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SYSTEM OF ADAPTIVE MANAGEMENT OF RAILWAY TRANSPORT INFRASTRUCTURE TECHNICAL MAINTENANCE (URRAN PROJECT)

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ABSTRACT

The paper considers issues related to well-balanced management of resources for JSC RZD infrastructure maintenance under the conditions of scarce finances. The authors have made an analysis of the RAMS methodology and its further transformation into a complex of Russian standards and normative and methodology documentation base applied for management of life cycle processes of railway transport systems (URRAN) in JSC RZD. The paper studies the prerequisites and key aspects for development of the innovative technology of management decision making support for increase of dependability and functional safety of transport in Russia at all life-cycle stages.

Keywords: Dependability, safety, availability, longevity, risks, life cycle, information support, decision making support system.

INTRODUCTION

The technical maintenance of the network of Russian railways requires tremendous expenditures related to maintaining the dependability of infrastructure facilities and ensuring the safety of transportation process. Under the conditions of scarce resources, an inadequate decision may cause mistakes in planning repair works for infrastructure sections which according to the existing rules call for repair but at the same time have a sufficiently high level of dependability [1]. On the contrary, infrastructure sections displeasing in terms of dependability are still being operated without refurbishment, capital repairs, or at least on-going remedial works. This in turn entails risks of traffic accidents.

At least two of the below prerequisites are required for good governance of scarce resources:

1. Real-time acquisition of actual information on the status of dependability and functional safety of all infrastructure assets of rail transport.

2. Setting-up of a system for decision making support of maintenance of infrastructure assets of railway transport at the unit, regional and network layers.

The first prerequisite implies establishment and deployment of an automated system for acquisition, analysis and processing of data about failures of infrastructure facilities and traffic accidents over the network of Russian railway. The second prerequisite means that since it is fundamentally impossible to set up and further operate a facility with absolute dependability and safety, then for solving this problem it is expedient to invest as many funds as really available and justifiable in terms of dependability reduction and safety ensuring. In other words, the residual risk of traffic accidents should have an accepted level.

Under these conditions, there arises a contradiction between the commercial interests of a railway infrastructure owner aimed at intense exploitation of infrastructure, on the one hand, and the need for routine breaks in operation for the purpose of maintaining the required levels of dependability and safety, on the other hand. This contradiction may be eliminated through the

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development of a system for integrated management of maintenance works on railway transport infrastructure. This system should ensure automation of processes dealing with real-time acquisition and processing of data on failures of facilities and traffic accidents, processes of identification of track sections which are most displeasing in terms of dependability, as well as automation of decision-making support for distribution of scarce economic resources for maintenance of infrastructure provided that accepted levels of safety and required levels of dependability of its component facilities are achieved.

1. PRINCIPLES, PURPOSE AND GOALS OF INTEGRATED MANAGEMENT OF DEPENDABILITY, RISKS, AND LIFE-CYCLE COST ON RAILWAY TRANSPORT

1.1. RAMS methodology

In 2010 JSC Russian Railways started to develop and introduce a set of standards, methods and guidelines used for management of life-cycle processes of railway systems (URRAN). To that end, Russian railways initiated the process of harmonization of the Russian infrastructure management regulatory framework with the RAMS standards widely used by the EU and US railway companies.

RAMS is a methodology for ensuring Reliability, Availability, Maintainability, and Safety on railway transport. This is a corporate effort of the European Union formalized by the standards EN 50126 and IEC 62278. The RAMS methodology is based on the ALARP principle (as low level of residual risk as it is reasonably possible) in ensuring safety and dependability at all life-cycle stages of a railway transport facility.

RAMS in relation to the conventional standards in the sphere of dependability of engineering systems features the following:

1. Integrated management of dependability and safety of a facility with its life-cycle stages taken into account;

2. Decision making as to management of dependability and safety of assets based on risk assessment;

3. Management of dependability and safety of an asset in terms of quantitative indicators as well as based on recommendations proven by the international community as listed, for instance, in the railway-related application standards EN50126/IEC62278, EN 50128/IEC62279, EN50129/IEC62425Ed, EN50159 (the first and second parts);

4. In the RAMS methodology, there are four safety integrity levels. Each level is characterized by numeric values as well as a set of requirements specified for the technology of product development and pertaining to the implementation of these levels.

