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Operations simulating of station duty officer in the case of breakdown in control system

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Abstract

Complex industrial systems are still very dependent on the operator's human errors. Many automated control systems have been developed for the needs of rail transport. The safety of train movement directly depends on some of them. In case of a malfunction during the operation of such systems, they pass into a safe state and most traffic safety tasks are transmitted to the operator or station operator. To obtain quantitative values of the probability of timely execution of operations by the duty officer at the station, a functional-semantic network and a corresponding model are proposed. This work investigates the connection between the probability of timely execution of operations and the psychophysiological state of the duty officer in case of complex industrial systems problems on the railway transport.

Keywords: Railway turnout systems; Failures; Service strategy

1. Introduction

The fact is that railway transport is an area of increased danger and represents a potential danger to its users. The features of railway transport affect the severity of the consequences of accidents on the railways and the complexity of their elimination and localization.

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At present, automatic and automated control systems are used to improve the safety of train traffic on stations and hauls. However, in case of a malfunction of the train control system, functions of security assurance of the train should be assigned to the operator or to the duty officer at the station.

Even the most advanced control systems and devices are not able to fully exclude human involvement in the provision of trouble-free work [1]. The safe and uninterrupted operation of railway transport always depends on the personal level of discipline, responsibility and demandingness.

A significant number of studies is devoted to the problems of assessing the impact of operator actions. The paper [2] presents a good overview of the approaches to assessing human error in relation to complex industrial systems. This paper [3] is proposed a methodology for determining human reliability in the analysis of a railway car, and the probability of occurrence of human errors for individual tasks is also determined. The assessment of factors and their impact on railway workers in the presence of extraordinary situations is considered in the work [4].In the work [5], to formalize the conflict situations that arise during the management of the train, proposed a method for assessing the adoption of rational management decisions in conditions that have different degrees of uncertainty. The work [6] defines the integral loading of operational-dispatching personnel and reveals the regularity of increasing the loading coefficient with increasing flow of operational information , which leads to the delayed actions of the DSP. A general assessment of the reliability of human-The operator in control systems is provided in the work [7] itself. The results of laboratory research are used as input data for the assessment, which makes it impossible to use them for further research in the field of railway transport. The paper [8] provides several methods for conducting examination of injury cases and without taking into account the characteristics of railway operators. Sufficient amount of output data on modeling operations by human operator in human-machine systems is provided in the work [9], except for the railway transport industry. At present, the operational-dispatching personnel have such intervals when the human-operator must determine priority of actions in a short time, which again indicates the need to reduce the information load of the human-operator. The analysis provided indicates the need to simulate the operation of the SSP notification which working on the station's tracks.

The purpose of the work is to obtain quantitative values of the probability of timely execution of the operation of the duty officer at station at the presence of malfunctions in the control system – the transfer of the point when false employment of the track area.

The definition of these data is based on the use of functional semantic networks. To achieve this goal it is necessary to solve the following tasks:

- Construction of the action model of the duty officer at the station in the presence of malfunctions in the control system
- The study of dependencies between the probability of timely execution of operations and psychophysiological condition of duty officer on the station

2. Synthesis of the model of execution of operations by duty officer on the station in the presence of malfunctions in the control system

The task of formalization consists in the compilation of a list of elementary (atomic, linearizable) actions, forming in aggregate a coherent activity, and in defining in aggregate their interrelations. For a formalized description of the process of performing operations by the duty officer in the presence of malfunctions in the control system as the set of actions, each of which consists of a number of interconnected operations, we use graphic schemes. Taking into account the recommendations [7-9], the results of processing photoconfiguration data [6] and assessing the status of duty officers [10,11], a functional-semantic network is built (see Fig. 1) for the implementation of DSP operations in the presence of malfunctions in the control system – switching the point with false clear of the track area.

Implementation by the duty officer the set of operations is presented in the form of a logical scheme (see Fig. 2), which is not related to creative thinking or making the intuitive decisions.

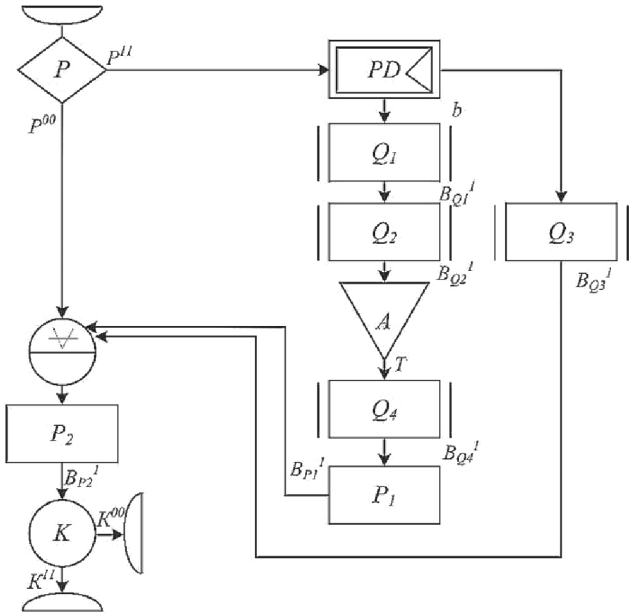

Fig. 1. Functional-semantic network of the performance of the DSP operation when moving the point with false clear of the track area.

