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MODEL FOR FORECASTING EMERGENCIES: THE REGIONAL DIMENSION

Providing safety in emergency situations requires a reliable functioning of the system for responding to emergency situations of natural and man-made nature, adequate to the level and character of the threats. An important aspect of this activity is the advance forecasting of the possibility of occurrence and economic consequences of such phenomena. The article developed a model and methods for forecasting emergencies in Ukraine and the administrative-territorial units of the state. When developing the model, a modular approach is used: the model is created as a set of separate modules, united in a single complex by information links. Input data for the implementation of the forecast are statistical data on emergency monitoring for a certain period of observation.
Keywords: emergency situation, model, threat risks, security, prognosis, monitoring, least square method, character and level of emergency situation.

Formulation of the problem. Protection of the population, economic objects, national wealth from the harmful impact of emergency situations (ES) of anthropogenic, natural and social nature is an integral part of the national security system of the state. The population and territory of Ukraine are under the significant negative influence of factors that lead to the emergence of emergencies and dangerous phenomena, loss of life, deterioration of living conditions of people, pollution of the natural environment, significant economic losses [1]. Ensuring safety in emergencies requires the reliable functioning of a system for responding to natural and man-made emergencies, adequate to the level and nature of the threats [2,3,4]. Preventing emergencies is a complex of legal, socio-economic, political, organizational, technical, sanitary and other measures aimed at regulating man-caused natural hazards, assessing risk levels, responding early to the threat of ES based on monitoring data, expertise, research and forecasts regarding the possible occurrence of events in order to prevent their development into the emergencies or mitigate their possible consequences [4,5]. An important aspect of this activity is the advance forecasting of the possibility of occurrence and economic consequences of similar emergencies. Proceeding from these positions, the development of a model, new approaches and methods for forecasting ES of various nature both in Ukraine as a whole and in regions of the state is an actual scientific and practical problem in the field of civil protection.

The purpose of the article is to develop a model and methods for forecasting ES across Ukraine and the regions of the state.

Analysis of recent research. The enormous regional load of the territory of Ukraine with powerful industrial and energy facilities, increases the risks of accidents and disasters. The presence in Ukraine of significant areas with adverse natural influences and a tendency to manifestations of dangerous natural phenomena reinforce the importance of the problem of studying the state of man-made and natural hazards, the need to find ways to improve it. This requires the development of a model and methods for forecasting ES in general, by the nature of origin and levels, both in Ukraine and in the regions of the state. An analysis of the latest literature on this problem shows that in most of them, regression analysis is used to solve this problem, and statistical-probability methods that use data over a certain period of observation are used to a lesser extent.

Methods for predicting the occurrence of emergencies depend on available statistical data and are based on probabilistic-statistical, probabilistic-deterministic and deterministic-probabilistic approaches [5-12]. Models and methods for predicting emergencies are most developed relative to dangerous natural events. When predicting the probabilities of the emergence of technogenic emergencies on the basis of modeling, typical scenarios for the emergence of these situations with respect to the technological processes being implemented [7,9].

The possibilities of a comprehensive solution of the problem of comprehensive forecasting of not only the possibility of occurrence of ES, but also the forecasting of their possible number by types and levels based on statistical monitoring data for both Ukraine as a whole and the regions of the state have not been adequately studied.

The main section. Natural, man-made and social risks are factors that determine the quality of life in the regions of the state. The degree of these risks to which a person is exposed depends on the following factors: the likelihood of occurrence of emergencies and the possible number of such risks, their extent and level, both in general in Ukraine and in the regions of the state.

The model for forecasting ES in general across Ukraine and the regions of the state is shown in Fig. 1. The modular approach is used in the development of the model: the model is created as a set of separate modules, united in a single complex by information links. Input data for the implementation of the forecast are the statistical data of emergency monitoring for a certain observation period (database of emergencies).

Module 1 is designed to predict the total number of ES n_{ES}^{pr} in Ukraine as a whole. The regression model of the change in the total number of ES is expediently sought in the form of a power polynomial:

$$n_{ES}(t) = r_0 + r_1 t + r_2 t^2 + r_3 t^3 + \ldots + r_k t^k . \quad (1)$$

where r_0, r_1, r_2, r_3,...r_k – regression model coefficients; t – estimated time; k – polynomial degree.

The degree of the polynomial k is chosen in such a way that the number of given points is five times higher than the degree of the polynomial [11]. The coefficients of the polynomial r_i, $i = \overline{0, k}$, based on the statistical data of monitoring the number of emergencies for each year of observation, can be found by the method of least squares (MLS) [9-11].

