

**INFORMATION TECHNOLOGY FOR DETERMINATION,
ASSESSMENT AND CORRECTION OF FUNCTIONAL
SUSTAINABILITY OF THE HUMAN-OPERATOR
FOR THE RELEVANT DECISION-MAKING
IN HUMAN-MACHINE CRITICAL APPLICATION SYSTEMS**

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Abstract. The questions of creation of information technology for determination, assessment, and correction of functional sustainability of human-operator for making relevant decisions in complex human-machine systems of critical application are considered. The main negative factors which influence on functional sustainability of the work and relevant decisions-making by the human-operator in critical situations are singled out. Information technology for assessment and correction of functional sustainability of human-operator operating in critical conditions, in such areas as power engineering, gas-petrochemical, etc. are offered. These industries have specific requirements for the human factor. Consideration is given to making decisions in real time by the decision maker (DM), in conditions of uncertainty, which depends on its cognitive component, the influence of the production process factors, and the environmental factors that significantly affect the functional sustainability. Mathematical models and methods of assessing the adequate influence of factors on the psycho-physiological and cognitive capabilities of the DM through his/her identification and the formation of an individual interface for him/her, so as to ensure the maximum effectiveness of interaction with the system, to make relevant decisions have been developed. The practical results of the study of the influence of a set of factors such as: the external environment, the cognitive component, the psychological state, the information load which

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are components of the DM's functional stability, which, how and to what extent negatively affects his/her condition, has been seen in the perception of operational information, its processing, and the speed of making relevant decisions. In this paper, the following theory and methods were used: the Bayesian network (graph probabilistic model) was used to quantify the relevance of the decision made by the DM; to reduce the complexity of filling the conditional probability tables, a method consisting of applying canonical (noisy) types of nodes – Noisy MAX was applied; to estimate the probabilities of negative influence of external factors on the DM and information load, a fuzzy logical conclusion based on Mamdani's algorithm was used. The method of determination and assessment of information load on the DM and the technology adaptation of the system and presentation of the adapted alternate solutions made by the DM in real time are proposed. Today these issues are problematic when creating human-machine interfaces. The results of the research used in the construction of this information technology (IT) will allow controlling of the adequate influence of factors on the DM's psycho-physiological and cognitive capabilities, by identifying him/her and creating an individual interface for him/her, in such a way as to ensure the maximum effectiveness of the interaction with the system for making relevant decisions.

1. Introduction

The relevance of this study is determined by a number of factors of an objective nature. Investigation of the problem in the presented research work is due to the fact that the share of accidents occurring in these systems is still high because of the inoperative and non-relevant decision-making by the human-operator, in particular, according to [1; 2], it can reach 60%.

In the study for the first time an information technology that would allow us in real time to quickly determine, assess and adjust the functional sustainability of human-operator, for making relevant decisions in critical situations, while managing a technological object of critical use is proposed.

In works [3-5] the creation of comfortable conditions of the production environment was considered; [6-8] the mathematical models and algorithms for assessing the relevance of the DM's cognitive component on the safety of the control systems operation were proposed; [9] the algorithms for formalizing the interconnection of environmental factors and the DM's cognitive component were presented. However, the issue of making

relevant decisions, taking into account the complex influence on the DM and correction of many negative factors, which is a component of his/her functional sustainability in real time was not considered.

Based on scientific novelty, the purpose of the research work is to create the information technology for assessment and correction of the functional sustainability components of the DM, namely the external environment, the cognitive component, information load, with their subsequent adaptation to the conditions of the dynamics of changes in the state of the controlled object, when making relevant decisions in complex, reliable, ergatic critical systems.

To achieve this goal, the following tasks must be accomplished:

1. To investigate the issues of creating adaptive man-machine interfaces for the management of complex, reliable systems of critical application. According to research results, to evaluate the influence of negative factors on the functional sustainability of the work and making relevant decisions by the human-operator in critical situations; 2. To develop an information technology for the determination, estimation and correction of functional stability of the operator in human-machine systems operating in critical conditions; 3. To develop mathematical models of estimating the probability of negative influence of factors on the functional sustainability of the DM, by his/her identification and formation of an individual interface for him/her, so as to ensure the maximum effectiveness of interaction with the system, for making relevant decisions; 4. To show the practical results of the introduction of the proposed information technology under the influence of many negative factors that are components of the functional sustainability of the DM, and to what extent they adversely affect the process of making relevant decisions.

In this paper, the following theory and methods were used: 1. To quantify the relevance of the decision making by the DM – the Bayesian network (graph probabilistic model); 2. To reduce the complexity of filling the conditional probability tables – a method consisting of applying canonical (noisy) types of nodes – Noisy MAX; 3. To estimate the probabilities of the negative impact of external factors and information load on the DM – a fuzzy logical conclusion based on the Mamdani algorithm.