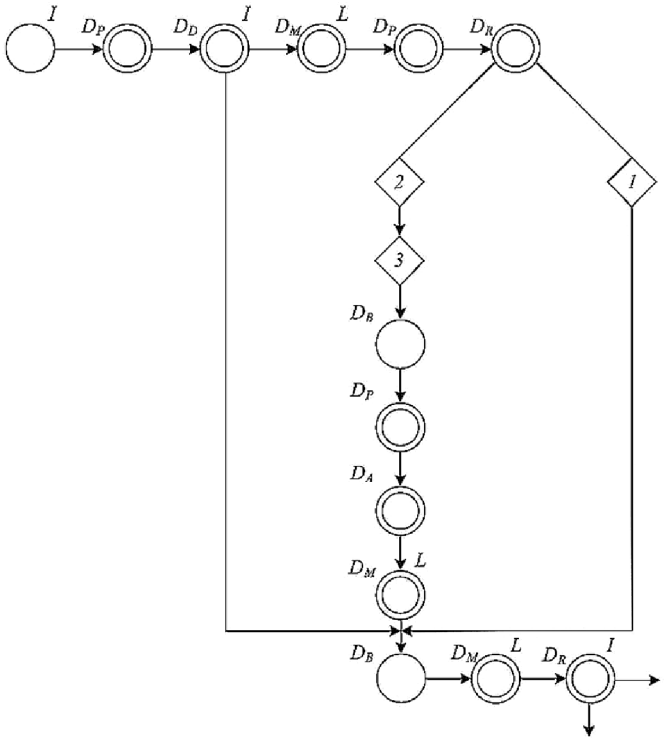

Fig. 2. Functional-semantic network of the performance of the DSP operation when moving the point with false clear of the track area.

Based on the functional-semantic network and the logical scheme of the operation of the particleboard during the switching of the point with the false clear of the track section at the operational-psychological level, a model was constructed:

$$\beta_e = k \cdot \left(P^{11} \cdot \left(\beta_{O1}^{1} \cdot \beta_{O2}^{1} \cdot \beta_{O3}^{1} \cdot \beta_{O4}^{1} \cdot \beta_{P1}^{1}\right) + P^{00}\right) \cdot K^{11} \cdot \frac{1}{1 - K^{00} \cdot \beta^{0}} \quad (1)$$

$$M_e = j \cdot \sum M_i \quad (2)$$

where *β, P, K* are probability of correct execution of the corresponding operation, *M* is the mathematical expectation of execution of the corresponding operation, *k* and *j* are respectively, the coefficient of probability and the coefficient of mathematical expectation of the operation, taking into account the psychophysiological conditions of the DSP.

The initial data for modelling are the results of the processing of the photogrammetric data of work of duty officers [6] and recommendations [7-9].

3. Analysis of the simulation results of the DSP interaction with a point in a case of false clear point`s track area

As a result of simulation, it was found that with the probability is not lower than Ra = 0.856 (accepted for systems of electric centralization [1, 2]), duty officer at the station is able to perform an operation for the transfer of the point with the false clear of the track area in optimal psychophysiological condition. However, with a significant deterioration in the psycho-physiological condition [6. 9] the duty officer is not able to perform the task with a given probability.

The M_{pe}'s mathematical expectation of performing an operation for moving the point with false clear of the track area also depends on the psychophysiological condition of the duty officer at the station [6.9]. If the psychophysiological state deteriorates, the time necessary for the transfer of the point with false clear of the track area is doubled, which greatly affects the safety of trains (see Fig. 3).

