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ASSESSING THE RELIABILITY OF COMPLEX SYSTEMS UNDER UNCERTAINTY IN THE CONTEXT OF ENSURING NATIONAL RESILIENCE

Introduction. *Existing methods for assessing the resilience of key processes and objects within the state and society as complex social systems need to be developed and improved in order to enhance the accuracy and objectivity of the results of such an assessment.*

Problem Statement. *There is an urgent need for the development of methods to assess the reliability of complex systems under uncertainty in the context of ensuring national resilience, which is an innovative and promising direction of interdisciplinary research.*

Purpose. *The purpose of this research is the development of recommendations on the formation of a methodology for assessing the continuity of governance as an element of ensuring national resilience.*

Material and Methods. *The methodology is based on the theoretical discussion including research of scholarly research literature and public sources using analysis, synthesis, as well as system, logical, structural-functional, comparative, abstract logical, and other methods.*

Results. *It has been proved that both qualitative and quantitative methods, including mathematical methods based on the theory of reliability of complex technical systems, can be used to assess the continuity of governance*

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as a process that is generated by a complex social system. The method of a quantitative assessment of the reliability of complex technical systems has been improved by taking into account the properties of multi-mode objects, the possibility of changing their structure during the operation, and the working time of their components in different modes of operation. The effect of the advanced method has been calculated by assessing the reliability of the governmental communication system and its subsystems as an example.

Conclusions. *Practical application of the methodology for assessing the continuity of governance, which should be developed on the basis of systematic and integrated application of quantitative and qualitative methods, is essential for enhancing national security and resilience strategic planning.*

Keywords: complex systems, national resilience, multi-mode objects with variable structure, methods of assessment, reliability.

National resilience is becoming increasingly important in the world, given the significant deterioration of the global security situation. Current risks and threats to national security are becoming increasingly difficult to predict. States and their societies operate under conditions that may change unpredictably and rapidly. Consequently, the current security environment is characterized by a high level of uncertainty. Shaping an effective state policy on national security should be based on the results of strategic analysis and assessment of the resilience of key processes and objects (or facilities) within the state and society as complex social systems. The existing methods of this evaluation need to be upgraded and advanced in order to improve its accuracy and objectivity. The spread of the application of mathematical methods in the area of national resilience assessment, commonly used to assess the reliability of complex technical systems, will help to address this problem. This will require certain improvements in these methods and their adaptation to uncertainties. In general, the study of methods to assess the reliability of complex systems in uncertainty in the context of ensuring national resilience is quite innovative since they are multidisciplinary and involve a combination of technical and social research.

Ensuring the continuity of governance and the provision of critical public services is recognized as a key area for national resilience by many states and international organizations. In particular, this is one of the seven NATO baseline requirements for national resilience, which were approved by the Heads of State and Government at the NATO Summit in Warsaw in 2016 as part of the Commitment to enhance resilience [1]. The document also indicates that states now face a broader and evolving range of military and non-military security challenges and threats, including hybrid ones. Under such circumstances, the protection of the population and territory requires not only adequate capabilities and preparedness of the armed forces to respond to threats but also civil preparedness, including the continuity of government and the provision of essential services to the population, security of critical infrastructure, sustainable development of the state and society, etc.

Ensuring national resilience is quite a new direction of state policy in Ukraine. The system principles and priorities in this sphere are defined by the Concept of the national resilience system development, approved by the Decree of the President of Ukraine of September 27, 2021, No. 479/2021 [2]. In particular, this document identifies that national resilience is the ability of the state and society to effectively counter threats of any origin and nature, adapt to changes in the security environment, maintain sustainable functioning, and recover quickly to the desired equilibrium after a crisis. It is also mentioned, that systemic support of national resilience is carried out on the basis of a set of purposeful actions, methods, and mechanisms of interaction of state authorities, local self-government bodies, enterprises, organizations, and civil society institutions that guarantee the preservation of security and the operational continuity of the main areas of society and state activity before, during and after a crisis.

