent such situations, the system can help audit and show where the organization is most vulnerable. Thus, the organization could focus on reducing the risks or at least be aware of them [5, 13]. This purpose of the intelligent system can be one of the important directions of our further research.

Strategy for ensuring functional sustainability

Here are the main stages of the strategy to ensure the functional stability of the system, which must be carried out to maintain the high-quality functioning of the organizational system:

I. Analysis of the graph of organizational system functions related to system elements' failure.

II. Identification of existing system resources - areas of redundancy.

III. Generation and calculation of options for replacing system elements that have temporarily or permanently failed. That is, the regrouping of a set of functions performed by a problematic element of a complex system is evaluated.

IV. Formation and application of the procedure for optimal or suboptimal use of redundancy.

V. Introduction of heuristics that allow building a model for determining the integral quality indicator of system functioning.

VI. Calculate the assessment of the integral state of the functional stability indicator and make the final decision regarding the option of choosing the structure of the system's functioning.

VII. Evaluation of the state of the system after redistribution of resources.

Results and analysis

The actual problem of the timely response of the organizational system to external influences, which are dynamically changing, is considered. It is proposed to apply the idea of functional stability to organizational systems at a time when most of the work in this field is devoted to the study of technical systems.

In addition, a feature of the proposed approach is the breadth of possible applications - a wide range of subject areas in which various organizational systems function. At the same time, to determine the quality of the functioning of organizational systems, a wide range of approaches, methods, and algorithms have been developed, both for modeling and for determining quantitative indicators of the functioning of organizational systems.

The result of the mentioned approaches to the modeling of the organizational system and the formalization of the relationships between the elements of the system is the structuring of the problem of ensuring the functional stability of the organizational system. At the same time, the basis of decision-making regarding the generation of options for the reconfiguration of the functions of the organizational system and the selection of a compromise option is the assessment of the subjective components of the functioning of the organizational system.

Discussion and Conclusion

Schemes for ensuring the functional stability of the organizational system are considered. Several variants of the reconfiguration of the relationships between the elements of the organizational system are proposed to ensure the stable functioning of the organizational system in a situation when some of its elements cannot perform their functions for various reasons. However, at the system level, the performance of these functions is essential. It is noted that subjective factors are essential factors that affect the introduction of quality criteria for the functioning of the organizational system and the definition of the type of such criteria. Research should focus on them, and adequate conduct of computational experiments should be ensured, etc. Variants of approaches to a compromise way out of possible decision-making situations are analyzed.

The main directions of modeling the functioning of the organizational system and possible bottlenecks in such modeling are outlined. Ideas for the further development of the intellectual system are also defined. It is obvious that applying expert decision-making technologies and modeling decision-making situations in ordinal scales will be a priority in the study of the functional stability of organizational systems.

A feature of this kind of model is the breadth of its application. Some areas of application of models of sustainable functioning of organizational systems are given in this work: business organizations, systems for ensuring the functioning of critical infrastructure, military units, information systems, etc.

References

1. Sanchis, R. & Poler, R. (2013). Definition of a framework to support strategic decisions to improve Enterprise Resilience. *IFAC Proceedings*, 46, 9, 700–705.

2. Sabatino, M. (2016). Economic crisis and resilience: Resilient capacity and competitiveness of the enterprises. *Journal of Business Research,* 69, 5, 1924-1927.

3. Pichkur, V. & Sobchuk, V. (2021). Mathematical models and control design of a functionally stable technological process. *Journal Of Optimization, Differential Equations And Their Applications (JODEA),* 29, 1, 1–11, DOI: 10.15421/141905

4. Sobchuk, V., Olimpiyeva, Y., Musienko, A. & Sobchuk, A. (2021). Ensuring the properties of functional stability of manufacturing processes based on the application of neural networks. *CEUR Workshop Proceedings*, 2845, 106–116.

5. Babenko, T., Hnatiienko, H. & Vialkova, V. (2020). Modeling of information security system and automated assessment of the integrated quality of the impact of controls on the functional stability of the organizational system. Selected Papers of the XX International Scientific and Practical Conference "Information Technologies and Security". CEUR Workshop Proceedings, 2859, 188–198.

6. Voloshyn, O. F. & Mashcenko, S. O. (2018). Decision-making models and methods: teaching. manual for students higher education closing. *Lyudmila Publishing House*, 292.

7. Hnatiienko, H., Snytyuk, V., Tmienova, N. & Voloshyn, O. (2021). Application of expert decision-making technologies for fair evaluation in testing problems. *CEUR Workshop Proceedingsthis link is disabled*, 2859, pp. 46–60.

