MATHEMATICAL MODELS OF DECISION SUPPORT SYSTEM FOR THE HEAD OF THE FIREFIGHTING DEPARTMENT ON RAILWAYS

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Rail transport is an important basic sector of economy of Ukraine, provides its internal and external transport and economic connections and transportation needs of the population.

Currently, the country's railways transport a large quantity of various goods, including nine form of dangerous goods.

We know that traffic accidents on the railway, according to the causes of origin, are divided into technological, natural, social, political and military character and, according to territorial distribution, disruption of traffic and volumes of technical and financial resources necessary to eliminate them, they can be national, regional and local or object level.

These transport events may lead to loss of life or create a dangerous situation on particular area or particular object which may lead to loss of health, lead to the destruction of buildings, equipment and vehicles, violations of the manufacturing or transport process and harm the environment.

Especially dangerous are accidents, accompanied by explosion of tanks with liquefied hydrocarbon gases and flammable liquids and throwing of flammable liquids and potent poison. Much of the danger comes from solid combustible substances during their transportation and storage [1].

Fighting fires on the railway is marked difficulty in organizing the operations of fire departments and related units of the railway, because of a large number of goods that have a variety of fire and explosive properties, the need to power down the contact network, the complexity of assessing the situation on the fire, the concentration necessary capabilities, etc. [2].

From the above, for the effective management of forces and means of fire must have an effective system of fire departments and relevant units of railroads, to organize a scientific basis for Task Force work to eliminate traffic accidents and fires at the operational headquarters, which is impossible without widespread use of modern information technology including decision support systems (DSS).

Application of DSS allows the informational, technological, analytical and organizational support iterative interactive process of analysis of the situation as a result of accidents, training and evaluation of solutions managers eliminate traffic accidents and fire suppression and selection of the final decision to eliminate such events.

To implement the DSSfor our opinion it is necessary to create mathematical models to assess the situation and the process of developing recommendations for their elimination, and the mathematical model for evaluating the effectiveness of firefighting units [3].

Creating models to assess the situation which arose as a result of traffic accidents accompanied by fire, in our view, should do with the productive systems that provide a view of human experience evaluating the situation in dangerous situations in the form of rules and allow the results to develop a search algorithm and are effective tool for developing expert systems [4].

Based on an analysis of work in addressing issues of liquidation of traffic accidents on the railway and general systems theory, set-theoretic model that reflects the cause-effect relationships of processes that create extraordinary situation, is given by [5]:

$$S=\{\ CS(t_1),\ \ FS(t_2)\ \},$$

where S - the set of emergencies; CS (t) i FS (t) - set the current and final states of emergency, respectively; t = t + t, t - duration of the emergency, t1 - the beginning of an emergency.

Current state of emergency determined by tuple:

$$CS\ (t_1) = \{E, \Gamma, X, Z, \Omega, \Xi, \Delta, T\}.$$

The set E defines a set of character attributes burning hazardous substances fire signs of the impact of hazardous substances at the emergency and the adjacent tank includes a set of Γ; warning signs of cargo tanks are set on X, the set Z consists of the signs of the impact of combustion leakage of substance on the emergency and the adjacent tank; signs of the impact of other (neighboring) emergency tank fires are set Ω, the set Ξ consists of flame characteristics influence another (neighboring) fires in emergency cases or a neighboring tank features of the environment and weather conditions contained in the set Δ, the set T consists of a period of time.

The set of final states FS (t2) emergency includes a set of SE, ME, i HE, which determine the results of such situations. SE set contains the final states of emergencies, bomb threats, when the tank is missing, the set consists of the ME final states of emergency when there is some danger of explosion, and the HE set includes final states with an explicit threat of explosion of the tank.

$$FS(t_2) = \{HE, ME, SE\}.$$

To create an information model of emergency, which is accompanied by fire hazardous cargo, the method of production systems, which is now widely used in artificial intelligence theory to retrieval algorithms and modeling problem solving person. Productive system manages the process of solving problems on the model and consists of a set of production rules, working memory and control cycle "recognition – action”.

The generalized production rules to determine the result of an accident is determined by the expression:

$$\{e_i^{fs}\} = [[\{cs_i(t_1)\} = \{\varepsilon_a\} \wedge \{\gamma_b\} \wedge \{\chi_c\} \wedge \{\xi_d\} \wedge \{\omega_k\} \wedge \{\zeta_m\} \wedge \{\delta_q\}] \rightarrow \{fs_l(t_2)\}], \quad (1)$$

Where

$$e_i^{fs} \in S, \varepsilon_a \in E, \gamma_b \in \Gamma, \chi_c \in X, \xi_d \in \Xi, \omega_k \in \Omega, \zeta_m \in Z, \delta_q \in \Delta, fs_i(t_2) \in FS.$$

Assessment of the situation and making recommendations on elimination of emergency situations that are accompanied by fire-hazardous cargo, is a complex multistep process. Given that the problem being solved and the heads of an emergency fire suppression in fire suppression is poorly formalized, their solutions should be undertaken using models, which formalizes the knowledge of experts to solve such problems.

