# *Peculiarities of supporting anti-crisis decision-making in the conditions of the epidemic danger of the spread of COVID-19*


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***Abstract*—The work examines the peculiarities of the functioning of situational centers in the event of an epidemic danger of the spread of COVID-19. A procedure has been developed to support the adoption of anti-crisis decisions at the regional management level regarding the implementation of targeted actions aimed at minimizing the consequences of medical and biological emergency situations in the conditions of the epidemic danger of the spread of COVID-19.**



***Keywords*—medico-biological emergency, epidemic danger, COVID-19, anti-crisis decision-making support, situation center, unified state system of civil defence, minimization of consequences**


## I. Introduction

The effectiveness of the functioning of the geoinformation system for the safety of emergency situations of a medical and biological nature, the functions of which are implemented according to the principle of the classical control circuit and are schematically presented in fig. 1, in many cases depends on the operation of the anti-crisis decision support system which is based on the synthesis of information and communication technologies, information storage and presentation tools, computer decision support tools. This decision-making support system can be presented in the form of a situational center which means a set of methods, algorithms, management decision-making models and a set of technologies both supporting and implementing these decisions [1, 2]. The development of such approaches to the adoption of effective anti-crisis decisions regarding the implementation of early actions as intended, which are aimed at minimizing the consequences of a medical and biological emergency, is an urgent task.

## II. Features of the functioning of the situation center for supporting the acceptance of anti-crisis decisions under the conditions of the epidemic danger of the spread of COVID-19

The situational center should, in accordance with the data in fig. 2, to ensure: 1) analysis of information received from the monitoring subsystem; 2) modeling of the development of emergency situations on the territory of the city, region, state; 3) development and adoption of management decisions regarding the prevention and elimination of emergencies, as well as minimizing their consequences [3].

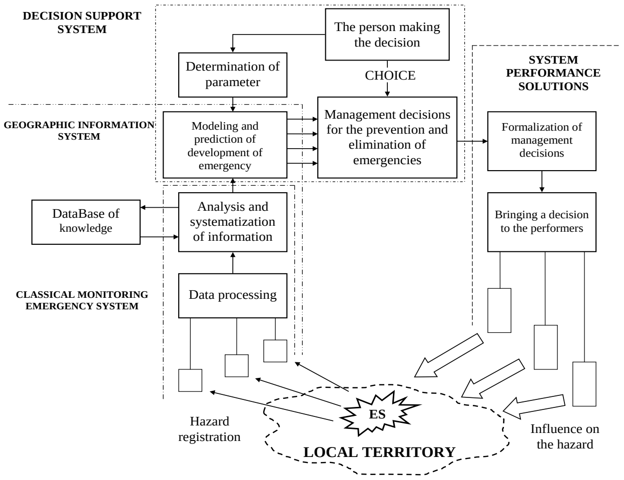


Fig. 1. Diagram of the emergencies monitoring structure as a means of control

The functioning presented in fig. 2, the scheme in conditions of completeness of input information and the presence of one partial criterion for evaluating the set of admissible solutions does not present difficulties in justifying optimal anti-crisis solutions. On the other hand, modern problem situations are characterized by incomplete knowledge (uncertainty) of the initial data and a set of partial evaluation criteria. Thus, the traditional approach based on the decomposition of the problem into two conditionally independent tasks - multi-criteria optimization in a deterministic (without taking into account uncertainty) formulation and decision-making under conditions of uncertainty for a scalar objective function in modern conditions does not meet the requirements of practice in terms of accuracy and efficiency.



