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**Dissertation work on the topic "Methods and models
automated assessment of environmental safety during
liquidation of consequences of accidents on railway transport"
for the degree of Doctor of Philosophy (PhD)
on educational program 8D07100 – "Automation and control"
ANNOTATION**

Relevance of the research topic. Analysis of works devoted to the scientific foundations of liquidation (elimination) of the consequences of railways. Emergency situations (ES) with dangerous goods showed that they are a chain of interconnected processes. These processes require a number of activities that are aimed at preventing various threats to people, protecting the environment, preserving cargo, RS, and railway facilities. Infrastructure, etc. in the shortest possible time. At the same time, the rational use of various resources necessary to carry out these activities is also important. [58]

Carrying out measures to localize railway ES and eliminate their consequences involves monitoring the current situation, including the use of automatic (automated) systems for monitoring the state of the environmental conditions at the railway transport ES, choosing effective methods of action taking into account all established safety measures.

The peculiarity of collecting information and assessing the situation at the site of the occurrence of railway ES   is that these processes are carried out in conditions of time shortage, continuous growth of negative impact on the environment and losses from violation of the train schedule, the presence of a threat to people, insufficient information about the condition of the cargo, Substation and railway infrastructure facilities (railway) and the like. [60]

To effectively solve problems related to the development of a rational and timely decision, the head of the operational headquarters (OPH) needs to have a clearly constructed management system, organize the work of the OPH on a scientific basis using modern information technologies, including intelligent decision support systems (IDSS) and mobile automated air quality monitoring systems (MAAQMS).

Making informed management decisions on the localization of railway nuclear power plants with opGr and eliminating their consequences should be carried out with the help of DSS, for the creation of which the proposed mathematical models for forecasting the development of such railway nuclear power plants and structural and logical diagrams of actions of the heads of the operational headquarters should be used. This circumstance determined the choice of the research topic.

The purpose of the study is the development of models, methods and information technologies for an automated system for monitoring air quality during the elimination of the consequences of railway emergencies during the transportation of DG as sources of environmentally harmful impacts on the environment.

Research objectives:

1) Carry out a review and analysis of previous studies on the issues of managing the elimination of emergencies on the railway, related to environmental safety during the transportation of DG;

2) formalize the railway transportation system of the DG in the form of an oriented graph of states of the safe operation of the railway transport system, taking into account the possibility of the occurrence of railway ES, its assessment, localization and elimination of its consequences;

3) obtain new and supplement existing models for substantiation and software modeling of various schemes for organizing emergency recovery work by structural units of the functional subsystem of the railway;

4) to design and implement a mobile automated system for monitoring air quality at railway infrastructure facilities (MAAQMS), which integrates developed models and new IT.

The object of the study is the processes of using a mobile automated air quality monitoring system when eliminating the consequences of railway emergencies during the transportation of dangerous goods as sources of environmentally harmful impacts on the environment.

Research methods - the work uses an integrated systematic approach, including analysis and generalization of domestic and world experience, as well as our own research on issues related to the development of scientific methods of environmental safety management when eliminating the consequences of emergency situations on the railway;

Based on the methods of operations research and mathematical modeling, a mathematical model of the functioning of the railway transportation system in the event of emergencies during the transportation of DG, structural-analytical models for determining the values of emergency situations during the transportation of dangerous goods that are dangerous for environmental protection and human life, and an easily algorithmized structural logical scheme of actions have been developed operational headquarters for emergency response;

Based on the methods of the QS theory, a formal description of the functioning of the system "environment - emergency facility - liquidation units" was carried out. Object-oriented programming methods were used in the software implementation of a formal description of the actions of emergency units as processes of functioning of a queuing system without time restrictions on the ADO.net technology platform.

The subject of the research is methods, models and information technologies for managing environmental safety during liquidation of the consequences of emergency situations on railway railways with dangerous goods.

Theoretical and methodological foundations of the study. In the process of performing the dissertation work, an integrated systematic approach was taken as the basis. This made it possible to use classical methods of analysis and generalize domestic and world experience in the field of research devoted to the development of scientific methods for managing environmental safety when eliminating the consequences of emergency situations on the railway. In addition, based on classical methods of operations research and mathematical modeling, a mathematical model of the functioning of the railway transportation system in the event of emergencies during the transportation of DG was developed.