The development of such models currently being carried out by means of information technologies using expert techniques and theories of artificial intelligence techniques that allow professionals to take into account experience and easier to work with DSS not prohramuyuchoho specialist who has knowledge of the organization dealing with breakdowns, accompanied by fire of dangerous goods and involved in the process of making necessary decisions.

In order to create information models and recommendations to eliminate fire on the analysis of guidance documents that define the order of liquidation of accidents with dangerous goods during their transportation by rail, also found that elements of the decisions the leaders of an emergency and a fire that define for fire suppression, cooling and emergency protection of rolling stock and infrastructure, evacuation, equipment and rolling stock, and take into account the experience of experts in making decisions regarding operations of fire departments in emergency situations, which are accompanied by fire-dangerous goods.

Accordingly, the expression for the information model recommendations regarding emergency is defined components:

$$Ra = \{Ex, Col, Ev, Liq, Ac, Det, Ob\}$$

Ex set includes recommendations for actions aimed at putting an emergency rolling stock and prevent formation of explosive concentrations of fuel mixture; Col set includes recommendations for cooling rolling stock; recommendations for measures to eliminate leakage of dangerous substances includes set Liq; Ev has set guidelines that define the arrangements for the evacuation of people, equipment and rolling stock; recommendations for the General measures: isolation of the danger zone, in her handling of personnel, compliance with fire safety measures, provide first aid to victims, etc. contained in the set of Ac, Det set includes recommendations for the parameters of explosion and fire areas and the number of forces and capabilities necessary for fire, cooling and protection of rolling stock and facilities; recommendations for analysis of infrastructure, environment are in set Ob.

Situation assessment and recommendation of the software DSS to eliminate accidents accompanied by fire, carried out in several stages [6].

In the first phase recommendations determined by state emergency rolling stock, infrastructure and rolling stock that are in dangerous areas of the accident, and fire suppression methods in such hardware.

The first procedure φ_2' of this stage is to identify the hazardous event occurring in emergency hardware. Procedure φ_1' by using the generalized production rules (1).

The procedure φ_2' allows to identify the infrastructure and rolling stock of railway transport, which are located in dangerous areas of the accident.

Calculating the size of zones of influence of hazards and accidents and detection of rolling stock in these areas is the methodology and algorithms are created in developing automatic working place for leader fighting a fire at the facilities and rolling stock of railway transport.

The procedure φ_2', based on the above factors is given by:

$$\varphi_2' = \{\varphi_1', Det', Det'', T, Ob, Ev'\}. \tag{2}$$

Elements Det^{I} subsets are recommendations from the calculation of accident hazards of liquefied hydrocarbon gases. Guidelines for determining the size of accidents hazards with combustible (flammable) liquids are in the subset of Det^{II}. Ev^{I} subset includes recommendations for evacuation.

Given (2) production rules for such a procedure defined by the expression:

$$\varphi_2' = [[\{ec_{2i}'\} = \{e_i^{fs}\} \wedge \{det_r'(t_2)\} \wedge \{det_0''(t_2)\}] \rightarrow$$
$$\rightarrow [\{so_{2\rho}\} = \{ob_{\rho_1}^{P}\} \wedge \{ob_{\rho_2}^{q}\} \wedge \{ev_\eta'\}]],$$

where $ec_{2i}' \in EC$, $EC \subset S$ - subset of the set of emergencies S, which takes into account the consequences of an accident e_i^{fs}; $det_r'(t_2) \in Det'$; $det_0''(t_2) \in Det''$ - calculated from a formula determining the size of hazardous zones accident at the time t_2 ; $so_{2\rho} \in SO$, $SO \subset S$ - subset of the the set of emergencies S, considering the state of rolling stock and facilities that are in dangerous areas of the accident: $ob_{\rho_1}^{P}$ - rolling stock items that are in areas of excessive pressure of the front shock wave from the explosion facilities and rolling stock, suffering from flames; ev_η'

$\in Ev'$ - guidelines for notification and evacuation of the objects that are in dangerous areas of the accident.

After detection of such facilities and rolling stock, using the procedure φ_1' identified hazardous events have been found damaged rolling stock of dangerous goods and set its impact on the surrounding objects and railway rolling stock.

Iterative process of application procedures φ_1' and φ_2' ends when they have not found an emergency rolling with the dangerous goods in zones hazards of accidents, followed by fires.

