EVENT MODEL FOR LOCALIZATION
OF EMERGENCY SITUATIONS

Voronenko M.
Kherson National Technical University
Beryslavskoe highway, 24, 73008, Kherson
mary_voronenko@i.ua

The presented article is devoted to constructing the event model of the processes of localization of Epidemic Emergency. The obtained calculations show that the expected gain of time for the localization of the ES, using the event model, according to the forecast data is 36–40 hours. *Key words:* Epidemic Situations, Event Model, localization, Epidemic Emergency.

Подійна модель локалізації надзвичайних ситуацій. Вороненко М.О. Представлено результати побудови подійної моделі процесів локалізації епідемічної надзвичайної ситуації. Отримані розрахунки показують, що очікуваний виграш часу на локалізацію епідемічної ситуації в разі застосування подійної моделі, за даними прогнозу, становить 36–40 годин. *Ключові слова:* епідеміологічні ситуації, модель події, локалізація, епідемічна надзвичайна ситуація.

Событийная модель локализации чрезвычайных ситуаций. Вороненко М.А. Представлены результаты построения событийной модели процессов локализации эпидемической ситуации. Полученные расчеты показывают, что ожидаемый выигрыш времени на локализацию чрезвычайной ситуации при использовании событийной модели, согласно прогнозируемым данным, составляет 36–40 часов. *Ключевые слова:* эпидемические ситуации, модель событий, локализация, эпидемическая чрезвычайная ситуация.

Introduction. Technocratic way of development of human civilization in the nineteenth and twentieth centuries led to the increase of the number of emergencies of anthropogenic nature (accidents at nuclear power plants, fires and explosions in industrial facilities, transport accidents), which today make up 75–80% of the total number of emergency situations [1]. The number of victims of natural disasters annually increases by an average of 6% [2]. According to the UN and WHO data, over the past 25 years, human losses due to the emergency situations are several times higher than losses during military operations [3]. Large-scale pollution of the water ecosystem is due to traffic accidents (on tankers, oil pipelines, oil platforms). Emissions into the biosphere often exceed its natural possibilities for self-purification and lead to the increase in the content of toxic elements – arsenic, cadmium, mercury, plumbum etc. in soils, natural waters and, consequently, in the flora and fauna.

Every year, the world ocean gets up to 30 million tons of oil and petroleum products, 6 million tons of phosphorus, 20 million tons of pesticides. At present, 5 nuclear submarines (7 nuclear reactors, 16 ballistic missiles, and two dozen torpedoes with nuclear warheads) have sunk into the world oceans – this creates uncontrolled disposal of radioactive waste [4; 5]. The consequences of major accidents, catastrophes, earthquakes, along with destruction, may be accompanied by outbreaks of infectious diseases, contamination of water intake systems and septic tanks, the breakthrough of sewage networks, the destruction of natural ecosystems and other unsanitary phenomena [6]. Every 20 seconds in the world one child dies as a result of improper water purification, which currently does not provide about 2,6 billion people on the planet [7].

On Fig. 1. there is a map of the ecological situation and state of water resources in Ukraine [4].

It is known that 1 m³ of wastewater destroys 50 m³ of fresh water from surface sources, which leads to allergic diseases on the epidemic scale. In reservoirs, where more than 70% of the population of Ukraine receive drinking water, 40% of untreated agricultural and industrial waste water is disposed. Water can become a chemical solution, dangerous not only for use, but also for use in general [8]. The outbreak of infectious diseases, in connection with which at least 1,3 million people die each year [8; 9], constitute a serious threat.

Problem statement. Provision of operative and coordinated actions of the regional level authorities requires the creation of a controlling influence over a period of time after which it makes sense to implement them. The proactive nature of these actions can be achieved by using the prediction principle [10]. Therefore, it is necessary to develop models of functioning of the region in conditions of epidemic situations and algorithms of effective management of regional resources.