The abovementioned Concept also identifies reliability as a key principle for ensuring national resilience. This implies that the system is fully operational and able to deal with disruptions caused by threats and crises and that all actors involved in ensuring national resilience have sufficient resources and capabilities to respond to threats. Among the basic directions of ensuring national resilience, the document identifies, inter alia, guaranteeing the efficiency and capability of the full functioning of the public authorities system, their organizational resilience, as well as ensuring the security and protection of critical infrastructure, including cyber security, the smooth operation of information and communication services, etc.

The practical implementation of the principles and objectives of the Concept of the national resilience system in Ukraine provides, inter alia, for the development of methods for assessing the reliability of facilities and processes that are key to ensuring national resilience, as well as determination of the level of optimum and reliability limits. In particular, continuity of governance can be analyzed in terms of various components such as legal and organizational framework, technical and social components of communications, social trust and assistance. Assessment of each of these components requires different methods. Their combination forms the basis of the resilience assessment methodology.

The improvement of the national resilience assessment methodology is an important task not only for Ukraine but for other countries and international organizations as well. A recent example of such a methodological flaw was the underestimation of Ukraine's resilience on the eve of the Russian invasion. Therefore, existing methods of national resilience assessment, which are based on expert surveys, can be biased and subjective.

We are currently facing various kinds of uncertainty. One of them is the level of resilience of the state and society, which is difficult to assess. The phenomenon is that resilience is enhanced in peacetime, and its real potential is revealed mostly in crisis. We can more or less precisely assess the readiness of government bodies or the armed forces to respond to various crises. Nevertheless, the assessment of social resilience is very challenging. Society has an embedded potential for resilience and self-organization, which can be hidden in peacetime.

Given this, there is an urgent need for the development of methods to assess the resilience of the state and society as complex systems that include the assessment of its components' reliability under uncertainty.

Modern research on national resilience, particularly by researchers like J. Joseph [3], M. Cavelty, M. Kaufmann and K. Kristensen [4], G. Lasconjarias [5], C. Holling [6, 7], C. Fjäder [8], C. Folke [9], and others, suggest that the state and society as complex social systems have a certain capacity for resilience, which can be enhanced by the formulation and implementation of the relevant state policy. A number of classical processes in the field of organization of public administration and national security are gradually losing their effectiveness in the changing security environment and require improvement according to the principles of resilience [10]. One such process is ensuring continuity of governance as a key attribute of national resilience [11, 12]. In the context of the development of effective state policy, there is a need to assess the relevant process by resilience criteria: reliability, redundancy, adaptability, absorption, readiness, speed of response and recovery [10, 13, 14].

The methodology for assessing processes and outcomes in complex social systems has been the subject of many studies, including the work of J. van Gigch [15, 16], J. Fiksel [13], D. Rensel [14], C. Churchman and P. Ratoosh [17], Resilience Alliance [18], etc. We can note that among the methods of the above-mentioned assessment, which are proposed by modern researchers, the most prevalent are methods of surveys, questionnaires, and expert reviews and evaluations. The disadvantages of these methods are certain subjectivity of the assessments, different professional levels of experts, the possibility of manipulation by the

organizational group that prepares the questionnaires and summarizes the results, etc. It should be added that the continuity of state governance is ensured not only by the establishment of reliable and effective professional social networks but also by appropriate technical means and systems that, inter alia, store, transmit, process, and protect the information (including confidential), necessary for the functioning of the state governance system. In contrast to complex social systems, other methods, mostly quantitative, are used to assess the resilience and reliability of complex technical systems.

The combination of the above-mentioned qualitative methods of assessing processes and evaluating results in complex social systems with quantitative methods based on mathematical calculations allow for increasing the objectivity and accuracy of the results, and in general — the effectiveness of public policies that are developed on the basis of respective assessments and evaluations. Given the above, a promising area for research is the improvement and adaptation of methods to assess the reliability of complex technical systems for their application in evaluating the resilience of complex social systems.