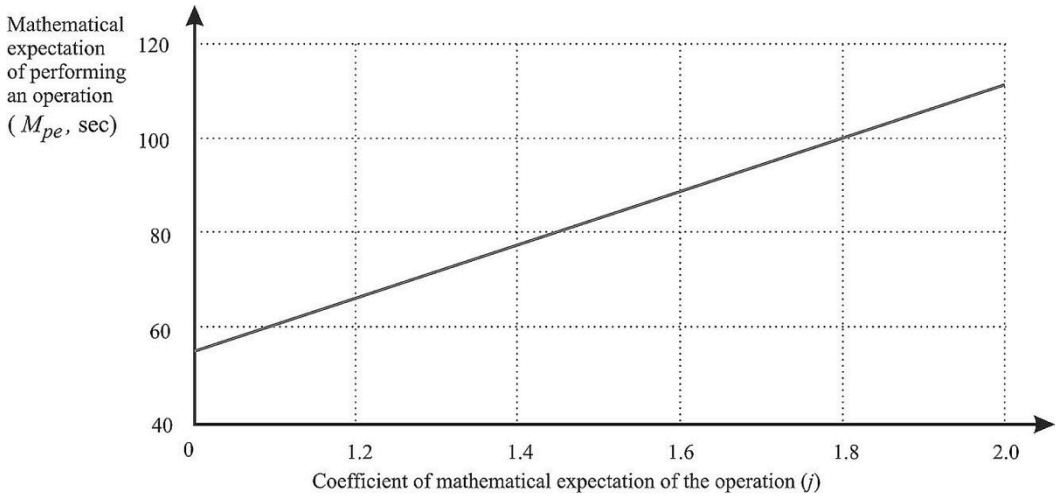

Fig. 3. Mathematical expectation M_{pe} of execution of the operation of moving the point with false clear of the track area.

To determine the dependence of the probability of performing an operation of the transfer of the point in the case of false clear of the track area from the time of execution when changing the psychophysiological condition of the duty officer at the station, defined parameters of gamma distribution, the distribution density of which has the form:

$$f(t)=\begin{cases}0, & t\le 0\\ \dfrac{\Psi^{\alpha}}{\Gamma(\alpha)}\cdot t^{\alpha-1}\cdot e^{-\psi\cdot t}, & t>0\end{cases} \tag{3}$$

$$\alpha_e=\frac{M_e^2}{D_e},\quad \alpha=1.4\cdot 10^3 \tag{4}$$

$$\Psi=\frac{M_e}{D_e},\quad \Psi=26.234 \tag{5}$$

where α is the distribution parameter that determines the shape of the distribution curve, Ψ is the scale parameter, *c-1*, *D* is the dispersion of operation time, *c2*, $\Gamma(\alpha)$ is the Euler gamma function.

Since the gamma-distribution parameter α assumes large values ($\alpha >> 10$), then the normal distribution law is to be used as the law of the time distribution of the operation for switching the point with the false clear of the track area:

$$f(t)=\frac{1}{D_e\sqrt{2\pi}}\cdot e^{-\left[\frac{(t-M_e)^2}{2\cdot D_e^2}\right]} \tag{6}$$

$$P(t)=\int_0^t f(t)dt \tag{7}$$

Further analysis of the calculations showed that the minimum required time t_{min} , for which the duty officer at the station is able to perform an operation on the transfer of the point in the case of false clear of the track area with a minimum acceptable probability P_a (0.856), is approximately 59 seconds (see Fig. 4).

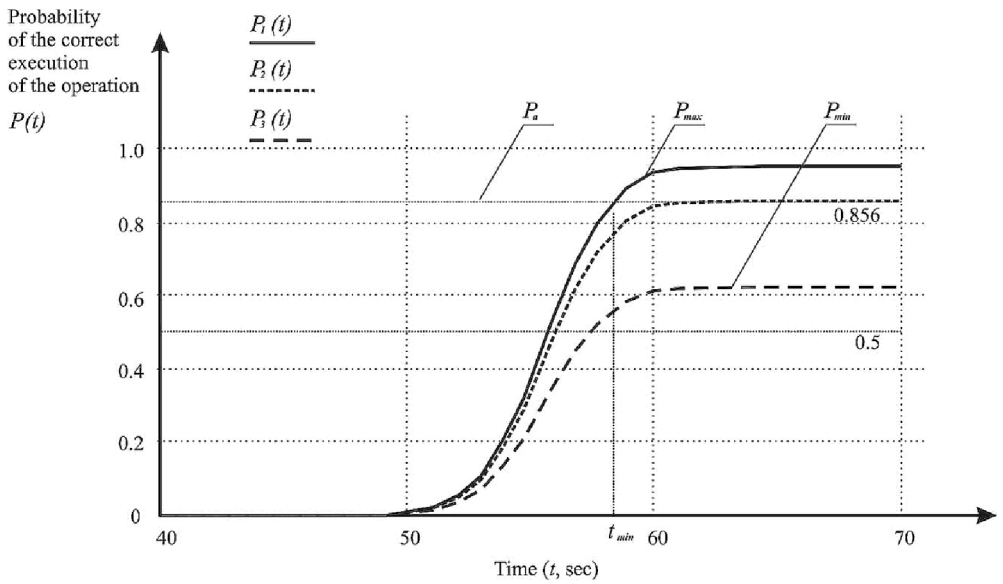

Fig. 4. Execution probability of switching the point from the time of t execution when the psychophysiological condition is changing.