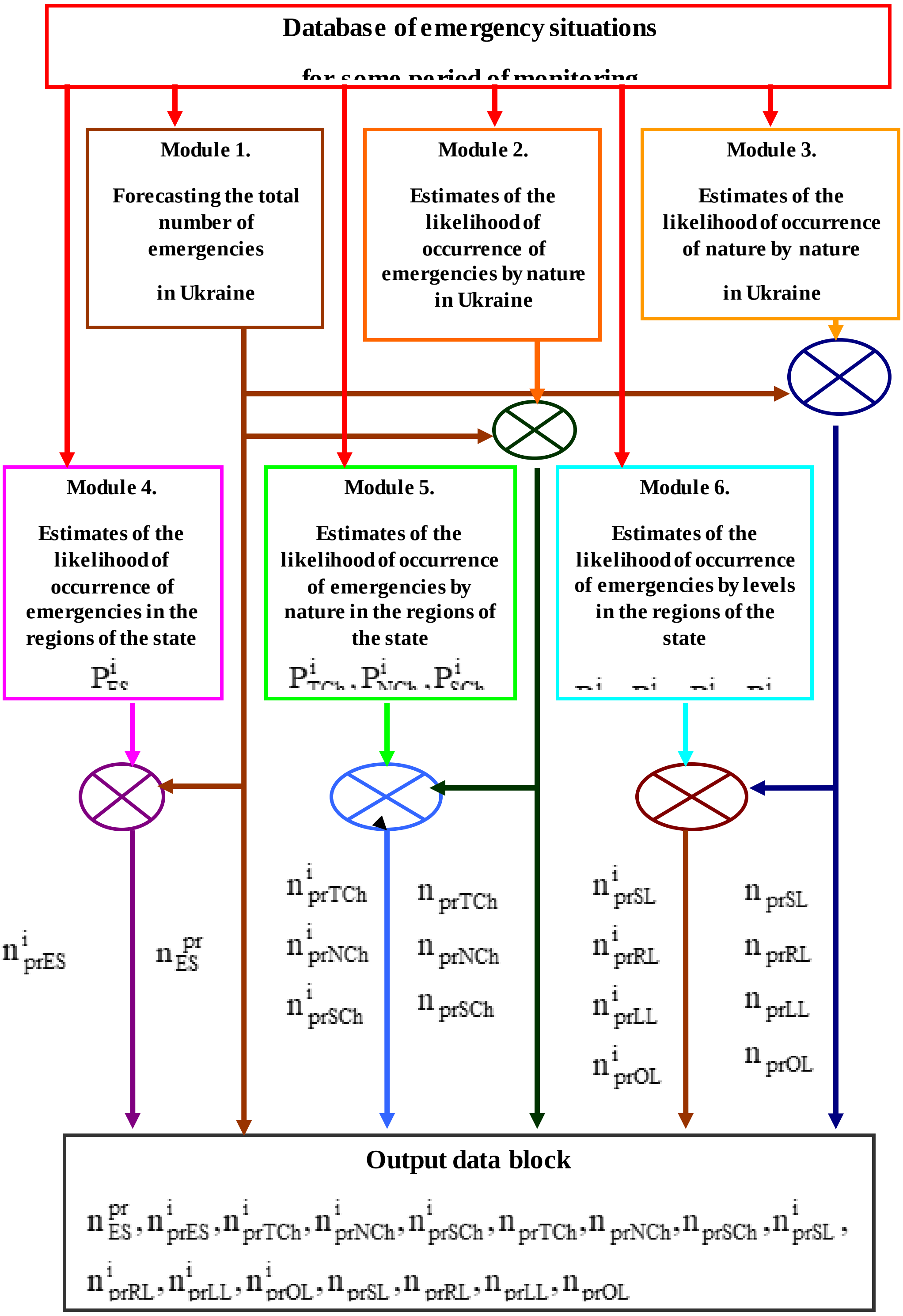

Fig. 1. Model of forecasting emergencies in general across Ukraine and regions of the state

After estimating the vector of coefficients of the regression model (1) $\overline{R} = (r_0, \quad r_1, \quad r_2, \quad ..., \quad r_k)^T$, the predicted value of the number of ES in Ukraine at the moment t_{pr} is:

$$n_{ES}^{pr} = n_{ES}(t_{pr}) = r_0 + r_1 t_{pr} + r_2 t_{pr}^2 + r_3 t_{pr}^3 + ... + r_k t_{pr}^k, \tag{2}$$

where t_{pr} – prediction time; n_{ES}^{pr} – predicted values of the number of ES in Ukraine at the time of forecast t_{pr}.

Module 2 is designed to assess the likelihood of occurrence of ES, respectively, technogenic (P_{TCh}), natural (P_{NCh}) and social (P_{SCh}) in the territory of Ukraine. The likelihood of occurrence of emergencies by nature of origin in Ukraine is calculated in accordance with the formulas [10-12]:

$$P_{TCh} = \frac{m_1}{n_{ES}}; \; P_{NCh} = \frac{m_2}{n_{ES}}; \; P_{SCh} = \frac{m_3}{n_{ES}}, \tag{3}$$

where m_1, m_2, m_3 – the total number of ES in Ukraine, respectively technogenic, natural and social nature during the monitoring period; P_{TCh}, P_{NCh}, P_{SCh} – probability of emergency situations, respectively, of anthropogenic, natural and social character in the event of ES in Ukraine.