Modern research in the field of the theory of reliability of complex technical systems is aimed at the creation of objects with predetermined values of reliability indicators through the reservation of the least reliable structural elements and the creation of the so-called "Absolutely reliable systems," which have a readiness coefficient of $A \geq 0.997$ (for example, for interplanetary spacecraft and robots for exploration of other planets) [19—23]. Special attention is paid to the development of software-controlled technical means and systems, the complexity of which is constantly increasing, which also affects their reliability [22, 24, 25]. We state that in Ukraine the requirements for the value of mean time between failures and the average recovery time of complex technical equipment and systems have not changed so far. The works of modern foreign researchers have presented various aspects of ensuring the reliability of complex technical systems and hardware, including radio-electronic — from improving the quality of the element base to forecasting the change of reliability indicators over time [26—30]. However, methods for assessing the reliability of objects with variable structures as a variant of complex technical systems are usually beyond the scope of these studies.

Thus, the improvement of existing methods for calculating the reliability values of complex technical facilities and systems should take into account their properties: multi-mode, multi-functionality, and redundancy. This changes the structure of the object or system when it is used for its intended purpose. At present, there are no theoretical and practical methods for calculating the performance efficiency of systems with variable structures, which can change randomly at short intervals. It should be borne in mind that the character of changes in the structure of a complex system depends on changes in its functions [19, 20] and external influences (e.g., war, natural or man-made disasters, etc.).

Given the *interdisciplinary nature* of the concept of national resilience, the article's combination of research results in various fields of knowledge to achieve the goal is a feasible and forward-looking approach to the solution of this research and practical problem and it opens a wide space for further research.

The methodology for analyzing the peculiarities of assessing the reliability of complex systems under uncertainty in the context of ensuring national resilience is based on theoretical discussion. The model for the analysis is built on the combination of the results of research in different fields of knowledge — social and engineering sciences. This composition within the scope of the goals of this research is possible due to the common theoretical basis of the *complex systems theory*.

The purpose of the research is to develop recommendations on the formation of a methodology for assessing the continuity of state governance as an element of ensuring national resilience.

The following ***main research objectives*** will contribute to achieving this goal:

- to reveal the peculiarities of assessing the continuity of state governance as a direction of ensuring national resilience;
- to prove that mathematical methods of assessing the reliability of complex technical systems can be used to assess the continuity of state governance;
- to identify opportunities and ways to improve the methods of the complex technical systems' reliability assessment, with a view to applying them to the assessment of the complex social systems' resilience;
- to improve the method of assessing the reliability indicators' values of objects with variable structure, given the operational time of separate aggregates of their elements for the purpose of its application for state governance continuity assessment.

For the purpose of this article, a review and analysis of scholarly research literature and public sources have been undertaken. A system, logical structural-functional, comparative, abstract-logical, and other methods as well as analysis and synthesis were selected as the main methods of the study. Concerning the data analysis, upon finding and uncovering the patterns and insights from the collected documents and publications, they have been studied carefully in terms of the information relevance, as well as categories and key concepts used in them.

In order to determine the methodology for evaluating the continuity of governance, an analysis of the constituents of the process and factors affecting it was conducted. According to the conclusion of the seminar on "Achieving the NATO Baseline Requirement for Continuity of Government" held on September 21—22, 2016, in Warsaw (Poland), to ensure the continuity of state governance, the main efforts should be aimed at guaranteeing the state's ability to take, justify and implement decisions in a lawful, effective and accountable manner, even in crisis situations. It was also stressed that not only a well-organized and legally regulated system of state governance particularly in the area of national security, contributes to reducing the risks of social chaos and disruption during crises, but also a set of timely measures to protect it from the consequences of terrorist and information threats, cyber attacks, natural disasters, hostile external influences, etc. as well as effective interagency cooperation [31].

According to J. van Gigch, [15, 16], C. Churchman and P. Ratoosh [17], the determination of the results to be evaluated cannot be separated from the determination of the properties (characteristics) that form those results. Therefore, in order to assess the continuity of state governance, it is important to describe the essential components of the process and the factors influencing it. Building on the methodology for assessing the resilience of socio-ecological systems developed by the Resilience Alliance [18], it is advisable to establish a model based on the main characteristics of the state governance system to fully assess the continuity of governance as a process generated by a complex social system.