Analysis of recent research and publications. The scientific basis for dissertation researches were the works of such scientists as: A. Stennin, M. Vasyukhin, L. Zade, S. Mikoni, V. Nogin, E. Petrov, T. Saati, R. Fishburne, O. Larichev etc. The works of these and other authors have created methodological and theoret-

ical preconditions for the dissertation work. Among the works on localization of the epidemic emergency and those dealing with the processes related to the prediction and optimization of the epidemic emergency, stands the fundamental three-volumed monograph by L. Goryev, S. Doroguntsov and M. Hvesyk "Optimization of ecoareas" [4]. Created by authors adequate mathematical models of related processes let to simulate the epidemic process. Computerization of simulation systems will allow finding efficiently the best options for the functioning and prevention of the occurrence of extra situations. But in order that the simulation systems could be used as a part of event model, it is necessary to simplify the numerical solution of differential equations describing epidemic processes, to make it more useful for practical implementation. The research of effective management in the conditions of the epidemic emergency shows that in this area practically no method of designing, there are no models for forecasting the development of the situation, resulting in a decision-making process delayed or misplaced. Leaders in making managerial decisions mainly use their experience and intuition, but do not see the picture as a whole. Therefore, carrying out scientific researches on the improvement and computerization of decision-making processes in the epidemic emergency environment, the development of models, methods, algorithms, programs and information technologies is an actual scientific and technical task.

The objective of the article. The purpose of this work is to create a model of epidemic processes, suitable for further application of situational control methods.

1. The main material

The reason for the ES, which is typical for the regions of Ukraine, is often the epidemic of infectious diseases. The main tasks during the epidemic are:

– prediction of the possibility of mass infections and other epidemic situations;

– creation of reserves of medicines, medical equipment, pills and other materials;

– organization of events (lectures, practical classes) with medical staff in order to ensure readiness for work in conditions of the epidemic and other mass diseases;

– rapid reaction to the ES, including an assessment of the nature and extent of possible consequences of such events, prompt notification of authorities and the population about the threat and the facts of the emergence of the ES.

Managing actions should be based on both current and projected states of regional components. Depending on how the situation arises, the required values of the control effects can vary. Therefore, there is a need for their multiple formation in a shorter time interval, taking into account reports of changes in the situation in the region. In practice, this means an operational redistribution of resources to take the necessary steps in the process of clarifying the situation. The considered approach allows us to decompose each major task of decision-making in the conditions of the epidemic situations for the sequence of tasks of operational decision-making, formulated on the results of periodic monitoring of the state of regional components. Each such problem is solved by performing relatively simple functional tasks.
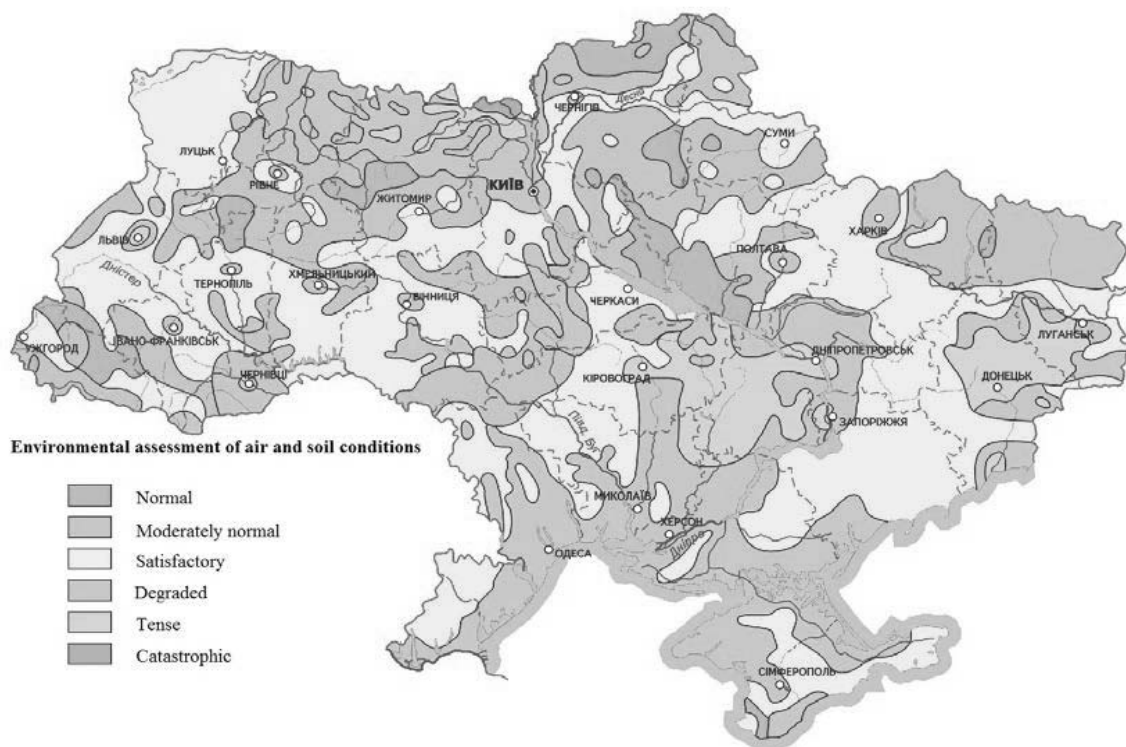