2. Information technology development

In ergatic systems of critical application, human-operator activity is mainly associated with operational decision-making. The analysis of the sources shows that a significant proportion of accidents in various sectors:

in the energy sector to 40%, in transport to 30%, etc. is caused not by the operational decision-making but by the errors of the humane – operator.

The questions of theory and methods of decision-making were considered in the works of T. Saati, D. Pospelov, N. Nilsson, P. Larichev, I. Bidyuk, and others. The question of accounting of the cognitive component and the influence of the environmental factors in the ergodic systems was considered in the works of B. Lomov, G. Salwendi, A. Anokhina, V. Pavlov, and others. In [10, p. 217], mathematical models and decision-making algorithms are proposed, taking into account the influence of the safety factors on the operation of information control systems; the issues of solving the problems of increasing the reliability of operational-dispatching personnel during the operation of power systems are considered. At the same time, the main attention is paid to the formation of alternatives for decision making based on the existing knowledge bases, the provision of the DM with the required for his/her work information, and the formation of an optimal sequence of actions for the elimination of emergency situations.

However, the practical implementation of the results of numerous studies is still rather difficult and ineffective because of their fragmentation and the conceptual separation of the individual publications. The difficulties of uniting them into a single system of various aspects of this problem are noted by the experts from many countries.

To solve these issues, an information technology for the determination, assessment and correction of functional sustainability of the DM, when making relevant decisions in complex, reliable, ergatic critical use systems is proposed (Fig. 1).

In accordance with the scheme of information technology (Fig. 1), in the process of performing the functional duties of monitoring the technological process, in real time, the indicators of influence on the DM are controlled. They are the following: the external environment – EE (with the device «Assistant») [11], the information load – IL (Lan2net NAT Firewall program) [12], results of psychological testing – PT (Lubscher test) [13, p. 61], cognitive component – CC (test Isenka) [14, p. 5].

All these current indicators come into the corresponding module: for assessing the impact of the EE on the DM (EE), assessing the information load on the DM (IL), assessing the psychological state of the DM (PT), assessing the cognitive state of the DM – (CS). The results of the assessments are then transmitted to the module for evaluating the functional

sustainability of the DM (FS), where they are evaluated and compared in accordance with the Engineering and Psychological Standard for the DM's (EPS) working conditions [15]. Information about the determined state of functional sustainability of the DM FS (EE, IL, PT, CS) enters the module for assessing the probability of making relevant decisions (MRDs). The main criterion for evaluation in this module is the assessment of the probability of making relevant decisions (PMRDs) by the DM-Q. When $Q > 0.95$ – the generation of alternatives to MRDs (A) is performed, with $Q < 0.95$ – in accordance with the engineering-psychological decisions of the system's adaptation to the DM (AS), the generation of adapted alternatives to DM (GAA) is performed.

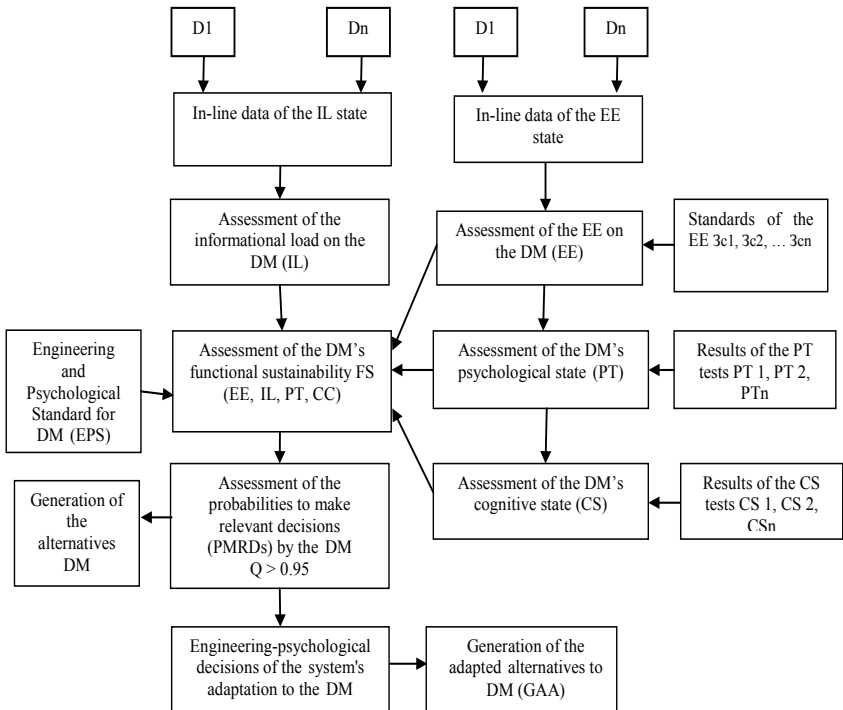


Figure 1. Information technology for the determination and assessment of DM's functional sustainability to make relevant decisions

As a consequence, this module, within the user interface, offers the most relevant alternatives to the decision-making by the DM in a format suitable for him/her, in accordance with the psychological and ergonomic standards of labor in human-machine systems.