1.2. URRAN project purpose and goals

RAMS targeting at manufacturers of technical equipment did not satisfy the goals of JSC RZD which are focused around operational activity. During the practical application of the RAMS methodology on Russian railways, several critical drawbacks thereof were revealed. Key ones are:

− Integrated analysis does not take longevity of facilities into account. This circumstance does not let us relate longevity and safety of facilities, assess the risks of transition from a set service life to their limiting state during operation and even correctly estimate the limit state of a facility;

− Life-cycle cost of a facility is estimated in isolation from its dependability and safety, i.e. not included into the RAMS methodology. This circumstance hinders reasonable distribution of investments into a facility at various stages of its life cycle;

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− RAMS methodology is well developed for the stages of designing and manufacturing facilities and is practically not developed for the stages of their maintenance, modernization, decommissioning and disposal. For railway transport, of key importance is the management of dependability and safety of compound facilities at the stages of their maintenance and modernization;

− Issues of risk management are interpreted in the RAMS standards at the conceptual level and call for all-round development;

− Issues of system resilience (robustness) under unfavorable impacts are not covered;

− RAMS methodology does not cover the issues related to safety of technological processes, impact upon the environment.

All the above has required to transform the RAMS methodology into a complex of Russian standards, methods, guidelines applied for the management of life-cycle processes of railway transport systems (URRAN) in JSC RZD [2,3]. The conceptual framework of the URRAN system is represented in Fig. 1.

A system life cycle is meant as a sequence of stages, each containing specific tasks. This sequence fully grasps the entire system service life – from the primary concept till decommissioning and disposal. The life cycle provides the framework for planning, management and control of all the system indicators for the purpose of manufacturing quality products at reasonable price and within agreed time limits. The life-cycle of railway transport including 15 stages and represented in the form of a V-shaped model is shown in Fig. 2.

The downward (left-hand part) of the V-shaped model is normally referred to as the system designing or development and is a process of system evolution that ends down in the manufacture of system components. The upward (right-hand) part is referred to the assembly, installation, acceptance and follow-up maintenance of a system.

The V-shaped representation has gained widespread application in the industry. It implies that the acceptance procedure is closely linked to the system designing and development, since the system under development should in the end be verified for compliance with the requirements. The approval and acceptance of a system are based on the requirements specification and are planned at earlier stages of the life cycle – during the designing or development. Such representation of a life cycle is effective for the tasks of system check-up and approval during the life cycle. The purpose of check-up is to confirm that for certain source data the output data at each stage fully meets the requirements of the given stage. The purpose of the approval is to ascertain that the system being reviewed fully meets the imposed requirements at each stage of development and after installation.