Fig. 1. Map of the ecological situation and state of water resources in Ukraine

The state of the population during the epidemic is determined by a number of internal and external factors. Internal factors include the natural ability of people to counter adverse environment, which depends on age and psycho-physiological characteristics, from training and readiness to act in the conditions of the epidemic. External factors include protective measures and disinfectant, or quarantine, directed from the outside. The state of the population is estimated by the level of sanitary losses: irreversible, heavy, medium and light. Estimation of losses directly depends on the results of the implementation of protective measures.

The development of the epidemic consists of different periods – threatening, crisis, post-crisis. The implementation of protective measures is determined by these periods of the development of the epidemic (Fig. 2). During the menacing period, preventive measures are taken, during the crisis period, rescue measures are carried out, in the post-crisis period – restorative measures.

The primary uncertainty and the variability of these characteristics are reduced with the help of scenario descriptions of possible alternatives to the development of the ES. Experienced experts, who establish a limited number of permissible states of regional components and their interconnections in threatening, crisis and post-crisis periods, are involved in the development of potentially implemented alternatives. This ensures the necessary completeness of the description of the processes under consideration, with sufficient account of their characteristics for setting and solving the tasks of supporting decision-making on regional protection.

2. The event model

Consider the general procedure for describing alternatives to the development of an epidemic ES. Formalized description of the development processes of the ES is based on the establishment of system-causing causal relations between the components of these processes. Since these causal relations lead to a change in the states and properties of the interacting components, we will use
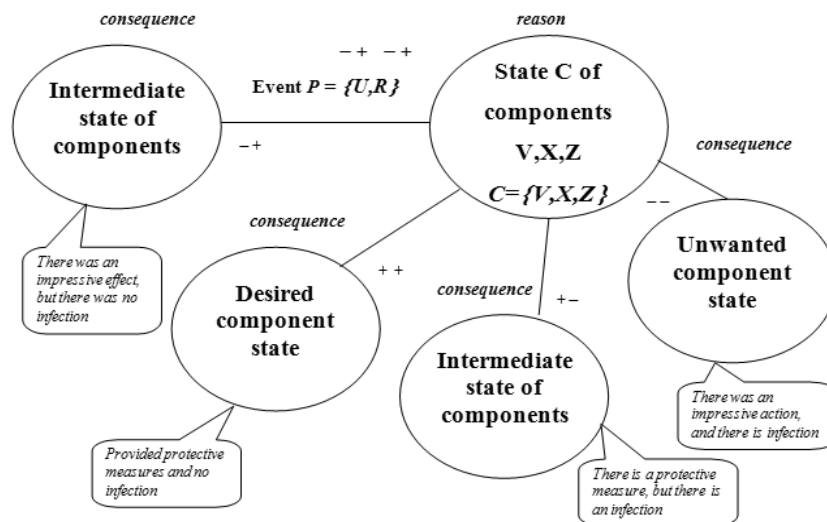