3. Mathematical models' development

When solving the problem of determining the probability of reasons for the low relevance of the DM's decision, it is often necessary to use indirect information that does not give one hundred percent confidence in the diagnosis.

Nowadays the Bayesian networks are one of the most appropriate models for dealing with incomplete, inaccurate, and contradictory information. The mathematical apparatus of the Bayesian networks is based on the probabilistic approach and is able to maximize the use of information coming from the chosen sources to achieve maximum effect [16].

To quantify the relevance rate of made by the DM decision, it is suggested to use the Bayesian network, shown in Figure 2. Note that when constructing the structure of this BN and filling the conditional probability tables for the network variables, the requirements of the engineering-psychological norm of the work conditions of the human operator and the expert knowledge were used.

We assume that the network variables are binary, i.e. have two states. The variables "Informational Load on the DM", "External Environment Influence on the DM", "DM's psychological State", "DM's Cognitive state" and "Assessment of the DM's functional sustainability" may take the values: "Positive" and "Negative", and the variable "Assessment of the Relevance of the Decisions Made by the DM" can be of the "relevant" and "irrelevant" value.

For the node of the Bayesian network «Assessment of the DM's Functional Sustainability» having 4 parent nodes, it is necessary to specify $16 = 2^4$ the values in the conditional probability table. In order to evaluate these probabilities, the expert will have to look for a joint distribution of various factors on the investigated value. As practice shows, it is much easier for experts to evaluate in isolation the degree of influence of this or that factor on the situation. Therefore, in this paper, we used the method described in [17, p. 231] and applied the canonical (noisy) type of «Noisy MAX» for the node «Assessment of the DM's Functional Sustainability».

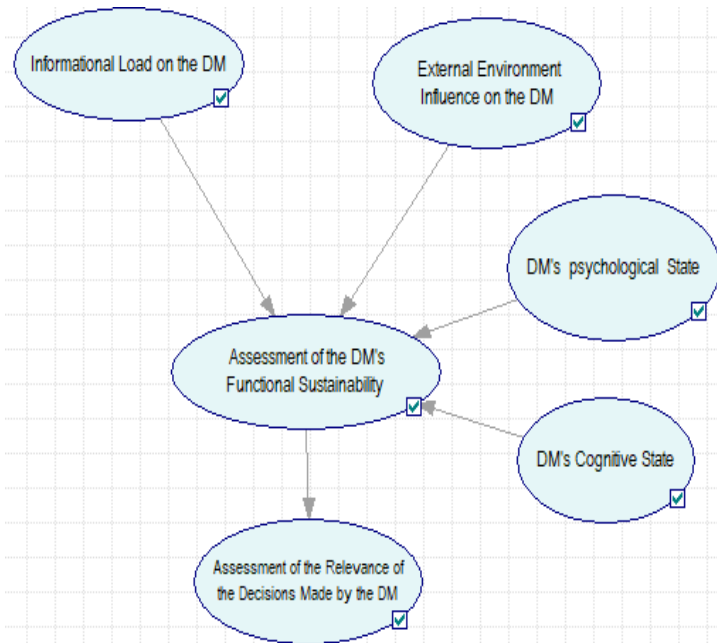


Figure 2. The structure of the Bayesian network to assess the probability of the relevance of the decision taken by the DM

The description of this noisy node is presented in Table 1.

Table 1

Description of the node «DM’s psychological State»

Parent state	Informational Load on the DM		External Environment Influence on the DM		Other reasons
	negative	positive	negative	positive	
negative	0,67	0,0	0,85	0,0	0,01
positive	0,33	1,0	0,15	1,0	0,99
Parent state	DM’s Cognitive state		DM’s Psychological state		Other reasons
	negative	positive	negative	positive	
negative	0,62	0,0	0,73	0,0	0,01
positive	0,38	1,0	0,27	1,0	0,99

We apply the types of nodes “Chance – General” for parent nodes “Informational Load on the DM”, “External Environment Influence on the DM”, “DM’s Psychological state”, “DM’s Cognitive state”.

Let us consider the node «External Environment Influence on the DM». The following factors influence the random variable «External Environment Influence on the DM»: noise intensity IN; intensity of vibration IV; workplace illumination E; temperature T; humidity H; atmospheric pressure fluctuations APF. Normative values of these factors [15] are given in Table 2.

Table 2

Normative values of environmental factors

factors	IN dB	IV mm/s	E lux	T °C	H %	$\frac{\Delta P}{\Delta t}$ MmHg
norma	≤ 50	7,6 – 11,2	250	22 – 24	40 – 60	≤ 4

The more external factors differ from the normative ones, the more likely that their impact on the DM will be negative. The question arises: what is the probability P_2 that the random variable “The influence of the external environment” on the DM becomes negative?

