Gapanovich V.A., Shubinsky I.B., Zamyshlyaev A.M.

MATHEMATICAL AND INFORMATION SUUPORT OF THE URRAN SYSTEM

The mathematical support of the URRAN information system comprises three interrelated parts wherein the first part is the support system for decision making as to reliability and functional safety management, the second part is the support system for decision making as to resources management, and the third part is the support system for decision making as to transport accidents. The information technology represents a system of collecting, analyzing, processing and investigating events and supporting decision making. It is based on a data warehouse and includes specialized automated applied information systems developed under the guidance and with the direct participation of the authors. These are the system of recording and managing the elimination of technical failures (KASANT), the system of traffic safety controllers (AS RB), the system of traffic safety situational analysis and decision-making support (IKSAR SC), AS URRAN and the corporate automated system of RZD's staff knowledge control (KASKOR). The URRAN information system has demonstrated the efficiency of its practical application.

Keywords: *reliability, functional safety, resources management, life cycle cost, information technology, railway transport, risks matrix, data warehouse.*

Introduction

The URRAN system is an information technology of reliability, resources and functional safety on railway transport. The system is based on an integrated application of the modified RAMS (reliability, availability, maintainability, safety) and LCC (life cycle cost) methodology, advanced information technology of decision-making support, distributed information systems of collecting and analyzing real-time data, and state-of-the-art regulation framework [1,2]. The URRAN provides a practical management of resources, risks, reliability and functional safety on the network of Russian Railways. For the first time, under the conditions of limited financial investments, this system enables to extend a specified life time of railway transport facilities till limit tolerance state based on estimating risks and to redistribute investments for improving the reliability and safety of the most vulnerable railway transport facilities [3].

Structure of mathematical support of the URRAN system

The mathematical support of the URRAN information system comprises three interrelated parts. Figure 1 shows a generalized structure of mathematical support of the system. It includes two com-

mon components, i.e. the information technology implemented with the KASANT system and the data warehouse regularly updated which contains risks matrixes for facilities of all railway transport enterprises, including track, signalling and remote control, electrification and power supply enterprises. The KASANT system accumulates information about failures of all infrastructure technical means, provides investigations about failures and groups them into three categories according to the criterion of train delay length. The third category failures do not influence economical risks in transportation process. Risks matrixes are updated twice in a month at the technical departments of infrastructure enterprises.

Information about infrastructure facilities failures and risks come into all the three of decision-making support systems that are a nucleus of the URRAN information system and presented in Fig. 1 as Part 1, Part 2 and Part 3 respectively.

● Part 1 is a system of support for decision making about reliability and functional safety management. It comprises (Fig. 2):

– Module of primary calculation and evaluation of reliability of railway transport infrastructure facilities. It is integral part of AC URRAN and perform calculations of failure-free operation, maintainability, availability, durability and safety parameters as well as life cycle costs of reference facilities of railway enterprises (track, signalling and remote control, electrification and power supply, telecommunication and information enterprises). All reference facilities are simple devices with specified factors required to calculate their reliability.