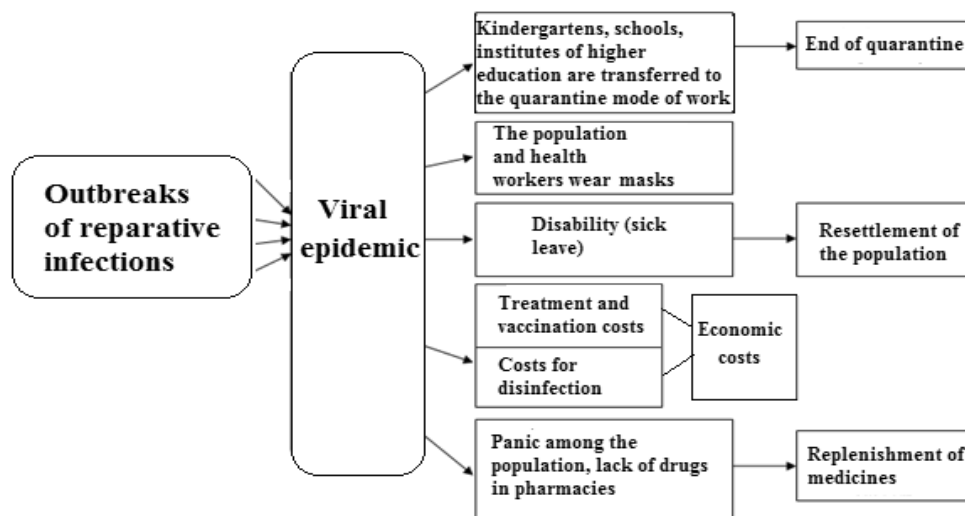*Fig. 2. Map of events during protective measures*

Fig. 3. Description of alternatives to the development of epidemic ES

the casual approach to determine them. Under the event we will understand the jump-like change in the properties of the component, in which it passes into a qualitatively new state. Each event occurs under the influence of mutually determined external and internal factors. External factors are manifested in the form of protective measures or impressive influences, internal – in the form of the ability to resist adverse environments or to produce spectacular actions. The results of the interaction of external and internal factors – this is the successive-parallel events, which constitute the development of epidemic ES. Each of these events implements a certain causal connection between the state-cause and one of the possible state-effects of the interacting components (Fig. 3). In case-by-case approach, the processes under consideration can be presented in general terms $\sum = (C, P)$, where the set of vertices C corresponds to the state of components of the ES components, and the set of arcs P – events occurring when these states change. Each component in any state can generate a series of alternative events that determine the possible variants of new states of the same or other components. Components of the ES form a mutual triad $C = \{V, X, Z\}$, where $V = U_i V_i$ – plenty of sources of striking influences, $X = U_j X_j$ – set of objects of defeat and protection (people), $Z = U_r Z_r$ – a set of resources for protective measures. Changes in the states of these components occur under the influence of external and internal factors $P = \{U, R\}$, where U – the set of disjoint subsets of the impressive influences W and protective measures M, and R is the set of internal factors of defeat Q and protection F. In this case, the factors W and Q cause the transitions of the components in the undesirable states, and the factors M and F are in the desired states. In Figure 3. for a plurality of U protective actions are denoted by "+", and the impressive actions "–"; for R, the resistance of the infection is indicated by "+" (healthy), and infection "–" (ill).