To answer this question, we will create a system for predicting probability values, based on the fuzzy logical conclusion on the Mamdani algorithm on the fuzzy knowledge base [18], in which the values of the input and output variables are given by fuzzy sets. Taking into account that according to [19, p. 120] the most noticeable influence on the DM is exerted by the factors of noise intensity, workplace illumination and intensity of vibration, the following fuzzy knowledge base is proposed:

RULE 1: IF u_1 is «not a norm» THEN v is a «high»

RULE 2: IF u_2 is «not a norm» And u_1 is «norm» And u_3 is «norm» THEN v is «above average»

RULE 3: IF u_3 is «not a norm» And u_1 is «norm» And u_2 is «norm» THEN v is «above average»

RULE 4: IF u_2 is «not a norm» And u_3 is «not a norm» THEN v is «high»

RULE 5: IF u_4 is «not a norm» And u_1 is «norm» And u_2 is «norm» And u_3 is «norm» THEN v is «average»

RULE 6: IF u_5 is «not a norm» And u_4 is «norm» And u_1 is «norm» And u_2 is «norm» And u_3 is «norm» THEN v is «below average»

RULE 7: IF u_6 is «not a norm» And u_4 is «norm» And u_1 is «norm» And u_2 is «norm» And u_3 is «norm» THEN v is «below average»

RULE 8: IF u_1 is «norm» And u_2 is «norm» And u_3 is «norm» And u_4 is «norm» And u_5 is «norm» And u_6 is «norm» THEN v is «low»

Here, u_i ($i = 1,6$) denotes the linguistic variables « noise intensity », «intensity of vibration», «workplace illumination», «temperature», «humidity», «atmospheric pressure fluctuations» respectively, and through v – is the linguistic variable «the probability that the random variable» External Environment Influence on the DM» takes the meaning» negative»».

To describe the linguistic variables u_i ($i = 1,6$) we will use the term set {«norm», «not a norm»}, and for the variable y – the term set {«low», «below average, «average», «above average», «high»}.

The membership functions $\mu_i(x_i)$ the term «norm» of the linguistic variables u_i ($i = 1,6$) will be given in the form of the Gauss distribution:

$$\mu_i(x_i) = \text{gauss2 fm}(x_i, [\sigma_1^i, c_1^i, \sigma_2^i, c_2^i]) = \begin{cases} e^{-\frac{(x_i - c_1^i)^2}{2(\sigma_1^i)^2}}, & \text{if } 0 \leq x_i \leq c_1^i, \\ 1, & \text{if } c_1^i < x_i < c_2^i, \\ e^{-\frac{(x_i - c_2^i)^2}{2(\sigma_2^i)^2}}, & \text{if } c_2^i \leq x_i, \end{cases} \quad (1)$$

where the parameters $\sigma_1^i, \sigma_2^i > 0; c_1^i, c_2^i \geq 0; c_1^i \leq c_2^i; x_i$ – are the elements of universal sets, on which the terms “norm” and “not a norm” are defined. Taking into account the values of the left and right ends of the intervals of normative values of external factors (Table 2), we will determine the values of the parameters c_1^i and c_2^i ($i = 1,6$). Then the membership functions $\mu_i(x_i)$ can be written in the form:

$$\begin{aligned} \mu_1(x_1) &= \text{gauss2 fm}(x_1, [\sigma_1^1, 0, \sigma_2^1, 50]), \quad x_1 \in [0, 150]; \\ \mu_2(x_2) &= \text{gauss2 fm}(x_2, [\sigma_1^2, 7.6, \sigma_2^2, 11.2]), \quad x_2 \in [0, 15]; \\ \mu_3(x_3) &= \text{gauss2 fm}(x_3, [\sigma_1^3, 250, \sigma_2^3, 250]), \quad x_3 \in [0, 600]; \\ \mu_4(x_4) &= \text{gauss2 fm}(x_4, [\sigma_1^4, 22, \sigma_2^4, 24]), \quad x_4 \in [10, 40]; \\ \mu_5(x_5) &= \text{gauss2 fm}(x_5, [\sigma_1^5, 40, \sigma_2^5, 60]), \quad x_5 \in [0, 90]; \\ \mu_6(x_6) &= \text{gauss2 fm}(x_6, [\sigma_1^6, 0, \sigma_2^6, 4]), \quad x_6 \in [0, 15]. \end{aligned} \quad (2)$$

Considering that the statement «the linguistic variable u_i gets the value «not a norm» is the opposite to the statement «the linguistic variable u_i takes the value «norm», we come to the conclusion that the membership functions $\phi_i(x_i)$ the term « not a norm «of the linguistic variables u_i is the following:

$$\phi_i(x_i) = 1 - \mu_i(x_i), \quad (i = \overline{1,6}).$$

We denote the membership functions of the terms «low», «below average», «average», «above average», «high» of the linguistic variable v as $\theta_i(y)$ ($i = \overline{1,5}$) respectively, where y are the elements of a universal set $Y = \{0 \leq y \leq 1\}$ on which these terms are defined.