Within the URRAN project, an object-element model of railway-related application has been developed which is based on the specially introduced concept of the reference element; also, dependability performance and operational safety indicators of railway transport have been developed and linked to the amounts of operational work performed. Table 1 represents the measurement units for the scopes of operational work performed for the divisions of JSC RZD which are used as arguments in dependability and safety performance indicators. In several cases, indicators which are functions of a facility's operation time are used. This applies only to the assets whose dependability and safety does not depend of the volume of operational work performed in transportation process.
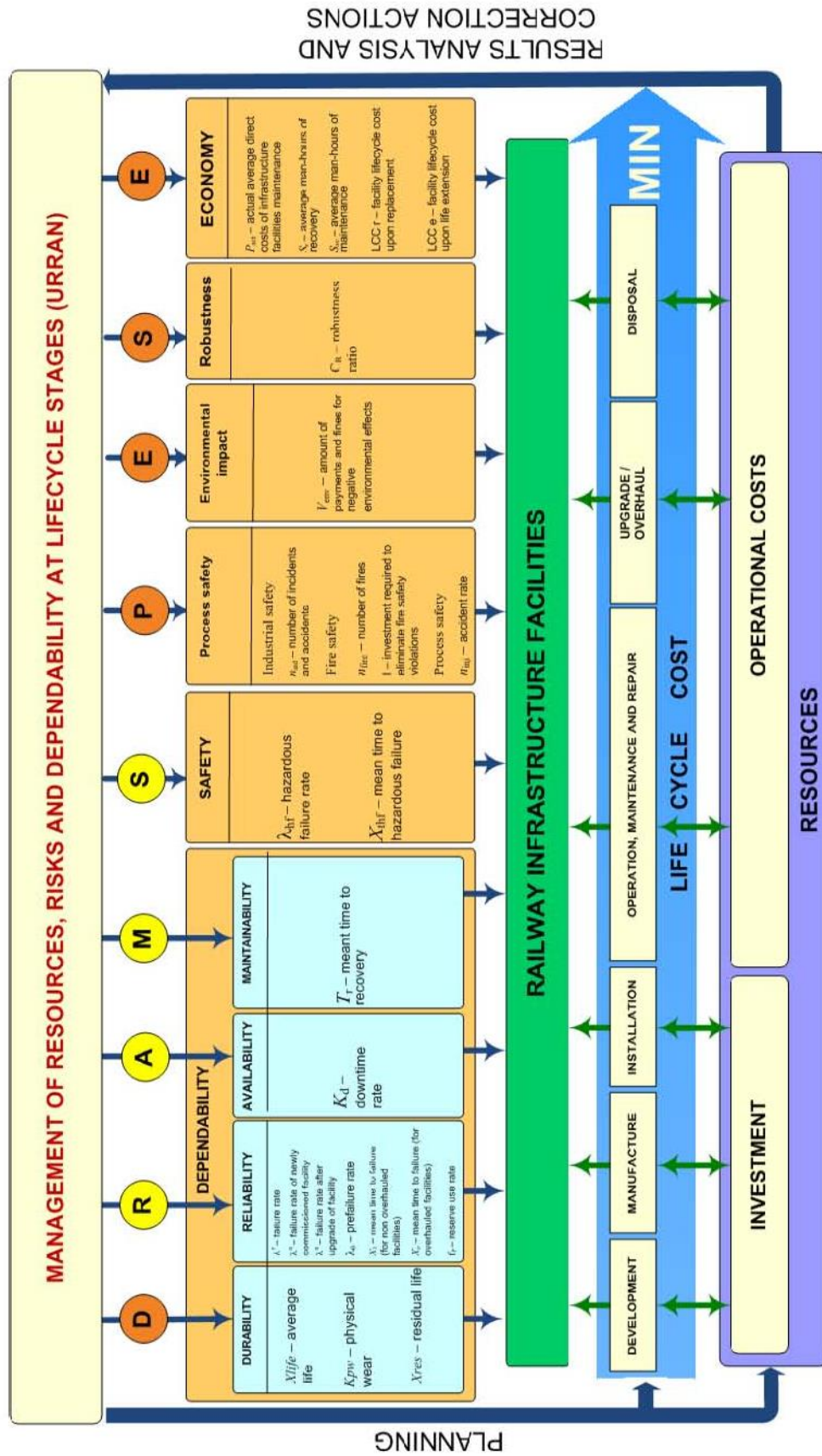
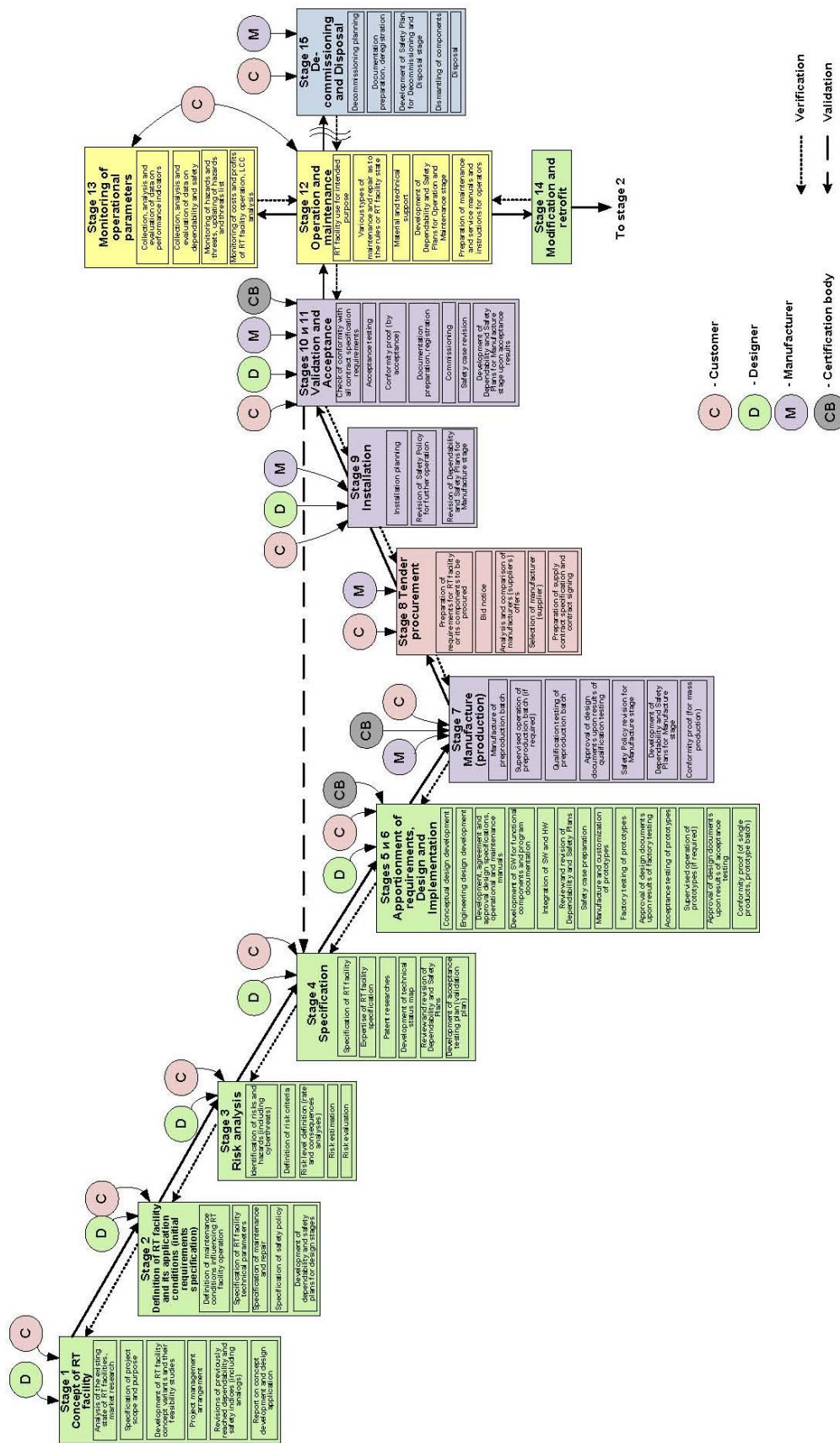Gapanovich V.A., Shubinsky I.B., Rozenberg E.N., Zamyshlyaev A.M. – SYSTEM OF ADAPTIVE MANAGEMENT OF RAILWAY TRANSPORT
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Fig. 1. Concept of the URRAN system