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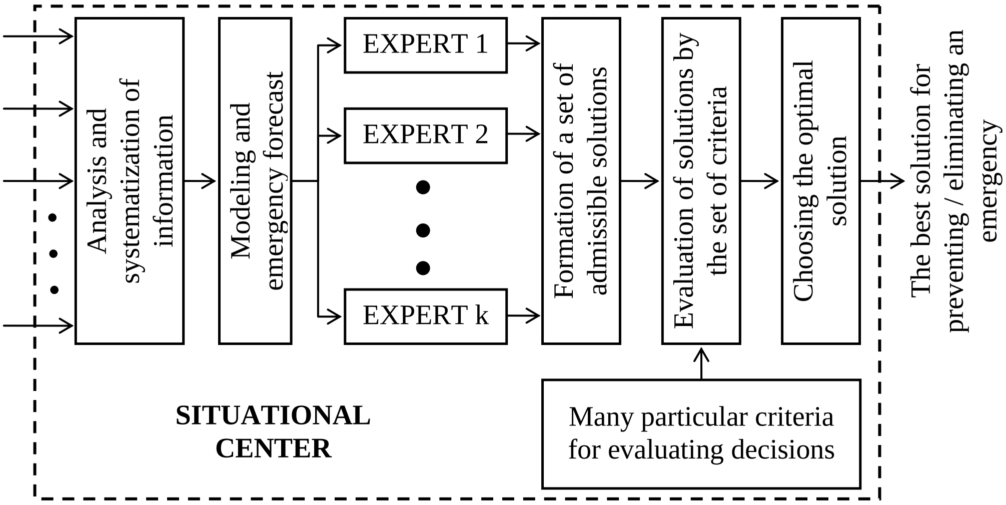


Fig. 2. Functional scheme for substantiating optimal anti-crisis solutions to ensure an appropriate level of life safety of the state in emergencies of a different nature, in conditions of uncertainty of initial information for experts of the system of situational centers of the system of civil defence

This is due to the fact that the problem of multi-criteria optimization is in principle incorrect, because it allows you to determine a solution only with accuracy to the area of compromise solutions, and its regularization to determine a single solution is based on the calculation of a generalized multifactor scalar evaluation, based on poorly structured subjective expert evaluations , whose determinism leads to large errors. On the other hand, decision-making methods in conditions of uncertainty based on a scalar estimate and the expected effect, without taking into account its multi-criteria, are also not adequate. Therefore, there is a need to develop a methodology for a comprehensive solution to the problem of decision-making, taking into account the multi-criterion and incomplete uncertainty of the initial data.

The permissible set of decisions of situation center experts in the general case, according to [4, 5], includes a subset of agreed $X^S$ and non-agreed (compromise) $X^C$ decisions to ensure the appropriate level of safety at the appropriate level of life (object, local, regional, and state) during an emergency. The peculiarity of the last subset is the impossibility of improving any partial criterion $k_i(x)$, $i=\overline{1,n}$ without deteriorating the quality of at least one other partial criterion. In addition, an effective solution $x^\circ$ necessarily belongs to the area of trade-offs. This means that the problem of multi-criteria optimization

$$x^\circ = \arg \underset{x \in X}{extr} < k_j(x) >, \forall j = \overline{1,n}, \qquad (1)$$

does not have a solution, this is an incorrect problem according to Hadamard [6], since in the general case it does not provide the determination of a single optimal solution from a set of compromises $X^C$. In this connection, the problem of multi-criteria optimization arises.

The procedure for the adoption by experts of the situational center of management anti-crisis decisions is complicated by the fact that the necessary conditions for the effectiveness of decisions are their timeliness, completeness and optimality. Therefore, increasing the effectiveness of the decisions made is related to the need to solve the problem of multi-criteria optimization in conditions of uncertainty when emergencies of various nature occur. This also requires the development of formal, regulatory methods and models for a comprehensive solution to the problem of decision-making in conditions of multi-criteria and uncertainty in managing the processes of prevention and localization of medico-biological emergencies to ensure the effective functioning of the system of civil defence.

## III. Development of the Procedure for the Operation of the Situation Center for Supporting the Acceptance of Anti-Crisis Decisions Regarding the Establishment at the Regional Level of Administration of the Appropriate Level of the Epidemic Danger of the Spread of COVID-19

Today, among medical and biological emergencies, the greatest danger is an infectious disease caused by a new strain of coronavirus (COVID-19). Yes, more than 50 million people worldwide have contracted COVID-19. More than 1.26 million people died from the disease. In Ukraine, the first case of COVID-19 was recorded in Chernivtsi on February 29 (confirmed on March 3), 2020, from a man who came from Italy. Since then, more than 3,500,000 cases of infection have been registered, of which about 91,000 have been fatal [7, 8].