Building a model $\sum = (C, P)$ is a difficult formalized process that is carried out in stages according to the allocated periods of the development of the epidemic emergency plan, the normative data on the sources of the impressive influences and resources of protective measures, methods of constructing trees of failures, prediction of the consequences of the impressive influences and expert assessments. At the first stage, the indicators determining the development of the ES in a menacing period are structured. First, with the help of experienced experts, the internal structure and external environment of the given region are studied. The alternative Vi sources are identified, for

each of which the most difficult scenarios are developed for possible manifestations of the impact, as well as the potentially vulnerable classes of the population Xj are identified and the resources of Zr are involved.

Indicator V_i^{HI} characterizes the ability of sources i to spread at the beginning of a threatening period. Indicators X_j^{HI} and Z_r^{HI} reflect the state of the people (possible human losses j) and the availability of necessary resources r, respectively. The states of sources, people and resources in different periods of development of the ES are shown in Fig. 4.

Thus, the development of the situation in time will be characterized by the sequence of such tuples:

$(V_i^{H_1}, X_j^{H_1}, Z_r^{H_1})$ – tuple of indicators of the estimation of initial conditions at the beginning of the threatening period;

$(V_i^{k_1}, X_j^{k_1}, Z_r^{k_1})$ – tuple of indicators of estimation of initial conditions at the end of the threatening period;

$(V_i^{H_2}, X_j^{H_2}, Z_r^{H_2})$ – tuple of indicators of estimation of initial conditions at the beginning of a crisis period;

$(V_i^{k_2}, X_j^{k_2}, Z_r^{k_2})$ – tuple of indicators for assessing outcomes at the end of the crisis period;

$(V_i^{H_3}, X_j^{H_3}, Z_r^{H_3})$ – tuple of indicators of estimation of initial conditions at the beginning of the post-crisis period;

$(V_i^{k_3}, X_j^{k_3}, Z_r^{k_3})$ – tuple of indicators of estimation of initial conditions at the end of the post-crisis period.

3. Decision Making Algorithm

Let's try to follow the way in which an expert works in a particular area. Examples of experts are the examining physician, the sanitary doctor who studies the living conditions of the population, or an employee of the Ministry of Emergencies, who manages the process of eliminating the epidemic ES. The diagram of the sequence of actions in the process of supporting the adoption of managerial decisions in the detection of epidemic ES is presented in Fig. 5.

Fig. 4. Event Model for the Development of the Epidemic Emergency

Evaluating the effectiveness of decision-making helps to understand the strengths and weaknesses, the compliance with the original plan, or leads to the achievement of the planned results, and what changes should be added in time to the process in order to make it more effective. The essence of assessing the effectiveness of using an event model is to compare the quality of decisions that are taken by the head without it and with its use.