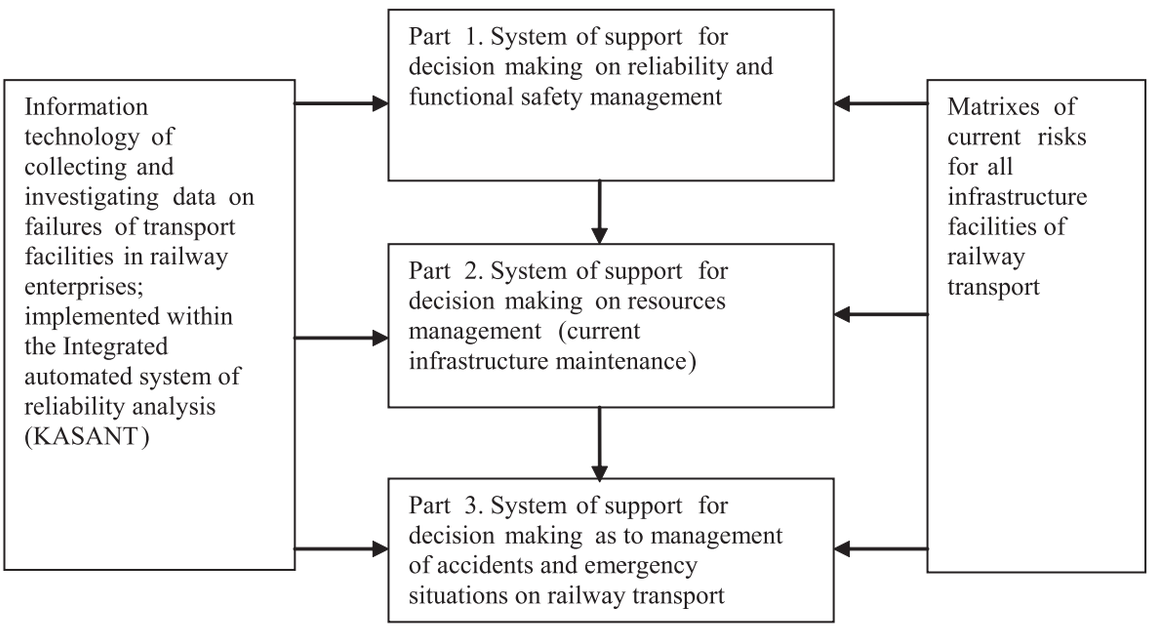

Fig. 1. Generalized structure of mathematical support of the URRAN system

– Module of calculation and prediction of reliability and functional safety parameters of complex systems. This module is designed to calculate redundant systems of signalling and remote control, power supply and AC URRAN information and management systems. It is based on a developed topological semi-Markov method and allows to calculate both a system's stationary and non-stationary reliability and functional safety metrics. The theoretical basis of the method is presented in works [4,5].

– Module of support for decision making as to management of reliability and functional safety on railway transport, with traffic intensity and speed, train delay length due to failure of equipment,

railway administration risks and, naturally, failure rates and recovery lengths taken into account [6]. The module is implemented in AC URRAN. It is worth mentioning that recommendations as to making a corresponding decision take into account results of risks estimations for each of infrastructure enterprises that are realized in compliance with the schematics developed and concentrated in the module of risks calculation and evaluation. The theoretical basis for construction of the module of risks calculation and evaluation including the schematics of risks management is presented in [7].

● Part 2 is a system of support for decision making as to resources management. It comprises:

– Module of optimization of facilities technical maintenance and repair as to their actual state. Theoretical provisions of the module are presented in the patent *Method of defining the time of scheduled preventive maintenance of a facility and system for its implementation* [8].

– Practical schematic of support for decision making as to facility technical maintenance is implemented in AC URRAN.

– Module of support for decision making as to life cycle cost management. According to this module, the assignment of works in AC URRAN is based on comparison of actual and reference values of a set of assigned parameters such as missed tonnage, million tons, failure rate per 1 km of track, direct expenditures on current maintenance of 1 km of track. The theoretical basis of the method is presented in [3].