These data determined the direction of our research regarding the further development of the scientific and technical foundations of the creation of a system of situational centers in the civil defense system. Thus, according to [9] and depending on the epidemic situation on the territory of Ukraine, a "green", "yellow", "orange" or "red" level of epidemic danger of the spread of COVID-19 is established. Based on these ideas, the work has developed a procedure for the functioning of the regional situational center to support the adoption of anti-crisis decisions regarding the establishment at the regional level of management of the appropriate level of the epidemic danger of the spread of COVID-19. This procedure is presented schematically in fig. 3, where $N_{\text{Infected}}^{\text{Region}}(t)$ – is the rate of detection of new cases of infection with COVID-19 per 100,000 population, $K_{\text{Test}_\Sigma}^{\text{Region}}(t)$ – is the rate of detection of cases of infection with COVID-19 (by the method of polymerase chain reaction and the express test for the determination of the antigen of the SARS-CoV-2 coronavirus), $K^{\text{Region}}_{\text{Test}^+}(t)$ – is the number of tests by the method polymerase chain reaction and express test for the determination of the antigen of the SARS-CoV-2 coronavirus per 100,000 population, $K^{\text{Region}}_{\text{Beds}^+}(t)$ – the occupancy rate of beds equipped with medical oxygen in health care facilities designated for hospitalization of patients with a confirmed case of COVID-19, $N^{\text{Region}}_{\text{Hospitalized}}(t)$ – the number of hospitalized patients with confirmed and suspected cases of COVID-19.