In addition, these methods of operations research made it possible to develop structural-analytical models for determining the values of emergency factors during the transportation of dangerous goods that are dangerous for the environment and human life. These schemes are easily algorithmized based on the object-oriented

programming paradigm. Based on the methods of the EC theory, a formal description of the functioning of the system "environment – emergency facility – liquidation units of railway transport" was completed.

Object-oriented programming methods were used in the software implementation of a formal description of the actions of emergency units as processes of QS functioning without time restrictions on the ADO.net technology platform.

The results obtained in the work are based on well-known proven engineering calculation methods. During the research, standard methods of data processing using a computer were used. Also for computer modeling, software was used for the simulation of complex systems and processes on railway lines. The convergence of experimental data obtained during computational experiments and the results of theoretical calculations is confirmed by the corresponding implementation acts, which are presented in the appendices to the dissertation.

Scientific novelty:

for the first time, the railway transportation system of the OpGr was formalized in the form of an oriented state graph of the safe operation of the railway transport system, taking into account the possibility of an emergency situation, its assessment, localization and elimination of its consequences;

Mathematical models have been developed, which have been brought to the level of practical calculations of the probabilities of railway vehicles being in a state of safe operation during the transportation of DG, depending on certain technological and organizational measures to support the system in a state of reliability, which, unlike existing ones, provide a synergistic effect in the form of a significant reduction not only the time of liquidation work, but also a more than proportional reduction in the negative consequences of these situations on the environment;

Mathematical models based on TMF methods and adapted versions of these methods have been improved, which, unlike existing ones, make it possible to justify various schemes for organizing emergency recovery work by structural units of the functional subsystem of railway transport.

Practical value.

A system for monitoring air quality at railway infrastructure facilities was designed and implemented. The system (or MAAQMS) consists of two main parts: a single data processing server and information collection devices. The transmitter is based on the ATmega328 microcontroller. For MAAQMS component devices whose operation depends on WiFi, a transmitter based on the ESP8266 microcontroller is used, which ensures stable communication according to the 802.11n standard.

This standard is the main protocol for transmitting data between environmental data collection devices and the MQTT server. In the implemented MAAQMS, the data processing server receives information via the MQTT protocol from all devices about the state of each sensor and the location of the device at the site of the railway accident, accompanied by environmental pollution. All data is recorded at a certain frequency into a database on the server in the appropriate format with timestamps. To access stored data, a WEB interface is used, which allows you to administer MAAQMS from all devices that have a web browser.

The railways of Ukraine and Kazakhstan for stability and speed of operation have successfully tested the monitoring system (MAAQMS). The operation of the

MAAQMS web application has been tested on different virtualization systems and with different amounts of provided computing resources.

A software implementation of a formal description of the actions of emergency units as processes of functioning of a queuing system without time restrictions on the ADO.net technology platform was tested and implemented.

In addition, the results obtained during the dissertation research are used in the educational process in the preparation of master's and doctoral students on the educational program "Automation and Control" at the International University of Transport and Humanities (IUTH).

The actual implementation and application of the results obtained during the dissertation research is confirmed by the relevant implementation acts. Scanned copies of these acts of implementation are given in the appendices to the dissertation.

Research results. The scientific and technical level of development of a mobile automated air quality monitoring system (MAAQMS) corresponds to the best world standards.

Approbation of the dissertation results.The main results and provisions of the dissertation, as well as conclusions drawn during the research, were reported and discussed at scientific seminars in the following organizations: Department of Automation and Electric Power Engineering in Transport, IUTH; departments of "Computer systems, networks and cybersecurity" and "Computer Science" of the National University of Life and Environmental Sciences of Ukraine (online, Kiev, Ukraine) and at international scientific and practical conferences (RK, Ukraine, Russia).

Publications. All results presented in the dissertation were previously published in 15 scientific papers. Including 3 articles published in journals recommended by CQAES of the MES RK; 7 publications in materials of international conferences, 3 article in journals included in the Scopus database and 2 articles in scientific journals.