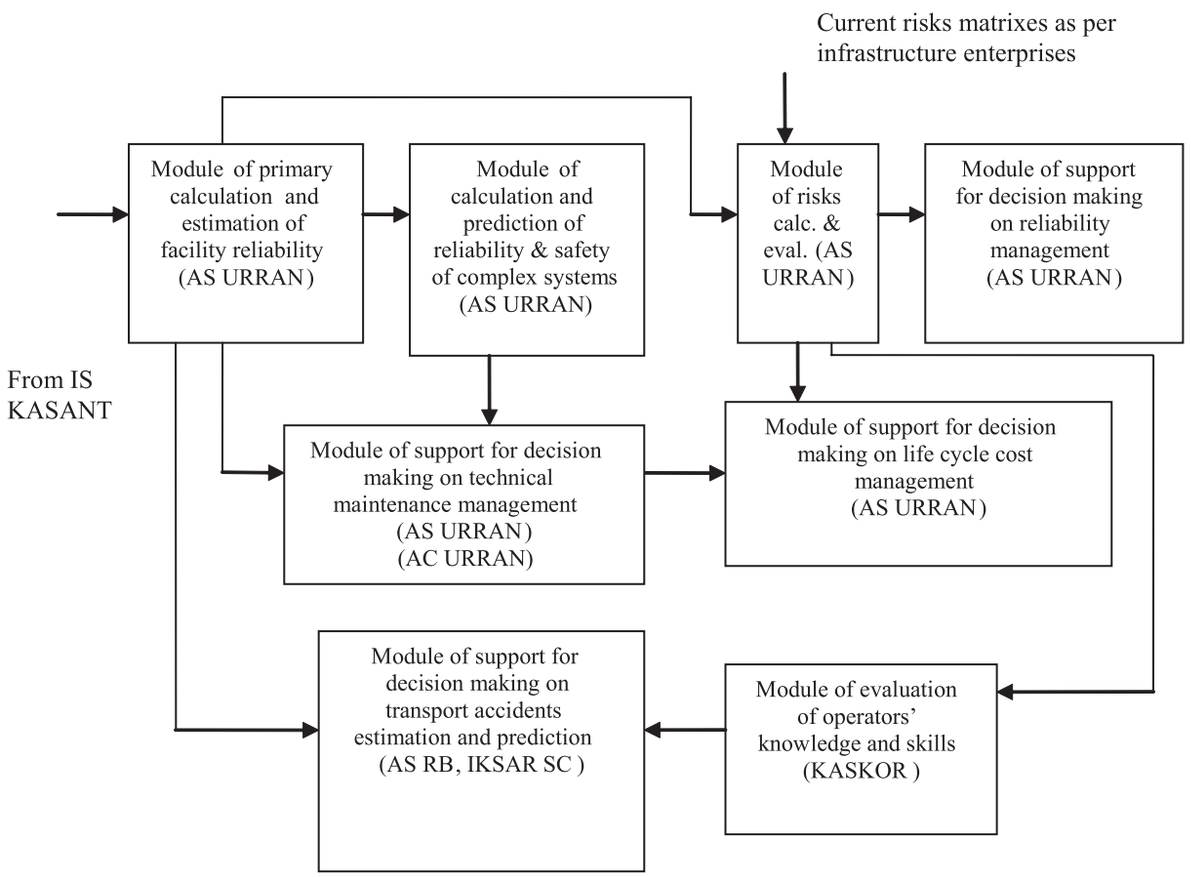

Fig. 2. Structure of mathematical support for the system of reliability, resources management, transport accidents prediction and emergency situations management on railway transport

● Part 3 is a system of support for decision making as to transport accidents. It comprises a system of transport accidents prediction and a system of support of decision making in case of occurrence of emergency situation on railway transport (fire, acts of God, large transport accidents, vandalism, and terrorism).

The former system is implemented as a module of decision-making support within the AS RB information and management system. The latter is implemented in RZD's situational centre. The URRAN system implements a statistical method of transport accidents and events prediction based on a posterior data processing by methods of nonparametric statistics. The data are materials (hereinafter referred to as protocols) of investigations prepared by RZD's Safety and Security Department. There are procedures of estimating these probabilities and an algorithm of decision-making support developed. The theoretical basis of the method is presented in [9].

The mathematical support under consideration also includes a module of distance evaluation of operators' knowledge and skills which permits to evaluate in a complex way a knowledge level of enterprises staff in general with the possibility of differentiating down to a division or an individual and his/her knowledge of particular provisions of regulatory documents.

Architecture of the URRAN information technology

The information technology of integrated management of reliability, resources and functional safety on railway transport is a system of data collection, analysis, processing and investigation of events and decision-making support, which aims to help decision-makers in difficult conditions to have the comprehensive and objective analysis of the subject.

The core of the URRAN information technology, without which it cannot function, is the repository of data (Fig. 3). The information in the company is often distributed over various information systems unrelated to each other. The goal of the data warehouse is to collect these data, structure and convert them, i.e. in fact to make them applicable for analysis and useful for decision making. The main advantage of the repository is that it collects information on all processes that take place in the company, not just the individual areas of its operations.