Given the experience of organizing the governance process in Ukraine in crisis conditions, including during the COVID-19 pandemic and the full-scale war of the Russian Federation against Ukraine, we can state that to ensure the continuity of state governance it is important:

- to create and promote basic and standby capabilities, as well as the development of alternative plans and strategies, which provide for the state's performance of socially important functions at the minimum necessary level during a crisis and rapid recovery in the post-crisis period;
- to develop and implement patterns and arrangements for the assignment of responsibilities and filling of key posts in public administration;
- to define clear and understandable algorithms of interaction in crisis, delimitation of authority, and establishment of responsibility;
- to establish communication channels that allow public decisions to be made, explained, and implemented in both regular and crisis situa-

tions, in compliance with the principles of legality, efficiency, and accountability [10].

We affirm that while the state plays a decisive role in ensuring national resilience, the role of other actors in the process is increasing. In a crisis, society consciously assumes some important functions of the state, thereby helping to ensure the continuity of government. One striking example of this phenomenon is the powerful volunteer movement that has been formed in Ukraine to help the state defend its territorial integrity and independence in the war waged by Russia. Thus, an important direction of ensuring the continuity of state governance is the development of partnership between the state and society, the shaping of cooperation programs in the field of national security and resilience, identifying areas of competence that can be devolved to communities for local implementation or for which public organizations can be involved. The Resilience Alliance concludes that bringing the state and society together enhances overall resilience by promoting flexibility, inclusiveness, diversity, and innovation [18].

In view of the above, we state that the following indicators should be taken into account in determining the methodology for assessing the continuity of governance and the performance of critical functions of the state:

- availability and reliability of alternative sources and supply chains of drinking water, food, and electricity for the population;
- availability and reliability of alternative sources and supply chains of electricity and potable water for administrative buildings;
- availability and reliability of alternative premises, to which state institutions, strategic enterprises and their employees, temporarily displaced persons, as well as medical facilities and victims can be relocated;
- reliability of warning, communication, and cyber protection systems;
- reliability and security of data storage and transmission systems, capability to work remotely, including taking into account the need to protect restricted information;
- availability and reliability of alternative transport routes, etc.

On the basis of the analysis of the above-mentioned indicators of governance continuity, we conclude that both qualitative and quantitative methods can be used to evaluate the relevant processes and objects.

We affirm that, in today's environment, state governance must be sufficiently flexible and adaptive. This implies the continuous obtainment and analysis of information that is essential for the identification and adjustment of the state and society's further development ways. As C. Holling states, this approach reduces the impact of uncertainty on the results of state policy [32]. The assessment of the objects and processes' resilience within complex social systems is primarily intended to identify weaknesses (vulnerabilities) that need to be addressed. The same applies to the assessment of state governance continuity. As defined by the Resilience Alliance, adaptive management considers uncertainty, tests assumptions about it, and attempts to fill the gap between knowledge and action [18].

Therefore, the assessment of the continuity of state government is not a static process. It should be repeated periodically, and the methodologies used should be updated as necessary, given changes in the context of the situation. Also, assessment methods can be improved. Evaluation criteria and indicators and their threshold values can be specified.

Currently, survey, analysis, generalization, observation, extrapolation, systematization, classification, and ranking are common qualitative methods for assessing the resilience and reliability of objects and processes within complex social systems. The main issues of concern are the inaccuracy and subjectivity of qualitative assessments. At the same time, the accuracy and comprehensibility of the formulation of the questions for the evaluation questionnaires, the level of research detail, and the clarity of the definition of its modalities, given the context of the current situation and its development trends, the reliability of the

data for analysis, the definition of relationships and interdependencies between results and their deviations in different conditions, etc. have a significant impact on the evaluation results.