Structure and scope of the dissertation. The dissertation consists of an introduction, four sections, and a conclusion, presented on 141 pages and contains 63 figures, 3 tables, 92 sources used and 3 appendices.

The Introduction substantiates the choice of research topic, its relevance, and scientific novelty, theoretical and practical significance of the work.

The first chapter reviewed previous research on environmental safety-related emergency response management for hazardous cargo transportation. An analysis of methods and models for automated assessment of environmental safety during liquidation of the consequences of accidents on railway lines was carried out.

Ground transport in industrialized regions of the world has become the basis for the development of other sectors of the economy. At the same time, the environmental load on the environment from transport also remains significant. An analysis of the environmental component of the triad of the system "transport – nature (Nature) – man" showed that the aggravation of environmental problems in transport and the increase in its negative impact on the RT were the result of insufficient attention to the environmental component of this triad. However, this problem today has begun to influence the environmental situation in the world because of the rapid pace of development of transport, primarily automobile and air, and the peculiarities of the interaction of transport systems with the environment.

Further, in this chapter, an analysis of statistics on transport accidents on railways in the countries of the European Union (EU) is carried out, as well as an analysis of the literature on the general problems of eliminating the consequences of accidents during the transportation of basic environmentally friendly goods, issues of improving preventive measures during the transportation of goods.

In many foreign countries, much attention is currently paid to the problem of intellectualization of transport processes, including increasing the level of transportation safety, improving the environmental situation, reducing the negative impact of the human factor on the quality of management, and the like.

Another area of scientific research devoted to scientific and methodological approaches to creating intelligent transport systems, taking into account the peculiarities of the functioning of railway transport, is the use of expert systems (ES) and decision support systems (DSS), the use of information technologies, the latest communication and monitoring systems. Condition of infrastructure facilities and rolling stock.

The second chapter examined the theory of systems and methods of decision-making, system analysis, mathematical modeling of environmental processes of response to railway nuclear power plants, regulatory documents on the definition of safety measures and the procedure for their elimination from the DG.

Elimination (elimination) of the consequences of the railway. emergency situations (hereinafter referred to as railway ES) with DG are a chain of interconnected processes that require a number of measures aimed at preventing various threats to people, protecting the environment, preserving cargo, substations, railway facilities. Infrastructure, restoration of train traffic, resumption of shunting work, etc. in the shortest possible time.

At the same time, the rational use of various resources necessary to carry out these activities is also important. Therefore, the balanced period for restoring train traffic (operability of the transport system) and the resources necessary for this are criteria for the effectiveness of the system for eliminating the consequences of railway stations during the transportation of opportunistic gas.

It should be noted that the current regulatory documents only provide for the procedure for notifying about the occurrence of railway AS. However, the procedure for responding to such situations is not defined. This situation can be explained by the fact that such situations are very diverse in both nature, scale, and methods of response.

Carrying out measures to localize railway nuclear power plants and eliminate their consequences involves monitoring the current situation, choosing effective methods of action, taking into account all established safety measures.

The staffing of the units with personnel and equipment also influences the success of the events.