The projected number of ES in Ukraine according to the nature of origin in accordance with the model (Fig. 1) is calculated on the basis of the projected total number of emergencies in the state $n_{ЧС}^{пр}$ (module 1) and the likelihood of occurrence of an ES P_{TCh}, P_{NCh}, P_{SCh} of the corresponding character (module 2) as follows:

$$n_{prTCh} = n_{ES}^{pr} \cdot P_{TCh};\ n_{prNCh} = n_{ES}^{pr} \cdot P_{NCh};\ n_{prSCh} = n_{ES}^{pr} \cdot P_{SCh}, \tag{4}$$

where n_{prTCh} – the forecast number of emergency situations of technogenic character in Ukraine for the forecast period; n_{prNCh} – the predicted number of natural character in Ukraine for the forecast period; n_{prSCh} – the predicted number of social character in Ukraine for the period of the forecast.

Module 3 is designed to assess the likelihood of ES, respectively, state (P_{SL}), regional (P_{RL}), local (P_{LL}) and object (P_{OL}) levels in Ukraine.

The likelihood of ES of state, regional, local and object levels in Ukraine are calculated as follows [10-12]:

$$P_{SL} = \frac{k_1}{n_{ES}};\ P_{RL} = \frac{k_2}{n_{ES}};\ P_{LL} = \frac{k_3}{n_{ES}};\ P_{OL} = \frac{k_4}{n_{ES}}; \tag{5}$$

where k_1, k_2, k_3, k_4 – the total number of emergencies, respectively, at the state, regional, local and object levels in Ukraine during the monitoring period; P_{SL}, P_{RL}, P_{LL}, P_{OL} – probability of emergency situations, respectively, at state, regional, local and object levels in Ukraine.

After estimating the probabilities P_{SL}, P_{RL}, P_{LL}, P_{OL} the predicted number of emergencies of the corresponding level in Ukraine in accordance with the model (Figure 1) is calculated as follows:

$$n_{prSL} = n_{ES}^{pr} \cdot P_{SL}\,;\; n_{prRL} = n_{ES}^{pr} \cdot P_{RL}\,;\; n_{prLL} = n_{ES}^{pr} \cdot P_{LL}\,;\; n_{prOL} = n_{ES}^{pr} \cdot P_{OL}\,, \qquad (6)$$

where n_{prSL}, n_{prRL}, n_{prLL}, n_{prOL} – the predicted number of emergencies, respectively, of the state, regional, local and object levels in Ukraine for the forecast period.

Module 4 is designed to assess the likelihood of occurrence of ES in the regions of the state P_{ES}^{i} in the event of an emergency in Ukraine. The likelihood of ES in the regions of the state in the event of an emergency in Ukraine are calculated by the formula:

$$P_{ES}^{i} = \frac{n_{ES}^{i}}{n_{ES}}, \qquad (7)$$

where P_{ES}^{i} – probability of emergencies in the i-th region of the state in the event of an emergency in Ukraine; n_{ES} – total number of ES in Ukraine during the monitoring period; n_{ES}^{i} – total number of ES in the i-th region of the state for the monitoring period.

The projected number of ES in the i-th region of Ukraine is calculated on the basis of the projected number of ES in Ukraine as a whole n_{ES}^{pr} (module 1) and the probability of ES in the i-th region of the state P_{ES}^{i} (module 4) as follows:

$$n^{i}_{prES} = n^{pr}_{ES} \cdot P^{i}_{ES}, \qquad (8)$$

where n^{i}_{prES} − predicted number of ES in the i-th region of Ukraine at the time of forecast t_{pr}.

Module 5 is designed to assess the likelihood of occurrence of an emergency of technogenic P^{i}_{TCh}, natural P^{i}_{NCh} and social P^{i}_{SCh} character in the regions of the state in the event of an emergency occurring in Ukraine.

The probability of occurrence of emergency situations of technogenic, natural and social character in the regions of the state is calculated by the formulas:

$$P^{i}_{TCh} = \frac{n^{i}_{TCh}}{n^{Ukr}_{TCh}};\ P^{i}_{NCh} = \frac{n^{i}_{NCh}}{n^{Ukr}_{NCh}};\ P^{i}_{SCh} = \frac{n^{i}_{SCh}}{n^{Ukr}_{SCh}}, \qquad (9)$$

where $n^{Ukr}_{TCh} = m_1$, $n^{Ukr}_{NCh} = m_2$, $n^{Ukr}_{SCh} = m_3$ − the total number of ES, respectively technogenic, natural and social character in Ukraine for the monitoring period; n^{i}_{TCh}, n^{i}_{NCh}, n^{i}_{SCh} − the total number of ES, respectively technogenic, natural and social character in the i-th region of the state for the monitoring period; P^{i}_{TCh}, P^{i}_{NCh}, P^{i}_{SCh} − the likelihood of occurrence of ES, respectively, of technogenic, natural and social character in the i-th region of the state in the event of an emergency of this nature in Ukraine.