Let us consider $\theta_i(y)$ in the form of a symmetric Gauss distribution:

$$\theta_i(y) = \text{gaussfm}(y, [\sigma_i, c_i]) = e^{-\frac{(y-c_i)^2}{2\sigma_i^2}}, \quad (3)$$

where the parameters are $\sigma_i > 0$; $c_i \geq 0$, ($i = \overline{1,5}$).

Below are the characteristic graphs of the membership function.

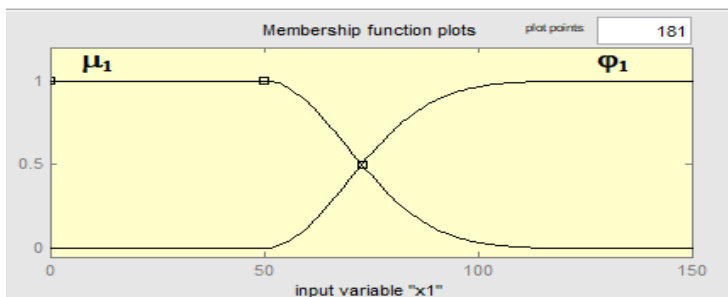


Figure 3. Membership functions $\mu_1(x_1)$ and $\phi_1(x_1)$

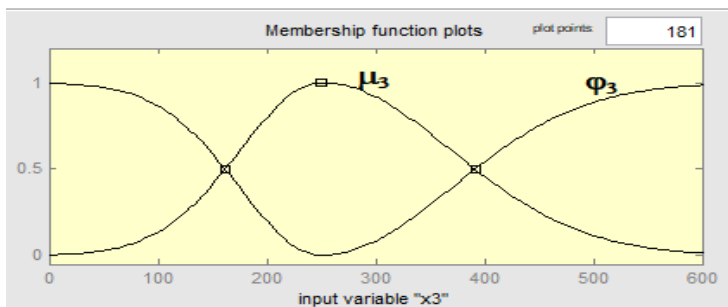


Figure 4. Membership functions $\mu_3(x_3)$ and $\phi_3(x_3)$

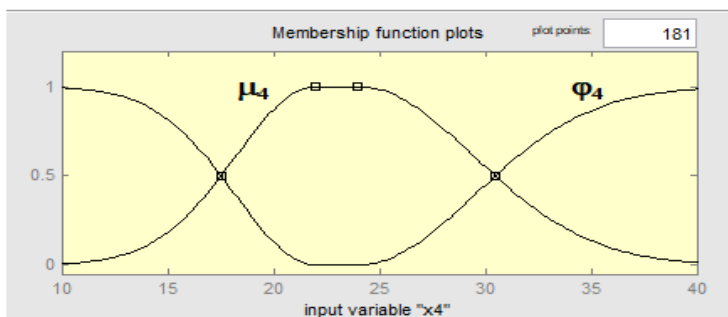


Figure 5. Membership functions $\mu_4(x_4)$ and $\phi_4(x_4)$

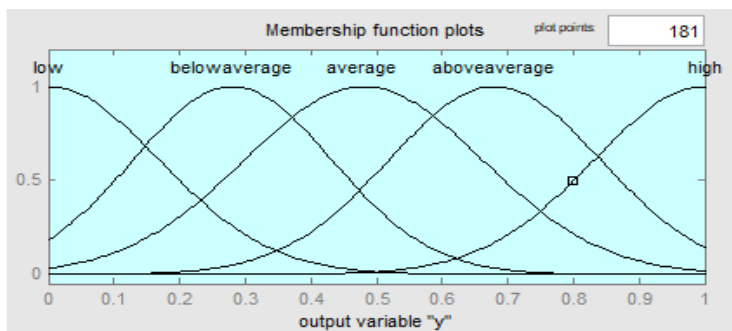


Figure 6. Membership functions $\theta_i(y)$ ($i = \overline{1,5}$)

To adjust the fuzzy F model, i.e. definitions of model coefficients $\sigma_1^i, \sigma_2^i, (i = \overline{1,6})$; $\sigma_j, c_j, (j = \overline{1,5})$, we require that the value of the mean square discrepancy R is minimal:

$$R = \frac{1}{n} \sum_{k=1}^n (y_k - \mathbf{F}(P, E_k))^2 \rightarrow \min. \quad (4)$$

Here n is the volume of a statistical sampling of experimental data linking the inputs $E = (x_1, x_2, x_3, x_4, x_5, x_6)$ with the output of the investigated dependence:

$$(E_k, y_k), \quad k = \overline{1, n},$$

where $E_k = (x_{k,1}, x_{k,2}, x_{k,3}, x_{k,4}, x_{k,5}, x_{k,6})$ is the vector of inputs and y_k is an output of the couple number k . In addition, $\mathbf{F}(P, E_k)$ is the value of the

output of the fuzzy model at the value of the inputs given by the vector E_k ; $P = (\sigma_1^i, \sigma_2^i, \sigma_j, c_j)$ is the vector of coefficients of the functions of the membership of the terms of input and output variables of the fuzzy model.