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Fig. 2. Life cycle of railway transport facility including the process of manufacturing

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Table 1. Quantities to measure the scopes of operational work performed in divisions of JSC RZD

No.	Division	Scope of field operation performed		
		Legend	Measurement unit	Dimensions
1	Division of tracks and structures	Tr	bln t*km of ton-kilometer operation	1
2	Division of signalling and remote control	S	mln train*km	1
3	Division of telecommunication	T	mln train*km	1
4	Division of electrification and power supply	E	mln kW*hr of transformed electrical energy	100
5	Locomotive division	L	mln locomotive*km of total mileage	1
6	Wagon division	W	mln wagon*km of total mileage	100
7	Passenger division	P	mln wagon*km of total mileage (passenger wagons)	10

The purpose of URRAN introduction is to increase the efficiency of railway transport operation based on the adaptive management under the conditions of resource scarcity. The object of URRAN application is the aggregate of technical facilities, systems, and technological processes of railway transport.

By adaptive management we imply the form and methods for control over business entities that assume the possibility and capability of the control system to change the parameters and structure of the regulator and the control subsystem in general depending on the change of internal parameters of the managed asset or the external environment (disturbances), as well as the changes in strategic goals.

The URRAN project solves the problems of optimization of resource management on the basis of dependability and safety performance criteria with risk assessment taken into account. At the same time, much attention is paid to the consideration of effect of the human factor in technological processes of the company's operation. In the conditions of shortage of funds, URRAN allows for increasing a set service life of railway transport assets to the limiting state on the basis of risk assessment and redistributing investments for the maintenance of dependability and safety of the most displeasing facilities.