Experimental studies show that the loss of time for the formation of informational training management decision is half the time from the total, allocated for preparing decision-making, and this is unacceptable in times of acute shortage of time. We select a set of elementary operations that are performed when localizing an epidemic ES. The ultimate goal is achieved in a phased manner, through the sequence of execution of all elementary operations (tasks). This approach allows
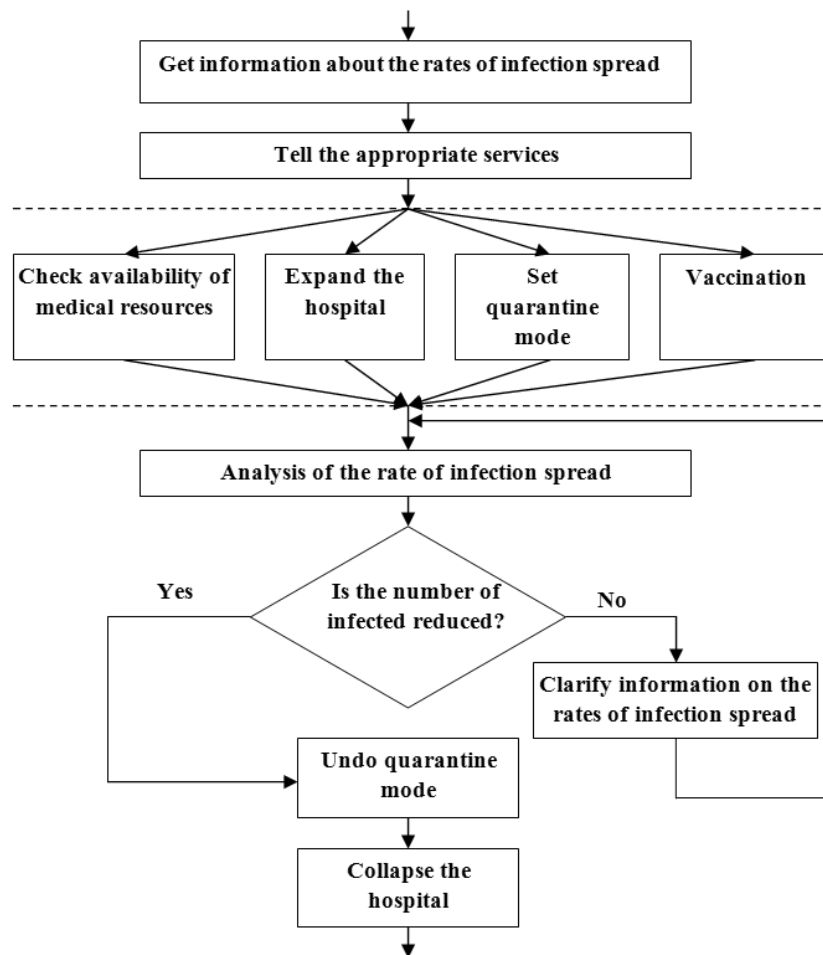

Fig. 5. Scheme of the sequence of actions in the localization of pandemics and viral epidemics
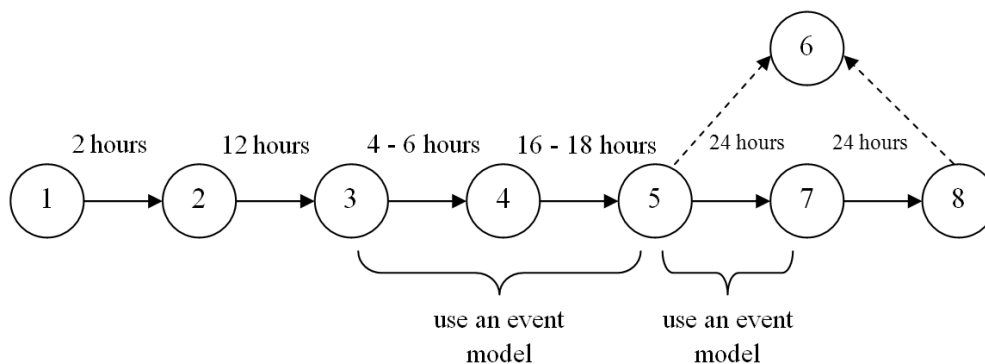

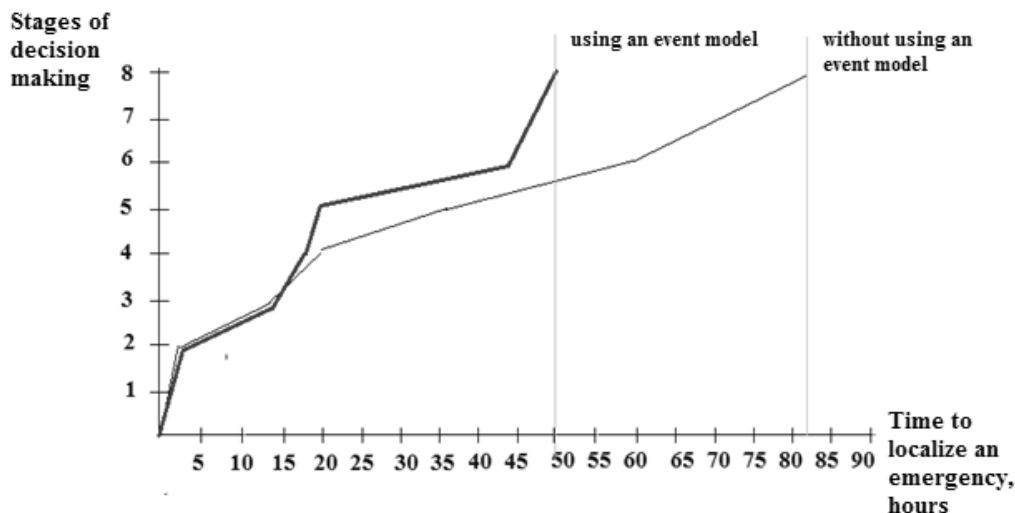*Fig. 6. Standards of time for localization of the epidemic*