Taking into account the recommendations [15; 20] and the results of experts' assessments of the influence of environmental factors on the DM, we solve the problem of mathematical programming (4) using Fuzzy Logic Toolbox and Optimization Toolbox packages and thus set up a fuzzy model.

A similar approach is used to estimate the probability P_1 that the random value of "Informational Load on the DM" takes the value "negative".

In accordance with the engineering-psychological standards of the working conditions of the operator [15, p. 308; 20, p. 52], the nature of the perception of the information load by the DM can be represented as follows (Table 3):

Table 3

**Dependence of the nature of the information perception
by the DM from the flow of information**

Informational loading (symbols/per hour)	Nature of the information perception
less than 3000	excellent
3000 – 3400	good
3400 – 3800	norm
3800 – 4000	bad
more than 4000	very bad

To estimate the probability P_1 , we will create a fuzzy prediction model for probability values, based on which we put the fuzzy logical conclusion on the Mamdani's algorithm on the proposed fuzzy knowledge base:

RULE 1: IF w is «excellent» THEN q is «low»

RULE 2: IF w is «good» THEN q is «below average»

RULE 3: IF w is «normal» THEN q is «middle»

RULE 4: IF w is «bad» THEN q is «above average»

RULING 5: IF w is "very bad" THEN q is «high»

Here w denotes the linguistic variable, the "character of the perception of information", and q is the linguistic variable, the probability that the random value of the "Informational Load on the DM" takes on a "negative" value.

To describe a linguistic variable w , we use the term set {«excellent», «good», «normal», «bad», «very bad»}, and for the variable q the term set {«low», «below average», «medium», «above average», «high»}.

The membership functions $\eta_i(z)$, ($i = \overline{1,5}$) of the terms “excellent”, “good”, “normal”, “bad”, “very bad”, respectively, of the linguistic variable w will be given in the form of a two-way Gauss distribution:

$$\eta_i(z) = \text{gauss2fm}(z, [\lambda_1^i, a_1^i, \lambda_2^i, a_2^i]) = \begin{cases} e^{-(z-a_1^i)^2 / 2(\lambda_1^i)^2} & .\text{if } 0 \leq z \leq a_1^i, \\ 1, & \text{if } a_1^i < z < a_2^i, \\ e^{-(z-a_2^i)^2 / 2(\lambda_2^i)^2} & .\text{if } a_2^i \leq z \end{cases} \quad (5)$$

where the parameters are $\lambda_1^i, \lambda_2^i > 0$; $a_1^i, a_2^i > 0$; $a_1^i < a_2^i$; z – are the elements of a universal set $Z = \{z | 0 \leq z \leq 5000\}$ on which these terms are defined.

We denote the membership functions of the terms «low», «below average», «middle», «above average», «high» of the linguistic variable q as $\omega_i(y)$ ($i = \overline{1,5}$) respectively, where y are the elements of the universal set $Y = \{y | 0 \leq y \leq 1\}$ on which these terms are defined.

Let us consider $\omega_i(y)$ in the form of a symmetric Gauss distribution:

$$\omega_i(y) = \text{gaussfm}(y, [\delta_i, e_i]) = e^{-(y-e_i)^2 / 2\delta_i^2}, \quad (6)$$

where the parameters are $e_i \geq 0$; $\delta_i > 0$, ($i = \overline{1,5}$).

Figure 6 shows the graphs of the membership functions $\eta_i(z)$ of the terms of a logical variable w . The graphs of the membership functions $\omega_i(y)$ ($i = \overline{1,5}$) have the same form as the graphs of the membership functions $\theta_i(y)$ ($i = \overline{1,5}$), as shown in Figure 5.

The setting of the fuzzy model G is done in the same way as setting the fuzzy model F. In this case, the coefficients of the model $\lambda_1^i, \lambda_2^i, a_1^i, a_2^i$, ($i = \overline{1,5}$) are determined from the solution of the problem of determining the minimum of the mean square disparity R:

$$R = \frac{1}{n} \sum_{k=1}^n (q_k - \mathbf{G}(P, z_k))^2 \rightarrow \min. \quad (7)$$

Here n is the volume of experimental data selection, linking the input z , with the output q of the investigated dependence:

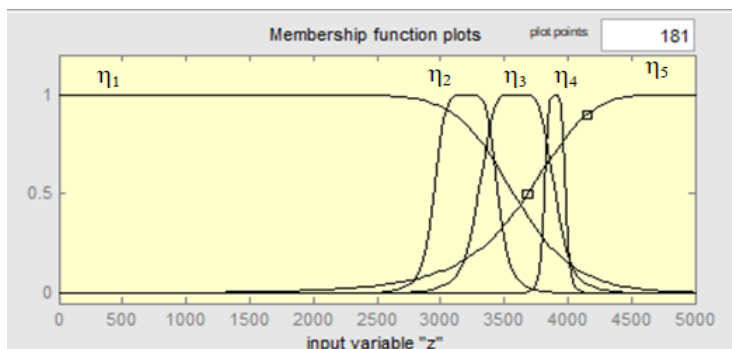


Figure 7. Membership functions $\eta_i(z)$ ($i=\overline{1,5}$)

$$(z_k, q_k), k = \overline{1, n},$$

where z_k is the input and q_k is the output of the couple number k . In addition, $G(P, z_k)$ is the value of the output of the fuzzy model with the input value which equals to z_k ; $P = (\lambda_1^i, \lambda_2^i, a_1^i, a_2^i, e_i, \delta_i)$ is a vector of coefficients of the membership functions of the terms of the input and output variables of the fuzzy model.