The procedure φ_3' is devoted to considering ways of fighting fires and emergency cooling tank, taking into account properties of the substance that burns, and develop measures to prevent the formation of explosive concentrations of vapor in a cloud for substances that do not burn.

Formally this procedure is determined by a tuple:

$$\varphi_3' = \{ S, A, Ex, Col, Ac\},$$

where A-set of properties of matter, which affect the processes of combustion, and of making fire and emergency cooling of the rolling stock (A=$\{A', A'', A'''\}$).

Subset $A' \subset A$ characterized by physical and chemical properties of substances. Signs of fire explosion properties of matter form a subset of A'', $A'' \subset A$. The danger to humans characterize subsets of features A''', $A''' \subset A$.

The second phase of recommendations designed to determine the measures for the evacuation of military servants, railway workers, equipment and rolling stock from dangerous areas of the accident and measures aimed at eliminating leakage alarm substance.

The procedure φ_1^2 for determining the necessary measures to evacuate people, equipment and rolling stock and eliminate leakage of dangerous substances is given a tuple:

$$\varphi_1^2 = < S, Ex, Ac, \Delta, X, T, Ev, Liq, Ob >.$$

The third stage of automated recommendations designed to determine the required number of fire departments for fire suppression and protection of the rolling stock, the definition of probabilistic assessments of operations of fire departments and optimization plan to focus their combat.

Determine number of fire departments to extinguish fires in rolling stock is carried out by known techniques, and using algorithms developed for the DSS leader fighting a fire in rolling stock and rail transport facilities.

The procedure φ_1^3 for determining the required number of capabilities for fire suppression and protection of the rolling stock is given a tuple:

$$\varphi_1^3 = < \varphi_3^1, Det''', T, N_\rho >.$$

Det^{III} subset includes recommendations for determining capabilities necessary for fire suppression. N_ρ - number of units required for fire extinguishing.

Procedure of the probabilistic estimates of operations of fire departments is given by a tuple:

$$\varphi_2^3 = < \varphi_1^3, T, Det^{IV}, J_м >.$$

Det^{IV} is decide on a probabilistic assessment of operations of fire departments in fire suppression and optimization plan to focus fire departments. $J_м$ - the likelihood of possible states of the system, which consists of fire units, facilities and rolling stock.

After defining the principal possibilities of success of fire suppression and protection facilities, optimization plan is to focus on capability, taking into account losses from fire and focus of time and input the required number of fire departments in each of the objects (rolling stock).

The procedure for optimizing the plan focus and putting fire departments is given a tuple:

$$\varphi_3^3 = < \varphi_1^3, c_\rho, Det^{IV} >,$$

where c_ρ - losses of time to concentrate fire departments.

To determine the probabilistic assessment of subdivisions fire department while managing traffic accidents in the DSS applies mathematical tools of queuing theory, including mathematical models, based on closed stochastic networks [7].

The system of "fire units - objects (rolling stock) railway affected by fires in DSS filed a stochastic closed network - a set of interrelated systems of mass service (CMO).

The view of the network depends on the particular priority designation capabilities to sites affected by fire.

A general view of such a closed stochastic network presented in Figure 1.

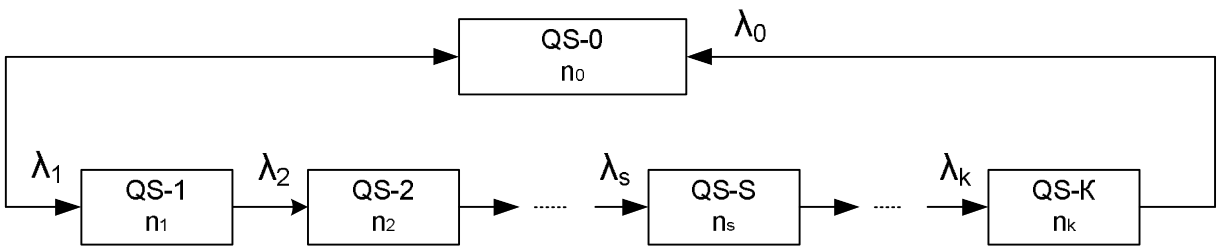

Fig. 1. Closed stochastic network system "fire units - objects (rolling stock), affected by fire. "

Number of fire departments Mrs required for all objects defined tactical calculations. Not allowed income units from outside the network and outputs the limits of their network. It is clear that

$$n = \sum_{j=1}^{\kappa} n_j, \tag{3}$$

where k - number of facilities affected by the fire; nj - number of fire units required for fire suppression and-so on the site.

The items affected by fire are the QS as storage systems with limited service applications. QS-0 is a model fire station, where fire units arrive. In theory queuing system with n parallel handling equipment queue. QS that describe the objects that suffer from fires, are a limited period of storage applications service.