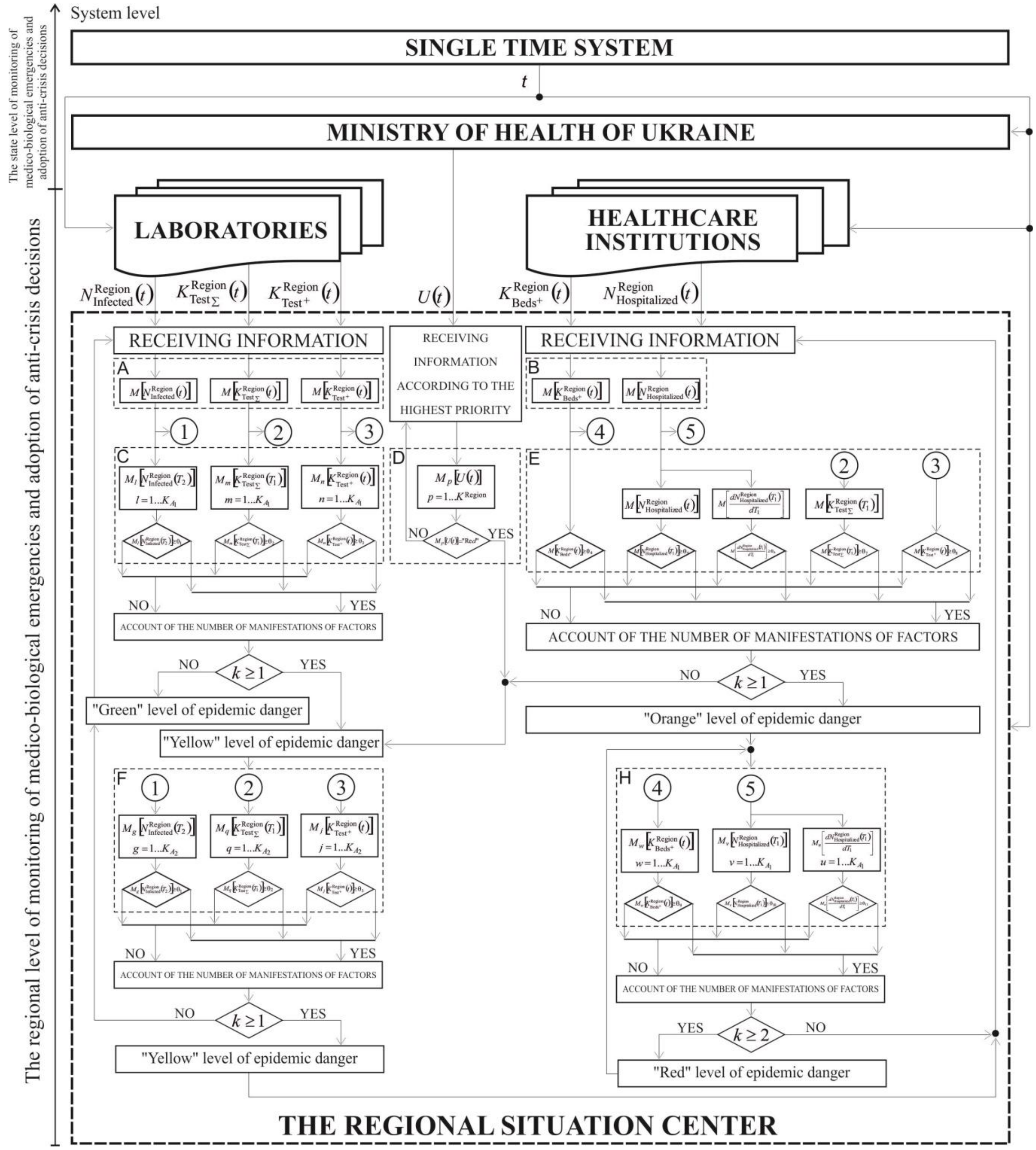


Fig. 3. Implementation scheme of the procedure of the situational center to support the adoption of anti-crisis decisions regarding the establishment at the regional level of management of the appropriate level of the epidemic danger of the spread of COVID-19

According to fig. 3 "green", "yellow" and "orange" levels of epidemic danger are determined in the system of a single time ( $t$ ) based on the results of daily assessment (where $K_{A_1} = 3$ days and $K_{A_2} = 7$ days – are the number of days for carrying out the procedure of the first and second stages of the analysis, $T_1 = 7$ days and $T_2 = 14$ days – are the first and second period of observation) of relevant signs of epidemic danger both in a separate territory and in the state as a whole.

The approach to establishing the "yellow" level of epidemic danger was implemented by implementing the following information and technical procedures in the regional situation center: 1) receiving real-time information from hospitals regarding the values of indicators: $N_{\text{Infected}}^{\text{Region}}(t)$, $K_{\text{Test}\Sigma}^{\text{Region}}(t)$ and $K_{\text{Test}^+}^{\text{Region}}(t)$; 2) receiving information on the level of epidemic danger in the regions of the state from the Ministry of Health of Ukraine on a higher priority in real time $(U(t))$; 3) formation in block "A" of dynamic arrays of laboratory activity monitoring data, namely: $M\left[N_{\text{Infected}}^{\text{Region}}(t)\right]$, $M\left[K_{\text{Test}\Sigma}^{\text{Region}}(t)\right]$ and $M\left[K_{\text{Test}^+}^{\text{Region}}(t)\right]$; 4) formation in block "C" of arrays of data requests for the results of laboratory activities in the relevant observation periods, namely: $M_l\left[N_{\text{Infected}}^{\text{Region}}(T_2)\right]$, $l = 1...K_{A_1}$; $M_m\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right]$, $m = 1...K_{A_1}$; $M_n\left[K_{\text{Test}^+}^{\text{Region}}(t)\right]$, $n = 1...K_{A_1}$; 5) formation of dynamic arrays of data from the Ministry of Health of Ukraine regarding the level of epidemic danger in the regions of the state in block "D", namely: $M_p[U(t)]$, $p = 1...K^{\text{Region}}$ (where $K^{\text{Region}}$ – number of regions of the state); 6) detection of facts of exceeding threshold levels of danger factors, namely: $M_l\left[N_{\text{Infected}}^{\text{Region}}(T_2)\right] \geq \theta_1$; $M_m\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right] \geq \theta_2$; $M_n\left[K_{\text{Test}^+}^{\text{Region}}(t)\right] \geq \theta_3$; $M_p[U(t)] = \text{"Red"}$ (where $\theta_1 = 75 \cdot 10^{-5}$ persons, $\theta_2 = 4\%$, $\theta_3 = 3 \cdot 10^{-3}$ testing); 7) calculation of the number ( $k$ ) of manifestations of danger factors; 8) formation, depending on the obtained results, of justified anti-crisis decisions for the State Commission on Technogenic and Environmental Safety and Emergency Situations (State Commission on TES and Emergency Situations) regarding the establishment of a "green" (at $k = 0$ – the number of manifestations of danger factors) or "yellow" (at $k \geq 1$ ) level of epidemic danger.