Based on the information that is kept in the data warehouse, the URRAN information system arranges the work of its other three systems, namely:

• System of risk analysis and assessment in RZD's operations based on operational reliability and safety parameters;

• Systems of managing the economical processes of infrastructure and rolling stock maintenance and development to ensure acceptable levels of safety and reliability, with tolerable residual risks taken into account;

• System of traffic safety situational analysis and decision-making support.

All the three systems mentioned above allow us to form corporate models and metrics of key reliability, life cycle cost, and safety parameters, and to manage them. With their help, the strategic goals of the company are specified, translated into a set of quantitative indicators and linked to the objectives and actions of enterprises. Systems help to monitor the activities of the company and to model possible scenarios in the short and long terms.

Identifying and tracking the parameters of reliability and safety, we can get an answer to the question how well the company is heading to set goals. Generally, there are three levels of reliability and safety singled out:

• Target indicators are of strategic nature, these are the goals to be achieved in the company for 3-5 years;

• Planned indicators are defined for 1 year ahead as a result of the preparation of the annual budget;

• Actual figures are calculated upon results of the actual performance of the company.

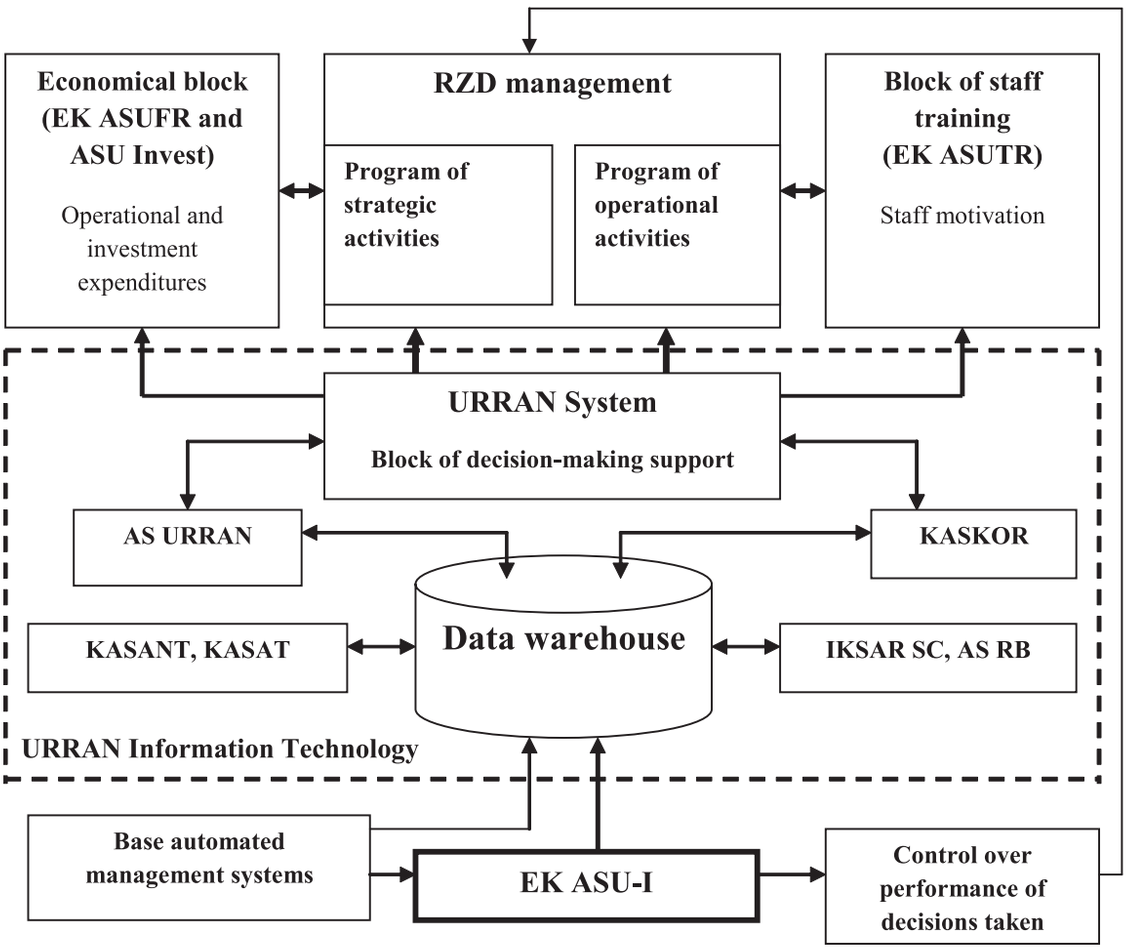

Fig. 3. Architecture of the URRAN information system

As a result, we have a kind of coordinate system that we can use to evaluate all decisions and actions in the context of achieving the company's goals.