In the modern world, the practice of self-assessment of resilience, which is carried out, as a rule, by various government agencies, organizations, and enterprises, has also become widespread. Their applicability is attributable to the ability of complex systems to self-organization and self-governance [32]. To employ this type of study, authorized bodies or organizations develop special questionnaires and instructions for their completion, and determine the range of agents (government agencies, organizations, enterprises, etc.) who have to respond within a fixed period. Completed questionnaires are analyzed using a certain methodology to determine the compliance and effectiveness of existing practices, identify vulnerabilities, etc.

Many researchers conclude that combining different research methods to assess the performance of complex systems increases the level of accuracy and objectivity of the estimates obtained. At the same time, with the simultaneous application of different quantitative and qualitative methods of evaluation, the problem of combining their results to form an integrated assessment of governance continuity arises.

One of the *limitations* of this research was that only continuity of state governance was selected as an area of national resilience to be assessed. This is due to the fact that the methodology for evaluating the continuity of state governance can combine both quantitative and qualitative methods for assessing the resilience and reliability of objects and processes within complex social systems.

Another limitation of the study was that only the government communication system that plays an important role in ensuring the continuity of state governance was in focus for analyzing the possibility of improvement in the methods of assessing the reliability of complex technical systems as multi-mode objects with a variable structure. For the purpose of this article, such components of the continuity of state governance as a legal and organizational framework, and social components of communications were neglected.

One more limitation concerns classified information that cannot be disclosed. All these aspects were taken into consideration while the research has been conducted.

In crisis, it is possible to temporarily stop or limit the volume of critically important functions that should be provided by the state, and also the mode of functioning of state bodies, their structure, and the amount of available reserves may change [33]. Thus, to assess the continuity of governance as a process generated by a complex social system, the method of quantifying the reliability of multi-mode objects with a variable structure can also be applied. First of all, it is about assessing the reliability of complex technical systems that play an important role in ensuring the continuity of governance. The specified method allows for the assessment of multi-mode objects with a variable structure, which can be identified both with systems and with individual products: for example, with the government communication system as a whole, or for individual means of communication.

The essence of the improvement of the specified method is to take into account the operating time of the object in each mode to determine the failure time and the average recovery time. The purpose of the quantitative assessment method of the reliability of multi-mode objects with a variable structure, its essence, initial data, limitations and assumptions, as well as the result of its use are given in the structural diagram shown in Fig. 1. Depending on the purpose of the research, the object can be understood as a system, subsystem, or their constituent parts.

The proposed mathematical apparatus is summarized in Table 1, where for the first time the coefficients of the use of collections of elements of the object, the values of which affect all other indicators of its reliability, are introduced [35].