In the event that the "yellow" level of epidemic danger is established on the territory of the state, the regional situation center carries out measures aimed at re-checking the epidemic state of the region and assessing the possibility of the system's transition to another level of epidemic danger.

This approach was implemented by implementing the following information and technical procedures in the regional situation center: 1) formation in block "F" of data arrays of requests for the results of laboratory activities in the relevant terms of observations, namely: $M_g\left[N_{\text{Infected}}^{\text{Region}}(T_2)\right]$, $g = 1...K_{A_2}$; $M_q\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right]$, $q = 1...K_{A_2}$; $M_j\left[K_{\text{Test}^+}^{\text{Region}}(t)\right]$, $j = 1...K_{A_2}$; 2) detection of facts of exceeding threshold levels of danger factors, namely: $M_g\left[N_{\text{Infected}}^{\text{Region}}(T_2)\right] \geq \theta_1$; $M_q\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right] \geq \theta_2$; $M_j\left[K_{\text{Test}^+}^{\text{Region}}(t)\right] \geq \theta_3$; 3) calculation of the number ( $k$ ) of manifestations of danger factors; 4) formation, depending on the obtained results, of justified anti-crisis decisions for the State Commission on TES and Emergency Situations regarding the transition of the system to the "green" (at $k = 0$ ) level of epidemic danger or keeping the state of the system at the "yellow" (at $k \geq 1$ ) level of epidemic danger.

In the event that the "yellow" level of epidemic danger is maintained on the territory of the state, the regional situation center carries out measures aimed at assessing the situation regarding the transition of the region to the warning "orange" level of epidemic danger, which requires the introduction of strengthened restrictive anti-epidemic measures.

The approach to establishing the "orange" level of epidemic danger was implemented by implementing the following information and technical procedures in the regional situation center: 1) obtaining information on the values of indicators from health care institutions in real time: $K_{\text{Beds}^+}^{\text{Region}}(t)$ and $N_{\text{Hospitalized}}^{\text{Region}}(t)$; 2) formation in block "B" of dynamic arrays of data for monitoring the activities of health care institutions, namely: $M\left[K_{\text{Beds}^+}^{\text{Region}}(t)\right]$ and $M\left[N_{\text{Hospitalized}}^{\text{Region}}(t)\right]$; 3) formation in block "E" of arrays of data requests of the results of the activities of health care institutions in the relevant periods of observation, namely: $M\left[N_{\text{Hospitalized}}^{\text{Region}}(T_1)\right]$; $M\left[\frac{dN_{\text{Hospitalized}}^{\text{Region}}(T_1)}{dT_1}\right]$; $M\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right]$; 4) detection of facts of exceeding threshold levels of danger factors, namely: $M\left[K_{\text{Beds}^+}^{\text{Region}}(t)\right] \geq \theta_4$; $M\left[N_{\text{Hospitalized}}^{\text{Region}}(T_1)\right] \geq \theta_5$; $M\left[\frac{dN_{\text{Hospitalized}}^{\text{Region}}(T_1)}{dT_1}\right] \geq \theta_6$; $M\left[K_{\text{Test}\Sigma}^{\text{Region}}(T_1)\right] \geq \theta_7$; $M\left[K_{\text{Test}^+}^{\text{Region}}(t)\right] \geq \theta_8$ (where $\theta_4 = 65\%$, $\theta_5 = 6 \cdot 10^{-4}$ persons, $\theta_6 = 50\%$, $\theta_7 = 3 \cdot 10^{-3}$ testing); 5) calculation of the number ( $k$ ) of manifestations of danger factors; 6) formation, depending on the obtained results, of justified anti-crisis decisions for the State Commission on TES and Emergency Situations regarding the transition of the region to the "orange" (at $k \geq 1$ ) level of epidemic danger or keeping the state of the region at the "yellow" (at $k = 0$ ) level of epidemic danger.