The system of risk analysis and assessment in RZD's operations based on operational reliability and safety parameters is one of the major components of the URRAN information technology. The system allows us to analyze collected data (such types of analysis as "what-if" analysis, risk analysis, target function analysis, sensitivity analysis, correlation and regression analysis and optimization analysis are supported) and to apply mathematical algorithms to them. This helps not only to answer the question of "how things are now in the company?" but also to understand why the situation is so, and then to develop a program of corrective actions.

With the help of the subsystem of support for decision-making as to integrated management of reliability, risks, life cycle cost on railway transport, resource support for the company's activities is formed. While preparing a budget, strategic goals and objectives are linked with the amount of funds that the company has or that will be available soon. When planning, the subsystem allows to see the data of previous years, to identify trends and patterns and to use them for preparation of a budget – it will help make it more reasonable and accurate. Another possibility is the application of "what if" modelling method by means of which we can have several variants of the plan (for example, "optimistic", "realistic", "pessimistic"), analyze and compare them, and then at each particular period choose the most relevant version. In addition, the subsystem is used to continuously monitor the implementation of plans and budgets, and how the

specified values of the indicators are achieved. The subsystem presents a possibility to set an automatic generation of required reports by a scheduled time and their distribution among specified people. This is particularly important in terms of sticking to budget limits and preventing from certain performance targets to be out of the established boundaries. If the subsystem sees that such situation develops, it automatically sends appropriate alert messages to responsible managers and generates a set of documents and reports that will help to understand the causes of deviations and to take proactive measures. It is possible to create different groups of recipients to receive these alerts, depending on the severity of a problem. For example, if a deviation from the plan is insignificant, then information will be sent only to the financial department, if the allowed limit is exceeded several times, the data are sent to the entire top management of the company.

The system of traffic safety situational analysis and decision-making support is used to find hidden patterns, trends, and to crate predictions (based on the found relations). This component allows seeing the unfavorable trends in traffic safety which are not visible and not obvious at first glance. After their detecting and analyzing, there arises an opportunity to develop a program of actions (measures) that will help promptly correct the situation.

The main advantage of the system is the advanced options for data visualization. All information is displayed on computer screen in a very illustrative and user-friendly form (graphics and charts, color display technology, “speedometers”, “signals”, etc. are used for this purpose). The system allows to build “situation rooms” and the control panels; with their help a manager not only sees the aggregated information related to all areas of the company’s operations, but can also itemize it to the required level (up to original documents) in order to fully understand the situation and make decisions to correct it. Using the data warehouse as a basis for the system’s operation allows to make “top – down” analysis – to instantly switch from a poor value in the management accounts to the analysis of a problem (with the help of analytical reporting), from problematic issues in a report to specific documents that may explain their appearance.

The KASANT and KASAT automated applied information systems implement processes of recording and control of equipment failures elimination, and occurrence and elimination of technological violations and transport accidents respectively. They are based on a set of technologies existing on RZD’s railway transport that address info-communications, technical and technological problems using the latest computer tools.

The purpose of development of *the automated traffic safety controllers (AS RB)* is to improve the efficiency of the work and role of controllers at all levels to ensure traffic safety in accordance with their assigned set of tasks, as well as to develop solutions coordinated for the whole railway transport industry and aimed at improving traffic safety through the use of information technology.

The system of traffic safety situational analysis and decision-making support (IKSAR SC) is functionally divided into four segments: traffic safety, transport security, fire safety, prediction and control of weather conditions, and also has two operating modes: regular mode and emergency response mode.