Let us consider the proposed scheme for managing the elimination of the consequences of an emergency, accompanied by a threat to the environment (Fig. 1), which can be considered universal in the sense that it takes into account the preliminary typification of railway ES and methods of responding to them.
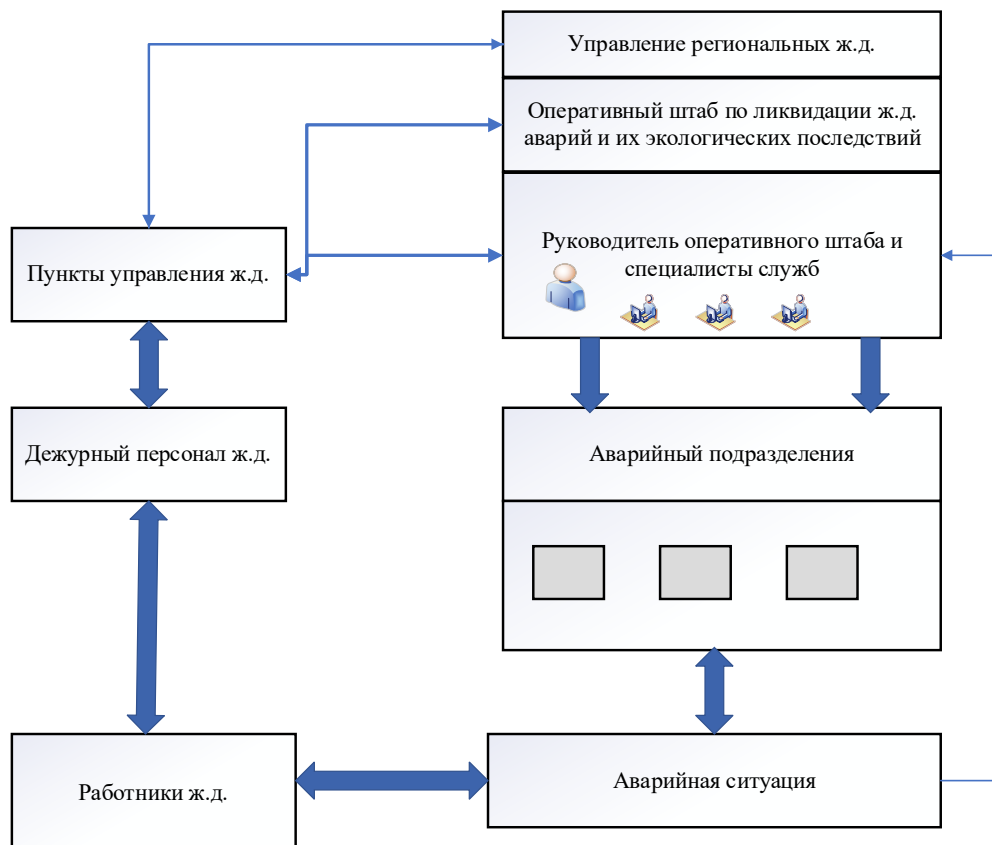
Figure 1 – Scheme for managing the elimination of the consequences of an emergency situation with DG, accompanied by a threat to environment

It has been established that when a railway accident occurs, the head of the operational headquarters in difficult conditions of the absence of complete and sufficient information about the cause-and-effect relationships between the components of such a situation needs to make a certain number of individual, collegial, informational, organizational, operational decisions aimed at harmonizing, coordinating and managing subordinates control points and liquidation units, which may exceed its ability to make such decisions and/or affect their validity.

Making informed management decisions on the localization of railway stations with opGr and eliminating their consequences should be carried out with the help of DSS, for the creation of which the proposed mathematical models for predicting the development of such situations and structural and logical diagrams of actions of the heads of the operational headquarters should be used.

In the third chapter of the dissertation, the possibility of using methods from the theory of queuing systems to formally describe the processes of functioning of the system "environment - emergency facility - liquidation units" is substantiated.

The study of railway (railway) emergency situations (ES) with dangerous goods (DG) [1-3] indicates that their development is complex, the end result of which can be: the occurrence of severe consequences associated with explosions, fires, death or injury to people, destruction of rolling stock (RS) and railway facilities. Transport (railway), environmental pollution (environment), and etc.In order to scientifically substantiate the effective management of the processes of restoring the safe state of operation of the "Environment - emergency facility - liquidation units system, it is necessary to highlight possible scenarios for their development:

Slow accumulation of negative factors of the railway AS, but not to the level of their critical values. This does not lead to explosions or fires, etc;

Slow accumulation of negative factors of railway transport, their going beyond critical values, followed by an explosion or fire, etc.

Rapid accumulation of negative factors of railway ES with their going beyond critical limits. Which leads to a fire or explosion, etc.

Such railway ES, as a rule, are characterized by incomplete information about the development of their hazardous factors, a detrimental effect on people, environment, infrastructure facilities and railway substations, and a rapid increase in environmental, material, economic and other losses over time.

To take measures to localize such railway ES and eliminate their consequences, it is necessary to involve a certain number of liquidation divisions of the Railways, diverse in purpose, and other ministries and departments.