The psychological and cognitive state of the DM is determined with the tests. Let us denote P_3 the probability that the random value “DM’s Psychological State” takes the value “negative”, and denote P_4 the probability that the random value “DM’s Cognitive state” takes the value “negative”. In estimating these probabilities, we will assume that $P_3 = \frac{n_3}{N_3}$, $P_4 = \frac{n_4}{N_4}$, where n_3 is the number of tests that characterize the DM’s psychological state negatively; N_3 is a total number of tests of the DM’s psychological state; n_4 is a number of tests that characterize the DM’s cognitive state negatively; N_4 is a total number of tests for estimating DM’s cognitive state.

For the node « Assessment of the Relevance of the Decisions Made by the DM» the type of nodes «Chance – General» is applied. The conditional probabilities that the corresponding random variable assumes values “relevant” or “irrelevant” are identified by experts and are presented in Table 4.

Description of the node «Assessment of the Relevance of the Decisions Made by the DM»

Parent state	Psycho-functional state	
	negative	positive
relevant	0,6	0,95
irrelevant	0,4	0,05

4. Practical results of the research

At one of the power supply facilities, when implementing the results of the research, the main task was to control and eliminate accidents by operational and dispatching personnel. Determination and assessment of the information load on the DM was carried out from remote objects of consumer power supply on the following issues:

- closures which are accompanied by burning of grounding arcs resulting in overvoltage, breakdowns of machines and apparatus isolation;
- false personnel actions, interruptions in consumer electricity supply, accidents or failures in work, depending on their nature and degree of damage;
- cases of violation of normal operation modes of substations (automatic shutdown of equipment at short circuits);
- accidents at the substations that may occur as a result of disturbances in the equipment from possible overvoltage.

Lan2net NAT Firewall, which has the ability to monitor online activity in the network, is used to determine flows and volumes of information load. The program can provide information on current information flows, display the tree of open information flows, allow us in real time to count and maintain statistics of the information flows for the required time interval.

Figure 8 shows the Information load (symbols/per hour) on the operator-controller who controls four feeders of 10kV of the central power system during a 12-hour working shift.

To scan the volume of information packets arriving at the central point of the dispatch service and assess the information load on the DM, an algorithm for the specified operation automation is developed (Figure 9).

With this algorithm, the system automatically intercepts and scans the sizes of information packets from the consumers. After scanning, the total amount of information is counted, the information load on the DM is

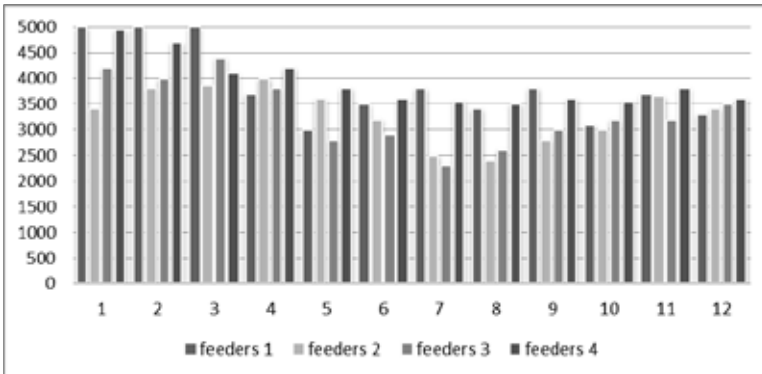


Figure 8. Graph of the operator's information load

evaluated, and the result is recorded in the monitoring system database for the further evaluation of the functional sustainability of the DM.

Figure 10 presents the results of the application of the proposed IT to assess the functional sustainability and the probability of making relevant decision by the DM.

When the functional sustainability of the DM is reduced by 10%, the probability of making a relevant decision is $Q = 0.951$, provided ($Q \geq 0.95$), and evaluated as «relevant». With a decrease in functional stability by 40% (Fig. 10, a) the probability of adopting a relevant decision by the DM is $Q = 0.834$ and is evaluated as «irrelevant». With a decrease of 70% (Fig. 10, b), the probability of making a relevant decision is $Q = 0.717$ and is also evaluated as «irrelevant».

In these cases, the system in real time brings the value of the above-mentioned negative factors into norm and adapts the DM to decision-making alternatives (AAD), to fulfill the condition ($Q \geq 0.95$), in which the probability of making a relevant decision is increased and evaluated as «relevant».