It is not difficult to establish that during this time the train will pass about 1 km at a speed of 60 km / h. However, in case of deterioration of the psychophysiological condition of duty officer, the probability of performing operations on the transfer of the point in the case of false occupation of the track area will decrease to the level of P_{min}, that is, the DSP is not able to perform the task.

The maximum value of the probability of timely execution of the operation for moving the point at the false clear of the track area P_{max} by the duty officer is 0.9. The minimum time t_{min} for performing the operation is about 62 seconds for ideal conditions. In the case with duty officer with insufficient work experience or with a low qualification, the probability of timely completion of the task is reduced to 0.585, which is well below the set level.

6. Conclusion

The proposed functional-semantic network and the logical scheme at the operational-psychological level gave the opportunity to create a model for performing operations by the duty officer at the switching of the point with the false clear of the track area, which in the future could be expanded and complemented by the creation of a model of the functioning of human-machine systems (human- machine systems). We see the dependence between the probability of timely execution of operations and the psychophysiological condition of the duty officer on the station. It is clear that in case of deterioration of the psycho-physiological state, the duty officer is not able to perform an operation of the switching of the point with the false clear of the track area on a set level.

Under ideal conditions, it takes not less than 59 seconds for a decision to be taken and an alert to the next, with a probability set. However, with deterioration of the psycho-physiological condition, it may happen that the station's duty officer will not be able to correctly assess the situation, as a result of which the possibility of violating the safety conditions of trains when moving the point in case of false clear of track area is not excluded. The results obtained can also be used for systems that are not directly responsible for security movement For example, in the part of detecting false records to information systems for controlling the movement of cars, with uncertainty in cases of evaluation of the technical condition of the carriage elements, etc.

References

[1] Stojiljković, E. (2013). The Application of an Event Tree for Human Error Analysis in the Electric Power Company in Serbia. *Facta Universitatis, Series: Working and Living Environmental Protection*, **10** (**2**), 135 – 142.

[2] Stojiljkovic, E., B. Bijelic, and M. Cvetkovic. (2017) Application of HEART technique for human reliability assessment – a Serbian experience. *Facta Universitatis, Series: Working and Living Environmental Protection*, **14** (**3**), 187 – 196.

[3] S. Singh, A. Majumdar, M. Kyriakidis. (2017) Incorporating Human Reliability Analysis to enhance Maintenance Audits: The Case of Rail Bogie Maintenance. *International Journal of Prognostics and Health Management*, **062**, 1-10.

[4] Singh, S., R. Kumar. (2015) Evaluation of Human Error Probability of Disc Brake Unit Assembly and Wheel Set Maintenance of Railway Bogie. *Procedia Manufacturing,* **3**, 3041-3048.

[5] Bekmuratov, T. F. (2008) Poorly structured decision – making in problems of management of risks. *Fifth World Conference on Intelligent Systems for Industrial Automation. WCIS – 2008.* Quadrat Verlag. Tashkent, 96-106.

[6] Moroz, V. P., and I. O. Filenko. (2010). Psykhodiahnostyka intehralnoho zavantazhennia operatyvno-dyspetcherskoho personalu na zaliznychnomu transporti. *Aktualni problemy psykholohii. Vol. 1: Orhanizatsiina psykholohiia. Ekonomichna psykholohiia. Sotsialna psykholohiia*, **25**, 209.

[7] Gubinskiy, A. I., and V. V. Kobzev. (1975). Otsenka nadezhnosti deyatel'nosti cheloveka-operatora v sistemakh upravleniya. *Moscow: Mashinostroenie*, 52.

[8] Asherov, A. T., and V. V. Sabadash. (2008). Sudebno-ergonomicheskaya ekspertiza neschastnykh sluchaev v sisteme «chelovek-tekhnika-sreda». *Kharkiv: UIPA*, 145.

[9] Adamenko, A. N., A. T. Asherov, I. L. Berdnikov, and E. A. Lavrov. (1993). Informatsionno-upravlyayushchie cheloveko-mashinnye sistemy: Issledovanie, proektirovanie, ispytaniya. *Moscow: Mashinostroenie*, 528.

[10] Ohar, O., M. Rozsokha, Yu. Kutsenko, and Smachilo. (2017) Evaluation of the railway traffic safety level using the additive resultant indicator. *Eastern-european journal of enterprise technologies* **6/3** (**90**), 48-57

[11] Panchenko, S., O. Ohar, V. Kuleshov, M. Kutsenko, and A. Kuleshov. (2018) Improvement of the Organizational Technological Model of the Route Made Up of the Groups of Cars of Different Owners *International Journal of Engineering & Technology* **7**(**4.3**), 266-269