8. Mashkov, O. A. & Barabash, O. V. (2003). Synthesis of the structure of an automated system according to the criterion of maximum functional stability. *Aerospace systems monitoring and management*, 193–196.

9. Barabash, O. V., Kozelkov, S. V. & Mashkov, O. A. (2005). Understandable apparatus of functional efficiency of information-critical systems. *Collection of scientific works NTs VPS ZS Ukraine*, 7, 87–95.

10. Mashkov, O. V., Kononov, D. A. & Pekarev, D. V. (2006). Methods of building functionally stable complex dynamic systems. *Visnyk ZhDTU*, 93–103.

11. Kravchenko, Y. & Vialkova, V. (2016). The problem of providing functional stability properties of information security systems. Modern Problems of Radio Engineering, Telecommunications and Computer Science, Proceedings of the 13th International Conference on TCSET 2016, 526–530.

12. Mashkov, O. A., Chumakevich, V. A., Mamchur, Y. V. & Kosenko V. R. (2020). The method of inverse problems of dynamics for the synthesis of a system of stabilization of the movement of a dynamic object on operatively programmable trajectories. *Mathematical Modeling and Computing*, 7, 1, 29–38. DOI: 10.23939/mmc2020.01.029.

13. Babenko, T., Hnatiienko, H., Ignisca, V. & Iavich, M. (2021). Modeling of critical nodes in complex poorly structured organizational systems. Proceedings of the 26th International Conference on Information Society and University Studies (IVUS 2021). *CEUR Workshop Proceedings*, 2915, 92–101.

14. Xu, H., Kuchansky, A., Gladka, M. (2021). Devising an individually oriented method for selection of scientific activity subjects for implementing scientific projects based on scientometric analysis. *Eastern-European Journal of Enterprise Technologies,* 6 (3 (114)), 93–100. DOI: 10.15587/1729-4061.2021.248040.

15. Bushuyev, D., Bushuieva, V., Kozyr, B. & Ugay, A. (2020). Erosion of competencies of innovative digitalization projects. *Scientific Journal of Astana IT University*, (1), 70-83. DOI: 10.37943/AITU.2020.1.63658.

16. Biloshchytskyi, A., Kuchansky, A., Andrashko, Y., Omirbayev, S., Mukhatayev, A., Faizullin, A. & Toxanov, S. (2021). Development of the Set Models and a Method to form Information Spaces of Scientific Activity Subjects for the Steady Development of Higher Education Establishments. *Eastern-European Journal of Enterprise Technologies*, 3, 6–14. DOI: 10.15587/1729-4061.2021.233655.

17. Kuchansky, A., Biloshchytskyi, A., Andrashko, Y. & Wang, Yingxing. (2022). Devising A Competence Method To Build Information Spaces For Executors of Educational Projects in a Dynamic Environment. *Eastern-European Journal of Enterprise Technologies*, 1 (3 (115)), 66–73, 2022, DOI: 10.15587/1729-4061.2022.253043.

18. Dodonov, O. G., Gorbachyk, O. S., Kuznetsova M. G. (2021). Automated systems of organizational management of critical infrastructure objects: safety and functional stability. Information technologies and safety. Materials of the XXI International Scientific and Practical Conference ITB-2021, 3–8.

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КОНЦЕПЦІЯ АНАЛІЗУ ФУНКЦІОНАЛЬНОЇ СТІЙКОСТІ ОРГАНІЗАЦІЙНОЇ СИСТЕМИ

Анотація. *Описано концепцію системи підтримки прийняття рішення для забезпечення функціональної стійкості організаційної системи та математичну модель функціональної стійкості. Описано кілька способів переналаштування зв'язків між елементами системи для забезпечення функціональної стійкості системи у випадках, коли функціонування системи перебуває під загрозою через порушення або відсутність окремих елементів системи. Дано постановку проблеми сталого функціонування організаційної системи. Розглянуто окремі сфери людської діяльності та предметні області, в яких може бути застосована запропонована в цій роботі концепція. Запропоновано схеми організаційної системи, що ілюструють різні варіанти виконання функцій елементами організаційної системи. Запропоновано модель номінальної потреби в ресурсах при повній зайнятості. Також представлено модель заміни функцій, які виконує деякий елемент у штатній ситуації. Розглядалися ситуації, коли деякі елементи організаційної системи з різних причин не могли виконувати свої функції, вимагаючи реконфігурації. Деякі евристики вводяться для визначення ситуацій прийняття рішень, які виникають під час функціонування організаційної системи.*

Ключові слова: організаційна система; функціональна стійкість; елементи системи; реконфігурація; кадрова ситуація; номінальні потреби в ресурсах; евристики

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