If the "orange" level of epidemic danger is established in the territory of the region, the regional situation center carries out measures aimed at assessing the situation regarding the transition of the region to the "red" level of epidemic danger.

The approach to establishing the "red" level of epidemic danger was implemented by implementing the following information and technical procedures in the regional situation center: 1) formation in block "H" of arrays of data requests of the results of the activities of health care institutions in the relevant periods of observation, namely: $M_w\left[K_{\text{Beds}^+}^{\text{Region}}(t)\right]$, $w = 1...K_{A_1}$;

$M_v\left[N_{\text{Hospitalized}}^{\text{Region}}(T_1)\right]$, $v = 1...K_{A_1}$; $M_u\left[\frac{dN_{\text{Hospitalized}}^{\text{Region}}(T_1)}{dT_1}\right]$, $u = 1...K_{A_1}$; 2) detection of facts of exceeding the values of danger factors of threshold levels, namely: $M_w\left[K_{\text{Beds}^+}^{\text{Region}}(t)\right] \geq \theta_9$; $M_v\left[N_{\text{Hospitalized}}^{\text{Region}}(T_1)\right] \geq \theta_{10}$; $M_u\left[\frac{dN_{\text{Hospitalized}}^{\text{Region}}(T_1)}{dT_1}\right] \geq \theta_{11}$ (where $\theta_9 = 65\%$, $\theta_{10} = 6 \cdot 10^{-4}$ persons, $\theta_{11} = 50\%$); 3) calculation of the number ($k$) of manifestations of danger factors; 4) formation, depending on the obtained results, of justified anti-crisis decisions for the State Commission on TES and Emergency Situations regarding the transition of the region to the "orange" (at $k \leq 2$) level of epidemic danger or keeping the state of the region at the "red" (at $k \geq 2$) level of epidemic danger.

Thus, the results presented in the work are part of planned scientific research aimed at creating a system of situation centers in the unified state system of civil defence, with the aim of improving the procedure for supporting anti-crisis decision-making regarding the mutual functioning of state authorities, local self-government bodies, law enforcement agencies and communal services for the effective implementation in peacetime and in a special period of a complex of measures aimed at protecting the population, territories, natural environment, property, material and cultural values at various stages of the development of natural, technological, social and military emergencies.

## IV. Conclusion

It has been established that the creation of situational centers in Ukraine, as elements of the civil defence system, takes place in conditions of probabilistic territorial and temporal distribution of the sources of the danger of the spread of COVID-19. This is due to the uncertainty of the parameters that affect the conditions of normal functioning of the territory of Ukraine. In this connection, there is a problem of making optimal anti-crisis decisions in conditions of uncertainty regarding ensuring the appropriate level of security of the state's vital activities.