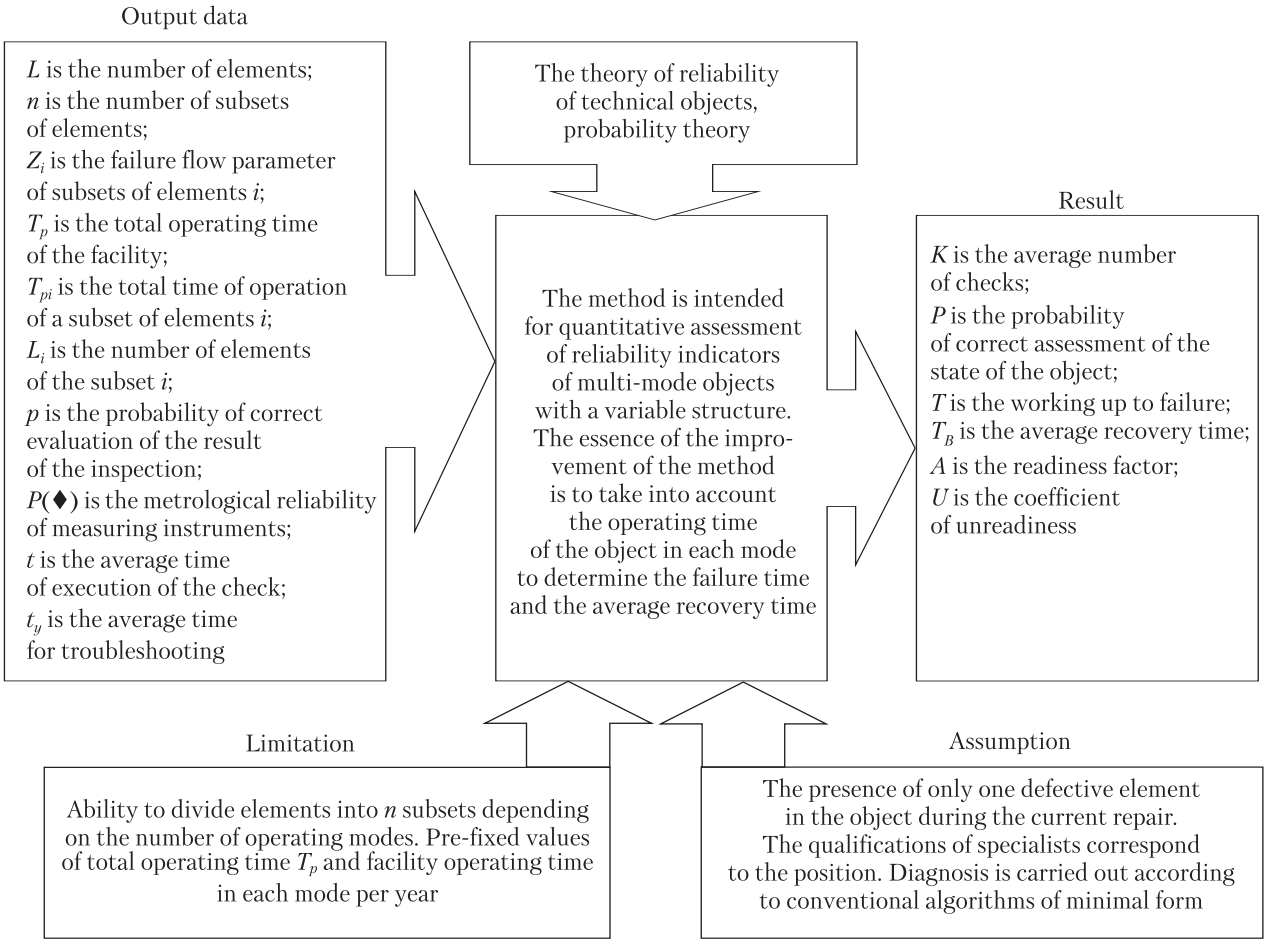

Fig. 1. Scheme of using the method of quantitative assessment of the reliability indicators of objects with a variable structure

Let's consider the procedure for using the obtained results on the example of the government communication system that consists of the following subsystems:

wire and fiber optic communication lines (i = = 1);

radio relay communication (i = 2);

radio communication (i = 3);

satellite communication (i = 4).

The uncertainty lies in the fact that it is difficult to estimate the operating time of each subsystem u_i in advance. For example, from operating experience we have: $u_1 = 0.7$; $u_2 = 0.2$; $u_3 = 0.05$; $u_4 = 0.05$.

In this case, at $Z_1 = 0.4545 \cdot 10^{-3}$ h^{-1}; $Z_2 = 1.25 \times \times 10^{-3}$ h^{-1}; $Z_3 = 0.909 \cdot 10^{-3}$ h^{-1}; $Z_4 = 0.4 \cdot 10^{-3}$ h^{-1} is obtained for the government communication system as a whole:

$$Z = (0.7 \cdot 0.4545 + 0.2 \cdot 1.25 + 0.909 \cdot 0.05 + + 0.05 \cdot 0.4)\ 10^{-3}\ \text{h}^{-1} = 0.6336 \cdot 10^{-3}\ \text{h}^{-1}.$$

That is, the working time for the failure of the government communication system is equal T = = $1/Z$ = 1578 h.

Considering that the current repair of communication equipment is carried out by the aggregate method with the depth of the defect search to a typical element of replacement, we get the

average number of checks during diagnosis, given the experience of operation (L_1 = 64, L_2 = 128, L_3 = 32, L_4 = 256):

$$K = \frac{1}{4}(\log_2 64 + \log_2 128 + \log_2 32 + \log_2 256) = 6.5.$$

The use of modern digital measuring devices (p = 0.997) [34, 36, 37] increases the probability of correct diagnosis to the value $P = p^K = 0.99$.

