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METHOD FOR EVALUATION OF AN OPERATOR'S DEGREE OF PREPAREDNESS TO MAKE DECISIONS ON LIQUIDATION OF SWIFT-FLOWING TECHNOGENIC RAILWAY TRANSPORT EMERGENCIES

The paper proposes a method for evaluating an operator's degree of preparedness to make decisions on liquidation of transport technogenic swift-flowing emergencies. The following indices that characterize the degree of an operator's preparedness to make decisions are introduced: the index of an operator's preparedness quality, the operator's response index. Expressions are proposed for calculation of the introduced notions. The above indices are entered into the Employee's Passport and characterize the operator's qualification level and his preparedness for making decisions.

Keywords: *decision making, DSS, transport emergencies, operator's preparedness degree.*

Introduction

According to statistics, fast development of technologies in the information society, constant growth of their complexity and production volumes are, unfortunately, accompanied by a significant growth in the number and scopes of technogenic emergency situations (TES) [1].

As a special class of TES, the so called swift-flowing technogenic emergency situations (STES) should be distinguished. They are characterized by rapid changes in the parameters of the environment and require extremely fast decision making and response to the situation in the absence of sufficiently complete and accurate information, in the conditions of a strong psychological stress and unpredictability of events. The price for improper actions in such circumstances can be extremely high and expressed not only in the destruction of valuable equipment and resources, but also in the environment pollution and loss of human lives.

As a separate class of STES, transport STES (TSTES) should be distinguished as they can occur at any place and at a great distance from emergency management centers. Well-known TSTES that occurred during railway transportation of cargoes can be given as characteristic examples

As an example of such a situation we can describe a railway accident that occurred in Lviv region on November 15, 2006. The accident occurred at Striy - Bilche rail crossing on a double-track railway line. 234 workers and 10 pieces of equipment were working at the place where 10 cars and 2 tanks rolled off the railway line at the Piatnychany station, Striy district, Lviv region. Among them were 17 rescuers and 3 units of equipment from the Ministry of Emergency Situations (MES). The routes of passenger trains did not coincide with those of cargo trains at that area of the railway, and so it was possible to avoid casualties [2].

Strict time limits for decision-making and limited information available during TSTES liquidation as well as remoteness of highly qualified experts from the place of such situations necessitate the development and continuous improvement of specialized decision-support systems (DSS). Such systems should provide automation of a considerable part of work on the analysis of swift-flowing situations on the basis of processing incomplete and unreliable information as well as simulation of possible scenarios. They should also support simulation of various TSTES scenarios for training of MES personnel, taking part in their liquidation, as well as of specialists, who provide transportation of dangerous cargoes (such as railway machinists), that may find themselves alone with such a situation, so that they could acquire skills of rapid decision making under the conditions of incomplete information.

Hence, the problem of not only creating a corresponding DSS, but also evaluation of the operator's preparedness to take decisions on liquidation of TSTES is of vital importance.

Papers [3] and [4] consider the influence of incomplete DSS for ES management, which is caused by divergence between an expert's judgement with that of an operator concerning the linguistic meaning of a certain parameter, affecting the outcome, in the context of a situation that arose. Formally, such a divergence is sensitivity of the system to the operator's mistake.

Let us consider the existing studies on evaluation of the personnel preparedness to make decisions on liquidation of TES.

In [5] it is proved that the existing approaches do not provide comprehensive information on the state of readiness of subdivisions to act in emergency situations and that parameters for evaluating the state of readiness are not objective.

Work [6] considers the saviors' preparation system that provides their training and certification. As a part of certification, qualification level of a person is determined. Depending on the evaluation criteria values, a person certified is referred to one of five classes.

In [7] an approach for evaluating the reliability of operator's work in the "man-machine" system is proposed. This paper examines the influence of a human factor in complex decision-making systems by the example of railway transport subject area. The author develops models for determining indicators that characterize reliability for different conditions of operator's work on the basis of probabilistic approach.

But the above papers do not provide an operator's preparedness evaluation in the context of divergence between judgments of an expert (or a group of experts) and of an operator concerning linguistic meaning of the parameters.

Evaluation of the system sensitivity to the operator's mistakes

In [3, 8] the following approach to evaluation of the system sensitivity to the operator's mistakes is proposed:

1) Values of the ranking indices are calculated by the expressions (1) or (2):

$$F_3(A,B) = \frac{\int_{a_1}^{a_2} \mu_A(a)da \int_{b_1}^{a} \mu_B\ (b)db}{C}, \tag{1}$$

$$C = \int_{a_1}^{a_2} \mu_A(a)da \int_{b_1}^{b_2} \mu_B\ (b)db,$$

$$a_1 = \inf_{a\in S(A)} a, a_2 = \sup_{a\in S(A)} a, b_1 = \inf_{b\in S(B)} b, b_2 = \sup_{b\in S(B)} b,$$

$$F_4(A,B) = \int_{0}^{0,5} \max\{0,(1-\mu_D(x))\}dx + \int_{0,5}^{1} \mu_D(x)dx, \tag{2}$$

$$D = {A}/{(A+B)}.$$

2) If in 1) no difference was found between expert and operator membership functions, fuzziness ranking index is calculated using expression (3).

$$I_C(A,B) = 1 - \frac{\int_{a-a_L}^{a+a_R} \mu_A(a)da}{\int_{a-a_L}^{a+a_R} \mu_A(a)da + \int_{b-b_L}^{b+b_R} \mu_B(b)db} = \frac{\int_{b-b_L}^{b+b_R} \mu_B(b)db}{\int_{a-a_L}^{a+a_R} \mu_A(a)da + \int_{b-b_L}^{b+b_R} \mu_B(b)db} = 1 - I_B(A,B). \tag{3}$$

3) If in 1) and 2) a difference between expert and operator membership functions was found, the

obtained value is added to set DIF.