Moreover, in the process of organizing liquidation work, it is necessary to provide certain criteria for their effectiveness (situational criteria), which can only be achieved based on scientifically based prediction of the success of completing these works on time and with available resources.

The development of the railway ES determines the difficult conditions for the process of analyzing the situation and developing decisions to respond to it by the head of the operational headquarters, which, in particular, are characterized by a lack of time associated with the need to quickly restore train traffic, as well as the reception and understanding by him of a large amount of various information about emergencies.

Therefore, an effective solution to the problems of localizing railway stations and eliminating their consequences requires the use of modern IT, including DSS [3].

In the course of the research, the possibility of using methods from the theory of queuing systems to formally describe the processes of functioning of the system "environment - emergency facility - liquidation units" was substantiated. The following results were obtained:

The possibility of using classical methods of queuing theory and adapted versions of these methods for justifying and modeling various schemes for organizing emergency recovery work by structural units of the functional subsystem of railway transport, forming network systems (connections) of such units, providing them with the necessary resources, forecasting and evaluating efficiency is shown. Actions of such units.

It has been proven that a significant reduction in the negative impact of railway nuclear power plants on the environment is possible by reducing the period of liquidation work, as well as by reducing the time of concentration of units and the use of forces and means of the required productivity. In addition, an increase in concentration time requires a significant increase in the productivity of such forces and means.

The fourth chapter of the dissertation describes the designed mobile automated air quality monitoring system (MAAQMS), which can be used in places of emergency or synthetic accidents on the railway. The results of computer modeling show that a significant reduction in the negative impact of railway nuclear power plants on the environment is possible by reducing the period of liquidation work, as

well as by reducing the time of concentration of units and the use of forces and means of the required productivity.

The mobile automated air quality monitoring system (MAAQMS) at railway transport (RT) infrastructure facilities consists of two main parts: a single data processing server and information collection devices. The transmitter is based on the ATmega328 microcontroller. For MAAQMS component devices whose operation depends on Wi-Fi, a transmitter based on the ESP8266 microcontroller is used, which ensures stable communication according to the 802.11n standard.

This standard is the main protocol for transmitting data between environmental data collection devices and the MQTT server. In the implemented MAAQMS, the data processing server receives information via the MQTT protocol from all devices about the state of each sensor and the location of the device at the site of the railway accident, accompanied by environmental pollution. All data is recorded at a certain frequency into a database on the server in the appropriate format with timestamps. To access stored data, a WEB interface is used, which allows you to administer MAAQMS from all devices that have a web browser.

A software implementation of a formal description of the actions of emergency units as processes of functioning of a queuing system without time restrictions on the ADO.net technology platform was completed. Quantitative relationships have been established between the intensity of exposure to hazardous factors of railway stations, the time of arrival, deployment and performance of liquidation units and the efficiency of liquidation work related to minimizing damage to the environment from dangerous goods transported by railways.

The results of computer modeling using the developed application show that a significant reduction in the negative impact of railway nuclear power plants on the environment is possible by reducing the period of liquidation work, as well as by reducing the time of concentration of units and the use of forces and means of the required productivity. In addition, an increase in concentration time requires a significant increase in the productivity of such forces and means.

During simulation computer experiments, it was established that if the means of eliminating the consequences of a railway nuclear power plant do not correspond to its nature and/or are extremely unproductive, then even if they are timely concentrated at the liquidation site, they would not be effective. Alternatively, even if the means of elimination are quite effective, but their concentration at the place where this situation occurred happened too late, then they will also not have an effect.

The Conclusion provides a brief description of the essence of the dissertation research, the main findings and conclusions on the dissertation.

9 articles and 6 theses were published on the topic of the dissertation:

1. Shalabaeva M. Kh., Abuova A. Environmental problems in railway transport. Bulletin of KazNRTU named after K.I. Satpayev. Vol. 143 No. 5 (2021). – pp. 115-122.