Knowing the average troubleshooting time t_y = = 0.2 h and the metrological reliability [33] of the measuring equipment $P(\tau) = 0.96$ we get the average time to restore the government communication system at the time of the inspection t = 0.1 h:

$$T_B = \frac{0.2 + 0.1\,(0.7 \cdot 0.4545 \cdot 6 + 0.2 \cdot 1.25 \cdot 7 + 0.005 \times}{0.99 \times} \times \frac{\times 0.909 \cdot 5 + 0.05 \cdot 0.4 \cdot 8 + 0.05 \cdot 0.4 \cdot 8) / 0.6336}{\times 0.96} =$$

$$= 0.8824 \text{ h}$$

Table 1. **Mathematical Model for Estimating Values of the Reliability Indicators of Objects with a Variable Structure**

Indicator	Functional dependencies
The coefficient of use of combinations of elements i	$u_i = T_{pi} / T_p;\ i = \overline{1, n}$
Object failure flow parameter	$Z = \sum_{i=1}^{n} u_i Z_i$
Building up the facility for failure	T = 1/Z
The average number of inspections during the current repair	$K = \frac{1}{n}\sum_{i=1}^{n} \log_2 L_i$
Probability of correct diagnosis	$P = p^K$
Average object recovery time	$T_B = \frac{t_y + \frac{t}{Z}\sum_{i=1}^{n} u_i Z_i \log_2 L_i}{P \cdot P(\tau)}$
Facility readiness factor	$A = T / (T + T_B)$
The factor of unpreparedness of the object	$U = T_B / (T + T_B)$

Source: [34—35].

The comprehensive indicator of the reliability of the communication system is equal to $A = \frac{1578}{1578 + 0.8824} = 0.99944$, and the coefficient of unpreparedness, respectively U = 1 – A = = 0.00056.

Thus, based on the conclusions of V. A. Ostreikovsky and A. M. Polovka [19, 20], the government communication system should be classified as absolutely reliable systems.

If we evaluate its reliability according to known methods [19—25] without taking into account the property of a possible change in the structure during operation, we get the following failure flow parameter (assuming that all subsystems work simultaneously):

$Z' = (0.4545 + 1.25 + 0.909 + 0.4)\ 10^{-3} = 3.0135 \times$ $\times\ 10^{-3}$ h^{-1} and system failure time T' = 331.84 h that underestimates the real value η = 4.75 times and to ensure the required values of the reliability indicators of the government communication system as a whole requires the use of a more expensive element base.

With $T'_{B'} = \frac{t_y + t\sum_{i=1}^{n} \log_2 L_i / n}{P \cdot P(\tau)} = \frac{0.2 + 0.1(6 + }{0.99 \times}$

$$\frac{+ 7 + 5 + 8)/4}{\times 0.96} = 0.894 \text{ h}.$$

The comprehensive indicators of the reliability of the government communication system are equal to A' = 0.9973 and U' = 0.0027, respectively.

That is, the proposed method allows not only clarifying the reliability indicators of the government communication system, but also reducing the estimated value of the unreadiness coefficient 4.82 times. In general, this approach makes it possible to increase the accuracy of calculations of the reliability indicators of complex systems and their elements, and as a result, to increase the effectiveness of strategic planning in the field of national security and resilience.

CONCLUSIONS

The development and practical application of the methodology for assessing state governance continuity as a key area of national resilience are critical to improving strategic planning in national security. The complexity of such a methodology is that it should involve the simultaneous application of quantitative and qualitative methods to assess the resilience and reliability of complex technical and social systems. The suggested research approach enhances the accuracy and objectivity of integrated assessment. Another challenge is the need to combine evaluation results from different methods to form an aggregate assessment of governance continuity. The need to solve these problems determines the prospects for further research studies on the basis of interdisciplinary research.