The AS URRAN automated information system is designed to solve the following problems:

• Automation of initial processing of statistical data on failures of technical equipment of railway transport infrastructure facilities and rolling stock;

• Automated identification of operational reliability and safety parameters of infrastructure facilities;

• Quantification of production activities of infrastructure and rolling stock enterprises, with failures and organization of maintenance and operation of infrastructure facilities taken into account;

• Motivation of activities of structural units within enterprises based on operational reliability and safety parameters;
• Assessment of compliance of achieved reliability and safety indicators with specified standards;
• Preparation of design data to develop recommendations to reduce risks;
• Identification of vulnerable facilities in terms of risk assessment;
• Preparation of draft work plans as to technical maintenance of infrastructure and rolling stock;
• Drafting of investment allocation for most vulnerable railway transport facilities.

The AS URRAN comprises the following subsystems:
• Subsystem of receiving information on infrastructure facilities from automated management systems of enterprises;
• Subsystem of receiving information about equipment failures from the KASANT system;
• Subsystem of forming a reference object-element structure of infrastructure facilities;
• Subsystem of automated calculation of operational reliability and safety parameters of infrastructure facilities;
• Subsystem of generating output forms and references.

The KASKOR corporate automated system for monitoring RZD's staff knowledge is designed to automate the testing of knowledge and training of employees of JSC Russian Railways. Subject to inspection is a circle of staff's knowledge as well as their abilities and skills in safe performance of operations. The KASKOR system is part of the distance training system (SDO) for the employees of JSC Russian Railways. The purpose of establishing the KASKOR system is to improve the level of safety and economic efficiency of RZD's operations based on improving the quality of professional knowledge and skills of workers.

As it was already noted, one of the key goals of the URRAN system is a task related to support of decision making on management of resources necessary for operational maintenance of railway transport facilities as well as support of decision making as to investments in infrastructure and rolling stock. To this end, the URRAN information technology is foreseen to interface with the existing automated management systems of the Company's economical block, such as EK ASUFR (common corporate automated system of finances and resource) and ASU Invest (Fig. 3). Recommendations generated by the URRAN system are submitted to the management of the Company to plan available resources strategically and operationally. Depending on current economical indices, on the one hand, and demand in attracting resources to reduce risks related to infringement of transportation safety, on the other hand, the management of the Company promptly correct operational programs in compliance with recommendations provided by the URRAN system, and/or volumes of investment or modernization of facilities are increased (perhaps redistributed) in case of strategically planning. Practical results obtained and efficiency of resources management are controlled by the Company's management using EK ASU-I (common corporate automated system of infrastructure) which keeps and promptly updates the whole range of information related to current availability state of all infrastructure enterprises, and all activities and related expenditures on operational maintenance of infrastructure. Depending on previous and ongoing investments, an availability level of railway transport facilities shall change. By supervising trends in changes of an availability level, the management of the Company are able to evaluate the efficiency of decisions taken.

The URRAN system also interacts with RZD's base automated management systems which provide the system with online information about traffic flows, operations as well as information about existing and updated reference documents and standards. Recommendations generated by the system are used in EK ASUTR (common corporate automated system of HR management) to motivate individual employees as well as departments and enterprises.

Conclusion

Application of the URRAN information technology allows [10]:

• To substantially increase operational efficiency and objectivity of data on failures and technological violations. Thus, owing to the technology it has been identified that the annual number of recorded failures on the network of Russia is 4 times more than declared. At the same time it has been found that a share of technical equipment failures in train delays does not exceed 10 per cent. The main cause is technological violations.

• To manage technical maintenance of railway transport facilities based on current states of their reliability and safety.

• In case of financing deficits, to provide maintenance of the most vulnerable segments and to ensure the reliable operation of infrastructure and traffic safety. Thus, according to the data of trial operation on the Northern Railway, it has been identified using the URRAN technology that there is a possibility of decreasing by 200 km (approximately 25 per cent) the volume of repairing of 1 and 2 class main tracks while decreasing almost by 2 times the residual mean failure rate of track infrastructure after repairing.

• To evaluate risks of occurrence of hazardous events on railway transport in real-time mode and to predict possibilities of occurrence of transport accidents.

• To predict possibilities of occurrence of transport accidents on railway lines identified as vulnerable.

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