2. Shalabaeva M. Kh. Analysis of methods and models for automated assessment of environmental safety during liquidation of the consequences of accidents on railway transport. //Problems of computer science in education, management, economics and technology: collection of articles of the XX MNTK. Penza: Privolzhsky House of Knowledge, 2020, p. 226-231

3. Akhmetov B. S., Shalabaeva M. Kh. Mathematical support for responding to railway emergency situations. Bulletin of ENU named after. L.N. Gumilyov. Series Technical Sciences and Technologies. Nur Sultan, 2021. No. 1 (134). With. 80-90.

4. Akhmetov B. S., Shalabaeva M. Kh. Management of response to railway emergency situations during the transportation of dangerous goods and assessment of environmental safety during liquidation of consequences. MNPK "30 years of independence of the Republic of Kazakhstan: Successes of independence" (KAU). Almaty, 2021, p.60-62

5. Shalabaeva M. Kh. Features of response to railway emergency situations accompanied by environmental damage. XXI MNTK "Problems of computer science in education, management, economics and technology." Penza, 2021, p. 239-242

6. Shalabaeva M. Kh., Abuova A. Model of processes for restoring the safe state of the "environment-emergency facility" system. Bulletin of Pavlodar State University named after. S. Toraigyrova. Science and technology of Kazakhstan. – No. 2 (2021). – P.173-182. ISSN 2788-8770

7. Akhmetov B., Lakhno V., Blozva A., Shalabayeva M., Abuova A. Skladannyi P., Sagyndykova Sh. Development of a mobile automated air quality monitoring system for use in places of technogenic accidents on railway transport. Journal of Theoretical and Applied Information Technology. 15th March 2022. Vol. 100, No. 05-2022. P.1287-1300

8. Akhmetov B.S., Lakhno V.A., Shalabaeva M.Kh., Alimseitova Zh.K., Abuova A.K. Sapany monitoring leudin mobile automattandyrylgan zhuyesin zhasau. Bulletin of KazATK named after M. Tynyshpayev No. 4 (123), 2022. p.235-244

9. Akhmetov B.S., Lakhno V.A., Blozva A.I., Shalabaeva M.Kh., Abuova A.K. Mobile automated air quality monitoring system. XIII All-Ukrainian NOC "State and improvement of security of information and telecommunication systems." Koblevo, 2021, p.49-50

10. Shalabaeva M.Kh. Development and implementation of a mobile automated air quality monitoring system (MAMSKV) for use in places of man-made accidents in railway transport. MNPK "Modern information and communication technologies in transport, industry and education." Dnepr, 2021, p. 41

11. Mazin Al Hadidi, Shalabayeva M. Automated system for monitoring air quality in railway accident sites. MNPK "Modern information and communication technologies in transport, industry and education." Dnepr, 2022, p. 54

12. Blozva A., Kydyralina L.M., Matus Y.V. Osypova T.Y. Sauanova K. , Brzhanov R.T., Shalabayeva M. Iot devices integration and protection in available infrastructure of a university computer network. Journal of Theoretical and Applied Information Technology. 2021. Vol. 99, № 8. P.1820-1833

13. Valerii Lakhno, Maira Shalabayeva, Olena Kryvoruchko, Alona Desiatko, Vitalyi Chubaievskyi, Zhibek Alibiyeva. Hardware-Software Complex for Predicting the Development of an Ecologically Hazardous Emergency Situation on the Railway. Journal of Electronics and Telecommunications. 2023, VOL. 69, NO. 4, PP. 707-712. DOI: 10.24425/ijet.2023.147691

14. Ахметов Б. С., Лахно В.А., Шалабаева М. Х. Темір жолдағы апатты жағдайларға ден қою үшін компьютерлік қолдау көрсету. «Вестник КазАТК» № 2 (131), 2024. с.385-392 (ISSN 1609-1817, ISSN Online 2790-5802, DOI 10.52167/1609-1817)

15. Абуова А. К., Шалабаева М. Х. Модель процессов восстановления безопасного состояния системы «окружающая среда-аварийный объект». СБОРНИК ТРУДОВ Международной научно-практической конференции «Транспортный потенциал Казахстана: истоки и перспективы», посвященной 80-летию государственного деятеля Н.К.Исингарина. Алматы: Академия логистики и транспорта, 2021, с.180-183