The procedure for supporting the adoption of anti-crisis decisions (a feature of the implementation of which is the creation of situational centers) has been improved for the implementation by the subsystem of medical, biological and psychological protection of the population and the subsystem of ensuring the sanitary and epidemiological well-being of the population of the system of civil defence for actions aimed at minimizing the consequences of medico-biological emergencies nature, in conditions of epidemic danger of the spread of COVID-19. The procedure for supporting the adoption of anti-crisis decisions at the regional level of management involves the complex performance of the following five interrelated (both under the conditions of an increase and under the conditions of a decrease in the level of epidemic danger) functions in a single time system: 1) continuous monitoring of the nature of parameter dynamics: $U(t)$, $N_{\text{Infected}}^{\text{Region}}(t)$, $K_{\text{Test}\Sigma}^{\text{Region}}(t)$, $K_{\text{Test}^+}^{\text{Region}}(t)$, $K_{\text{Beds}^+}^{\text{Region}}(t)$ and $N_{\text{Hospitalized}}^{\text{Region}}(t)$ in the region; 2) assessment, based on the results of monitoring studies, of the nature of the dynamics of the parameters: $U(t)$, $N_{\text{Infected}}^{\text{Region}}(t)$, $K_{\text{Test}\Sigma}^{\text{Region}}(t)$ and $K_{\text{Test}^+}^{\text{Region}}(t)$, the need to establish in the region the "yellow" level of epidemic danger of the spread of COVID-19 or to maintain the "green" level of epidemic danger in the region; 3) re-checking, based on the results of monitoring studies of the nature of the dynamics of the parameters: $N_{\text{Infected}}^{\text{Region}}(t)$, $K_{\text{Test}\Sigma}^{\text{Region}}(t)$ and $K_{\text{Test}^+}^{\text{Region}}(t)$, the "yellow" epidemic state of the region and the assessment of the need to transition the system to another (higher or lower) level of the epidemic danger of the spread of COVID-19; 4) assessment, based on the results of monitoring studies, of the nature of the dynamics of the parameters: $K_{\text{Beds}^+}^{\text{Region}}(t)$, $N_{\text{Hospitalized}}^{\text{Region}}(t)$, $K_{\text{Test}\Sigma}^{\text{Region}}(t)$ and $K_{\text{Test}^+}^{\text{Region}}(t)$, situations regarding the transition of the region to the warning "orange" level of epidemic danger of the spread of COVID-19, which requires the introduction of strengthened restrictive anti-epidemic measures, or the preservation of the "yellow" level of epidemic danger in the region; 5) assessment, based on the results of monitoring studies, of the nature of the dynamics of the parameters: $K_{\text{Beds}^+}^{\text{Region}}(t)$ and $N_{\text{Hospitalized}}^{\text{Region}}(t)$, situations regarding the transition of the region to the "red" level of epidemic danger or the preservation of the "orange" level of epidemic danger in the region.

## References


[1] V. Tiutiunyk, V. Kalugin, O. Pysklakova, A. Levterov, and Ju. Zakharchenko, "Development of Civil Defense Systems and Ecological Safety", *IEEE Problems of Infocommunications. Science and Technology*, October, 2019, pp. 295–299.

[2] V. Tiutiunyk, I. Ruban, and O. Tiutiunyk, "Cluster analysis of the regions of Ukraine by the number of the arisen emergencies", *IEEE Problems of Infocommunications. Science and Technology*, October, 2020, pp. 587–592.

[3] O. Tiutiunyk, I. Ruban, and V. Tiutiunyk, "Development of Scientific Basis for Decision Support by Experts of the Situational Center Under Conditions of Uncertainty of Input Information in Emergency Situations", *IEEE Problems of Infocommunications. Science and Technology*, October, 2021, pp. 261–266.

[4] Ye.H. Petrov, and N.I. Kalita Methods for evaluating the vector of individual preferences. *Bionics problems*, 2003, No.58, pp. 27–35. (*in Russion*)

[5] Ye.H. Petrov, Methods and means of decision making in socio-economic systems. Kiev, Appliances, 2004. (*in Russion*)

[6] Ye.H. Petrov, N.A. Brynza, L.V. Kolesnik, and O.A. Pysklakova. Methods and models of decision making under the multi-criteria and uncertainty. Kherson, 2014. (*in Russion*)

[7] I. Brovchenko. Development of a mathematical model of the spread of the COVID-19 epidemic in Ukraine. *Worldview*, 2020, No.2(82), pp. 2–14. (*in Ukrainian*)

[8] N. Shakhovska. 50.5 million people in the world have contracted COVID-19... *Worldview*, 2020, No.6(86), pp. 40–41. (*in Ukrainian*)

[9] On the establishment of quarantine and the introduction of restrictive anti-epidemic measures in order to prevent the spread of the acute respiratory disease COVID-19 caused by the SARS-CoV-2 coronavirus on the territory of Ukraine: Resolution of the Cabinet of Ministers of Ukraine dated December 9, 2020, No.1236 (*in Ukrainian*)