Fig. 7. Evaluating the effectiveness of decision-making

us to present our actions in the form of an algorithm that includes the following operations:

1 – to accept information about the beginning of the epidemic;

2 – get the preliminary answer from the laboratory (2 hours);

3 – assess the availability of required resources according to the laboratory report and notify the relevant services (12 hours allocated):

– television and radio broadcasting (notification of vaccination);

– hospitals (about preparation for admission of patients);

– veterinary service (if another infection is connected);

– port SES (in case of particularly dangerous infection);

4 – assess and predict the levels of infection, the rate of infection and determine the type of emergency (from 4 to 6 hours):

– an epidemic;

– an epizootics;

– a pandemic;

– especially dangerous infection;

5 – analyze the level of hazard of the ES, calculate the amount of resources for its localization and prepare the appropriate set of measures (it takes 16–18 hours):

– calculate and distribute medical resources;

– expand the hospital;

– set quarantine mode;

– vaccinate;

6 – to bring the necessary medical resources (allocated 48 hours);

7 – analyze the current information received and make the necessary calculations based on it (24 hours):

– get the final answer from the laboratory;

– receive data from hospitals (number of deaths, number of patients, number of infected);

– obtain data on the distribution of the hearth;

– Announce to the administration;

8 – get information on reducing the number of patients (24 hours).

4. Results and Discution

Data about time limits are taken in accordance with the comprehensive plan [3]. Any epidemic ES develops under the exponential law (due to the increase in the number of contacts and the admission of related infections), so it is very important to win time until the extent of distribution has not gone out of control. We see, as shown in Figure 6, that the total time for the localization of the epidemic ES without the use of the event model is: $2 + 12 + 4 (6) + 16 (18) + 24 + 24 = 86 (90)$ hours. When the health manager makes decision, following the proposed scenarios of the event model, the path from the 3rd to the 5th point, we believe, can be reduced by 4 times and will take no longer 20 (24) hours, and 6 hours (2 hours for information, 3 hours for analysis and 1 hour for decision making). The same thing, as we forecast, will be on the interval from the 5th to the 7th point – instead of 24 hours – 6. Foreseeable assessment of the effectiveness of localization of the ES is presented in Fig. 7.

Thus, we hope to get the total time for the localization of the epidemic emergency situation using the event model: $2 + 12 + 6 + 6 + 24 = 50$ hours. Expected winning time is 36–40 hours. This time can be used to prevent the occurrence of concomitant infections, to reduce the number of contacts and spreading panic among the population.

Conclusion. An event model for the development of the epidemic has been obtained, taking into account the causal relations between the regional components. Solutions to such tasks include the use of situational management and new information technologies. An evaluation of the effectiveness of the developed model is carried out. The obtained calculations show that the

expected gain of time for the localization of the ES according to the forecast data is 36–40 hours.

In further research, the authors plan to develop appropriate information technologies and software that, using the event model, will reduce the burden on OPR under uncertainty, optimize work on the elimination and prevention of emergency situations development, harmonize the work of medical and environmental services, reduce the amount of localization costs on emergency situations.

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