5. Conclusions

In this paper, IT for determination, assessment, and correction of functional sustainability of human-operator for making relevant decisions in complex human-machine systems of critical application is developed. According to the results of the study, the following conclusions on the implementation of this technology can be presented:

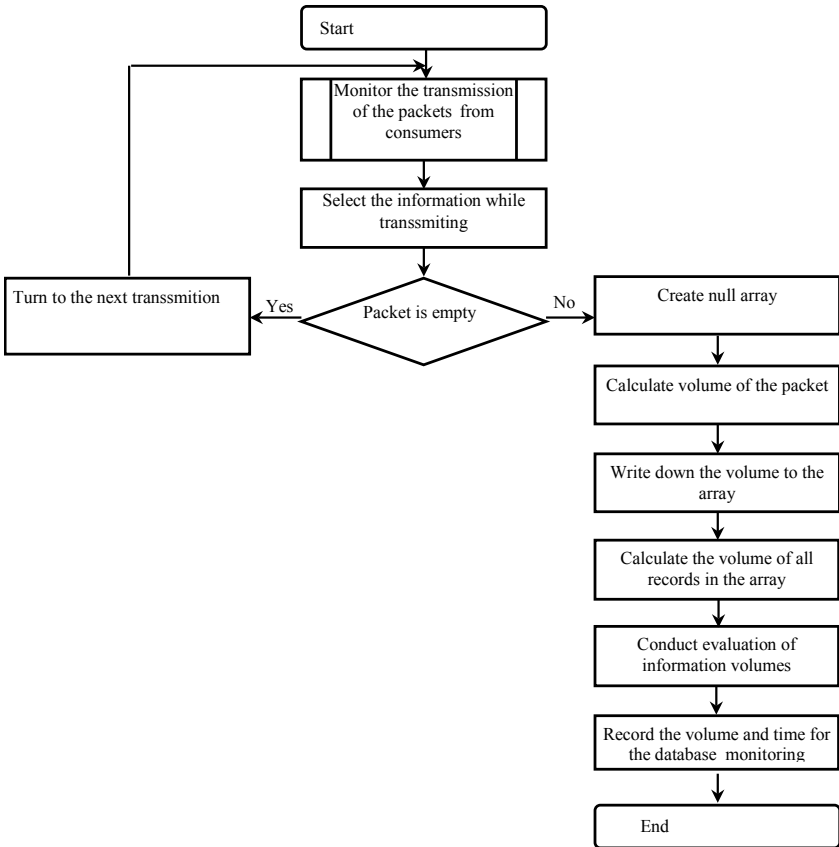


Figure 9. Algorithm for scanning and assessment of information load on the DM

1. At the first stage, the factors influencing the information load on the DM and factors of negative influence of the external environment on the DM are measured; tests are conducted to assess the DM's psychological and cognitive state.

2. Based on the data obtained in the first stage, the above-mentioned scheme estimates the marginal probabilities of the vertices of the Bayesian network "Information Load on the DM", "External Environment Influence on the DM", "DM's Psychological state", "DM's Cognitive state".

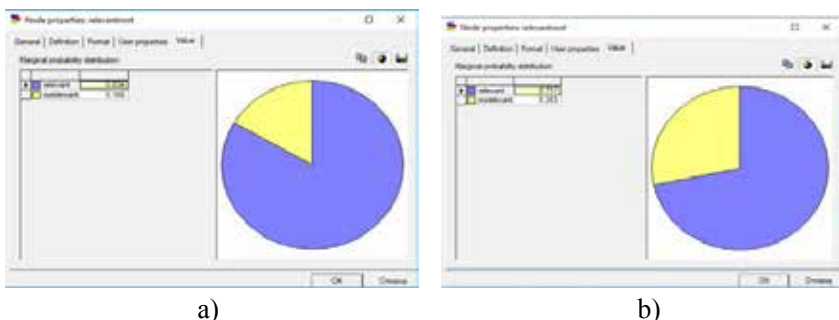


Figure 10. Modeling outcomes of the negative factors deviation from the normative requirements that reduce the DM’s functional sustainability: a) by 40%, b) by 70%

3. Using the proposed Bayesian network, the probability (Q) of the relevance made by the DM decisions is assessed. If this probability has a value of $Q \geq 0.95$, then the work of the DM can be considered correct or “relevant”.

If the work of the DM is incorrect ($Q < 0.95$), then the system brings the listed negative factors into line with the standards, in real time and adapts the DM to the alternative (AAD). Due to the generation of these factors the probability of making a relevant decision increases to ($Q \geq 0.95$) and is evaluated as “relevant”.

The application of this IT allows us to control the adequate influence of the factors on the DM’s psycho-physiological and cognitive state through his/her identification and the creation of an individual interface for him/her, in such a way as to ensure the maximum effectiveness of interaction with the system, for making relevant decisions.

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