The forecasted number of ES of a corresponding nature in the regions of Ukraine in accordance with the model (1) is calculated by the formulas:

$$n^i_{prTCh} = P^i_{TCh} \cdot n_{prTCh}; \; n^i_{prNCh} = P^i_{NCh} \cdot n_{prNCh}; \; n^i_{prSCh} = P^i_{SCh} \cdot n_{prSCh}, \qquad (10)$$

where n^i_{prTCh}, n^i_{prNCh}, n^i_{prSCh} − the predicted number of emergencies, respectively technogenic, natural and social in the i-th region of the state for the forecast period.

Module 6 is designed to assess the likelihood of the emergence of ES state P^i_{SL}, regional P^i_{RL}, local P^i_{LL} and object P^i_{OL} levels in the regions of the state in the event of an ES at the appropriate level in Ukraine.
The likelihood of occurrence of ES of different levels in the regions of the state in the event of occurrence of emergency situations of the appropriate level in Ukraine are calculated in accordance with the formulas:

$$P^i_{SL} = \frac{n^i_{SL}}{n^{Ukr}_{SL}}; \; P^i_{RL} = \frac{n^i_{RL}}{n^{Ukr}_{RL}}; \; P^i_{LL} = \frac{n^i_{LL}}{n^{Ukr}_{LL}}; \; P^i_{OL} = \frac{n^i_{OL}}{n^{Ukr}_{OL}}, \qquad (11)$$

where $n^{Ukr}_{SL} = k_1$; $n^{Ukr}_{RL} = k_2$; $n^{Ukr}_{LL} = k_3$; $n^{Ukr}_{OL} = k_4$ − the total number of ES, respectively, at the state, regional, local and object levels in Ukraine during the monitoring period; n^i_{SL}, n^i_{RL}, n^i_{LL}, n^i_{OL} − the total number of ES, respectively, of the state, regional, local and facility levels in the i-th region of the state for the monitoring period; P^i_{SL}, P^i_{RL}, P^i_{LL}, P^i_{OL} − the likelihood of ES, respectively, of the state, regional, local and object levels in the i-th region of the state in the event of an emergency at the appropriate level in Ukraine.

After estimating the probabilities P^i_{SL}, P^i_{RL}, P^i_{LL}, P^i_{OL} the predicted number of ES of different levels in the regions of the state in the event of occurrence of an emergency situation in Ukraine in accordance with the model (fig. 1) is calculated as follows:

$$n^{i}_{prSL} = P^{i}_{SL} \cdot n_{prSL};\ n^{i}_{prRL} = P^{i}_{RL} \cdot n_{prRL};\ n^{i}_{prLL} = P^{i}_{LL} \cdot n_{prLL};\ n^{i}_{prOL} = P^{i}_{OL} \cdot n_{prOL}, \quad (12)$$

where n^{i}_{prSL}, n^{i}_{prRL}, n^{i}_{prLL}, n^{i}_{prOL} – the predicted number of ES, respectively, of the state, regional, local and object levels in the regions of Ukraine for the forecast period.

The output data (the output data block) are: the forecast of the total number of ES in Ukraine n^{pr}_{ES}; the possible number of ES, respectively, of technogenic n_{prTch}, natural n_{prNCh} and social n_{prSCh} character; the possible number of ES, respectively, at the state n_{prSL}, regional n_{prRL}, local n_{prLL} and object n_{prOL} levels; total number of ES in the regions of the state n^{i}_{prES}; the possible number of ES, respectively, of technogenic n^{i}_{prTCh}, natural n^{i}_{prNCh} and social n^{i}_{prSCh} character in the regions of the state; the possible number of ES, respectively, of the state n^{i}_{prSL}, regional n^{i}_{prRL}, local n^{i}_{prLL} and object n^{i}_{prOL} levels in the regions of the state.

The application of this model will make it possible to implement the emergency situation forecast by the character of origin and levels both in Ukraine as a whole and in the regions of the state.

Conclusions. 1. A model and method for forecasting ES in general across Ukraine and regions of the state was developed. The model is of a complex character, it unites logically and informatively connected modules for each task, tasks, input and output data and other parameters, each of which is designed to solve specific problems.

2. The modular approach is used in the development of the model: the model is created as a set of separate modules, united in a single complex by information links.

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