The improvement of mathematical methods for assessing the reliability of complex technical systems should consider the possibility of changing their structure during operation. In this context, the use of multi-mode properties of objects clarifies the value of reliability indicators both for the failure run and the average recovery time. Further studies to assess the resilience and reliability of the government communications system and its technical components as essential ingredients of state governance continuity should focus on improving existing assessment methods, given the variability of the structural changes of this system when used as intended, especially during exercises, martial law or other crises, as well as the duration of operation of certain elements of the system.

The conducted study offers recommendations on the development of a methodology for assessing the continuity of state governance as an element of ensuring national resilience and proves that the use of modern advances in the theory of large technical systems' operation allows, even under uncertainty of the mode of application of the individual components of the systems, with the necessary accuracy for practice, quantifying the value of reliability indicators and thus ensures the necessary resilience of critical infrastructure. This corresponds to the tasks defined by the Concept of the national resilience system development, approved by the Decree of the President of Ukraine of September 27, 2021, No. 479/2021.

One of the directions of ensuring a given level of reliability is the development and implementation of measures to increase the level of cyber resilience of communication and technological systems that ensure the continuous functioning of government agencies, critical infrastructure, and the most important civilian and military infrastructure facilities. In this context, the practical significance of the obtained research results is that when modernizing existing and designing new notification systems, government communication, as well as communication systems of law enforcement agencies of Ukraine in conditions of uncertainty in the use of their individual components, it is possible to reduce the cost of components, keeping set values of system reliability indicators as a whole. The known methods assume simultaneous operation of all components, which, in turn, significantly reduces the value of such indicators as failure time and the system availability ratio as a whole.

In changing environment, state governance must be sufficiently flexible and adaptive. There is a need to study wartime response experiences in Ukraine. Gaps in emergency plans, procedures, or other arrangements should be identified. National laws and regulations should be updated to ensure better preparedness, response, and recovery efforts throughout society.

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ОЦІНЮВАННЯ НАДІЙНОСТІ СКЛАДНИХ СИСТЕМ В УМОВАХ НЕВИЗНАЧЕНОСТІ У КОНТЕКСТІ ЗАБЕЗПЕЧЕННЯ НАЦІОНАЛЬНОЇ СТІЙКОСТІ

Вступ. Наявні методи оцінювання стійкості ключових процесів та об'єктів у межах держави та суспільства як складних соціальних систем потребують розвитку й удосконалення з метою підвищення рівня точності та об'єктивності результатів такого оцінювання.

Проблематика. Існує нагальна потреба розвитку методів оцінювання надійності складних систем в умовах невизначеності у контексті забезпечення національної стійкості, що є інноваційним і перспективним напрямком міждисциплінарних досліджень.

Мета. Розроблення рекомендацій щодо формування методології оцінювання безперервності державного управління як елементу забезпечення національної стійкості.

Матеріали й методи. Методологія передбачає дослідження наукової літератури та публікацій з відкритих джерел із використанням методів аналізу й синтезу, а також системного, логічного, структурно-функціонального, компаративного, абстрактно-логічного та інших методів.

Результати. Доведено, що для оцінювання безперервності урядування як процесу, що генерується складною соціальною системою, можуть застосовуватися як якісні, так і кількісні методи, зокрема й математичні методи на основі теорії надійності складних технічних систем. Удосконалено метод кількісного оцінювання надійності складних технічних систем через урахування властивостей багаторежимності об'єктів, можливості зміни їхньої структури під час функціонування і часу роботи складників у різних режимах функціонування. Розраховано ефект від застосування удосконаленого методу на прикладі оцінювання надійності системи урядового зв'язку та її підсистем.

Висновки. Використання на практиці методології оцінювання безперервності державного управління, яку необхідно розробити на основі системного й комплексного застосування кількісних і якісних методів, має виключно важливе значення для підвищення ефективності стратегічного планування у сфері національної безпеки та стійкості.

Ключові слова: складні системи, національна стійкість, багаторежимні об'єкти зі змінною структурою, методи оцінювання, надійність.