Assuming that the number of fire units that travel to sites is limited, a closed network is always stationary.

Calculating the closed stochastic network made the assumption that the duration of service applications in the QS, which part of the network are random variables, which are distributed by the exponential law.

An important justification for studies of this network scheme is also that it can be considered as a set of independent QS with simpler input.

Closed stochastic network is determined by the following parameters:

- number of (K +1) queuing systems that are part of the network;
- quantity of devices for each QS (n^0,.......,n^κ);

- matrix of transition probabilities P=$\|P_{ij}\|$, where P_{ij} - probability that the application and after passing th QS will receive the input of that j-QS;
- n number of applications that circulate in a closed network;
- flux λ_j applications for the entrance of that j-QS.

The sequence of calculating the numerical parameters of stochastic networks [8].

1. Defining the matrix of transition probabilities.

The matrix of transition probabilities - square, the size of (K +1) x (K +1). Index 0 in the transition probabilities related to the source applications QS-0 (fire station):

It P_{oi} - a possibility that application of QS-0to the input and th QS, and P_{jo} -- the likelihood that an application after the passage of that j-QS tends to QS-0.

$$P=\begin{pmatrix} P_{00} & P_{01} & ..... & P_{0\kappa} \\ P_{10} & P_{11} & ..... & P_{1\kappa} \\ .... & .... & ..... & .... \\ P_{\kappa 0} & P_{\kappa 1} & ..... & P_{\kappa\kappa} \end{pmatrix}$$

Thus P_{oi} – is the probability of that the request from QS-0 comes to the entrance of i-th QS, and P_{jo} – is the probability of that the request after coming of j-th QS goes to QS-0.

It is obvious that elements of the matrix P sum of each tape is 1.

2. Determination of the intensity of flow at the entrance of each QS. Assuming that the intensity of the stationary mode flow of applications for the entrance and exit of any cleanse the same:

$$\lambda'_j = \sum_{i=0}^{\kappa} P_{ij}\lambda'_i, \quad j=\overline{o,\kappa};\ \lambda'_i = n\lambda_0,$$

we can write the system of homogeneous linear $\lambda_0, ..., \lambda_\kappa$,which will look like:

$$\left.\begin{array}{l} (P_{00}-1)\lambda'_0 + P_{10}\lambda'_1 + ... + P_{\kappa 0}\lambda'_\kappa = 0, \\ P_{01}\lambda'_0 + (P_{11}-1)\lambda'_1 + ... + P_{\kappa 1}\lambda'_\kappa = 0, \\ .... \\ P_{0\kappa}\lambda'_0 + P_{1\kappa}\lambda'_1 + ... + (P_{\kappa\kappa}-1)\lambda'_\kappa = 0. \end{array}\right\}$$

3. Calculating the probability of network status.

Network status determined by the number of applications in each QS network. Denote the number of entries in the j-and QS (j = $\overline{0,\kappa}$) by n_j. The set of values $\{n_0,\ldots,n_\kappa\}$ determines the state of the network. Given (3), the parameter that is calculated to be determined by the expression:

$$J_n\{n_0,.....n_\kappa\} = \frac{P^{(0)}_{n0}.....P^{(n)}_{nk}}{\sum\limits_{A(n,k)}\prod\limits_{j=0}^{\kappa} P^{(j)}_{nj}}.. \qquad (4)$$

In the numerator (4) - the product of probabilities of states of QS, which part of the network, and $P^{(j)}_{nj}$ - the likelihood of each j of that QS.

In the denominator (4) The summation is over all states for which $n = \sum_{j=1}^{k} n_j$ (the set of such states indicated A (n, k)). The denominator in (4) - is a normalizing factor that is introduced to the sum of probabilities of all possible states of a network unit equal.

According to the method of DSS considered various options for priority focus fire units at sites affected by fire, and determined the likelihood of possible states of the network.

From a comparison of the probabilities chosen focus option with a maximum value of such magnitude. Technique is used, you can determine the success of concentrating fire departments for fire suppression on objects (rolling stock) Railway provided when known only time characteristics of "fire departments - objects (rolling stock) railway affected by fire".

With DSS automatized process of assessing the situation, the parameters of transport developments in fire zones availability of rolling stock and rail facilities and to identify the required number of capabilities for fire suppression.

CONCLUSIONS

Using such a DSS can significantly reduce the time to evaluate the situation and making decisions on the organization of firefighting units to eliminate fire techniques to produce efficient thinking at training officers fire departments railroads, and develop knowledge base DSS.

Future directions of the development of DSS are its use in research networks, comprising some QS with different characteristics, and models that take into account the loss of combat vehicles and servants, and the sequence of different disciplines to focus on capabilities rolling stock, affected by fire.

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