4) For each deviation of the operator membership functions from those of an expert sensitivity value is calculated using expression (4):

$$M_i = |0.5 - DIF_i| * 2. \qquad (4)$$

Numerical value of the proposed estimate will always belong to the interval [0; 1] and, hence, is a normalized one. The "unit" value means that the advice, generated by the fuzzy inference system, is worth using. "Zero" value means that the system recommendations should not be trusted. Other numbers in the interval [0; 1] represent the degree of confidence in the system recommendaion. It should be taken into account that there could be several parameters which are not clearly defined. Therefore, the above procedure should be performed for all such parameters and the minimal one should be chosen. We obtain a numerical value M, which is an estimate of "confidence" in correctness of the recommendation.

$$M = \min\{m_i\}, i = 1...n, \qquad (5)$$

where M is a value of the resulting numerical characteristic; n – the number of input parameters that are not clearly defined, m_i – value of the numerical characteristic for the i^{th} parameter that is not clearly defined.

The presented procedure for evaluating the influence of input data on the results of inference in DSS makes it possible to calculate numerical value of the numerical characteristic that evaluates such influence. Numerical characteristic, obtained by means of such evaluation, is a normalized quantity, which simplifies its practical application and interpretation of the results. The proposed procedure does not take into account dimensionality and specific form of the membership functions and, therefore, is a universal one.

Taking the proposed material into consideration, a recommendation inference algorithm for TSTES liquidation is formulated [9]:

Step 1. Reviewing of all “unmarked” rules (i. e. those that have not worked yet) and forming a set that includes rules with maximal coefficient.

Step 2. If the set that was formed at step 1 is empty, this will be the end of the algorithm.

Step 3. Choosing one rule from the obtained set (the stage of conflict resolution).

Step 4. Refining values of the parameters in the left side of the rule chosen at step 2.

Step 5. Marking this rule as that used.

Step 6. Calculating the sensitivity value for the current parameter.

Step 7. If the right side contains a terminal expression, ask the operator if it makes sense to continue the process.

Step 8. If the answer is positive, pass to step 1, otherwise this will be the end of the algorithm.

Step 9. Calculation of the resulting sensitivity value using expression (5).

In order to resolve the conflict that consists in what production rule should be used, the following algorithm has been developed:

1. Making a list of all weights of the attributes of objects, contained in the consequents of production rules.
2. In case the attribute weight value is unavailable, the weight value of the object, to which this attribute belongs, should be used..
3. Sorting in descending order.
4. Choosing the first element from the list. If several elements have the same values, shoosing them and performing one more sorting operation in descending order of the object weight value and choose the first element form them.
5. Activating the production rule corresponding to the element chosen from the list.

This algorithm has quadratic complexity, which characterizes it as a productive one.

Evaluation of an operator's preparedness to make decisions

As it was noted above, there are several reasons for possible divergence between judgments of an expert (expert group) and of an operator regarding linguistic meaning of a certain parameter, that affects the outcome, in the context of a situation that arose. Formally, this is the difference between the membership functions of an operator and an expert (expert group). The essence of an operator's training lies in minimization of the differences between corresponding functions

To evaluate the operator's preparedness degree the following sequence of steps is proposed:

1. Performing steps 2 – 4 for all input parameters (i=1 ... n) of the system.

2. Performing steps 3 – 4 for all the terms of linguistic variables (j=1 ... m_i) of the current parameter.

3. Building current operator membership function.

4. Performing comparison of the operator membership function and membership function of an expert (or expert group), using one of the ranking indices, and saving the result of comparison in C_{ij}.

5. Calculating the index of an operator's preparedness quality using the expression:

$$P = \frac{\sum_{i=1}^{n}\sum_{i=1}^{mi} \max(WO_j, WA_j) \times |\, 0.5 - C_{ij}\,|}{n}, \tag{6}$$

where WO_j and WA_j – weigts of a current object and of the object attribute respectively.

For convenience, the value of weight (both for an attribute and an object) is an integral number from 1 to 10 (if not specified, then 1). Thus, the value of an operator's preparedness index is a real number from the interval [0; 5]. The closer the calculated value to 0, the better prepared operator is. The calculated value is entered to the Employee's Passport that is an internal document of the organization and includes the employee's personal data, his general characteristics, timeline of his work as well as a number of numerical estimates of his qualification level.

The operator's response index is another important indicator of his preparedness. It characterizes his ability of quick assessement of the circumstances, of introducing parameters and, consequently, of taking timely decisions. Since emergencies are not standard situations, the time required to determine and to introduce the value of a parameter is an objective indicator.

To assess the operator's responsiveness degree, the following sequence of steps is proposed:

1. To perform step 2 for all input parameters (i=1 … n) of the system.

2. To perform measurements of time required for the operator to determine the current parameter value.

3. To calculate the weighted average of the operator's response time (measured in seconds) using the expression:

$$t_R = \frac{\sum_{i=1}^{n} \max(WO_j, WA_j) \times t_i}{n}, \tag{7}$$

where t_i – response time, i. e. the value of the i^{th} attribute of an object; and the operator's response index using the expression (1 is a measurement unit):

$$R = \frac{\sum_{i=1}^{n} \max(WO_j, WA_j) * \frac{t_i}{t_{io}}}{n}, \tag{8}$$

where t_{io} – reference response time, i. e. the i^{th} attribute of the object is determined.

The operator's response index is also entered to the Employee's Passport.

Conclusions

Thus, to assess qualification level of an operator that could be trusted to participate in the liquidation of swift-flowing transport emergencies, it is proposed to use special indicators: response index and training quality index and to enter their values to the Employee's Passport.

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