2.   URRAN NORMATIVE AND METHODOLOGICAL FRAMEWORK

Currently, all the works related to infrastructure maintenance are arranged on the basis of a facility's standard service life, with disregard for its current state. Such national standards of dependability management as GOST 27.002-89, GOST R 53480-2009, GOST R 51.901.2002, GOST R 51.901.12-2007 etc. do not cover the issues of management of running maintenance investments and costs. For the practical implementation of the URRAN system, it was necessary to

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develop a set of regulatory and methodology documents which represent the principles and essential aspects of the system.

Due to the formation of the Customs Union, cooperation of organizations in the member countries has become more active in the sphere of railway transport, including cooperation in the sphere of ensuring safety and dependability of railway engineering. It is also of note that not only the JSC RZD is the largest railway organization in the countries of the former USSR, but it is also the most active participant of works aimed at standardization at the inter-state level since it is a secretariat of the International Committee for standardization 524 "Railway transport". Since the matters related to the dependability and safety of railway transport are important for all the organizations and users of railway transport services, a decision was made on the necessity of upgrading the status of the main URRAN standards to the inter-state and national level. That also facilitated the improvement of interaction between JSC RZD and organizations that are involved in railway sector but are not part of RZD's holding.

Within the URRAN project, GOST 32192-2013 "Dependability in railway equipment. Basic concepts. Terms and definitions" has been developed, which defines all the required terms and concepts of the subject matter with regard for the specifics of railway e and the best practices elaborated in the URRAN project [4,5,6] and helps the correct application of concepts and better mutual understanding among all the parties.

To establish the general rules for risk management on railway transport related to the traffic safety and operation, the following national standards have been developed:
- GOST R 54504-2011 "Functional safety. Safety policy and safety plan. Safety case of railway transport facilities";
- GOST R 54505-2011 "Functional safety. Risk management on railway transport".

The technical regulations of the Customs Union introduce the concept "risk" that is fundamental for safety. But the inter-state standards in risk management are missing. JSC RZD strives to extend its best practices [7,8] over the entire 1520 gauge space, so the company will continue activities in that direction jointly with the Rosstandard.

By now, within the URRAN project, 1 inter-state standard, 5 national standards of the Russian Federation and 17 corporate standards of JSC RZD have been developed. These standards set the requirements in the sphere of risk assessment, functional safety, dependability and life cycle cost of railway transport facilities. These standards are just the tool which may help solve the major issues in the development and introduction of innovations and enhance the factors that favor the success of the URRAN project. The standards provide the framework for elaboration of the common language of communications among all the interested parties that participate in the development and introduction of the new system.

The national and corporate standards developed within the URRAN project set the procedures for introduction and use of the URRAN methodology on railway transport and contain the requirements for management of resources, risks, and dependability as applied to railway transport.

For the practical implementation of the standards, 8 methodology recommendations and 55 methodology instructions have been developed. They allow for assessing technical condition of infrastructural facilities, providing data for decision making as to the necessity of conducting technical maintenance and repairs, planning investments for facility maintenance, as well as evaluating damages and generating risk matrices for each type of infrastructure facilities as the framework for the management of technological processes on railway transport.

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3. THE UNIFIED CORPORATE PLATFORM OF URRAN (UCP URRAN)

3.1. Development directions of information systems in JSC RZD and prerequisites for the development of the KASANT system

Currently, JSC RZD uses a lot of information systems which cover almost all the aspects of the company's production activities, which have been developed and introduced into commercial operation over a long time.

The general direction of development for information systems (IS) and automatic control systems (ACS) meets the worldwide trends:

–   from accounting systems (transactional systems, OLTP systems) which allow to get the precise answer to the questions "what?", "where?", "when?", "how much?" that are related to the past — to analytical systems (of OLAP class) which not only let us answer the question "why?", but also let us move to forecasts of development;

–   from systems which in many ways do not meet the scopes of activities of JSC RZD and its divisions — to systems that are based on large world-renowned industrial platforms (SAS Intelligence Storage, SAP AG, Oracle, IBM Maximo) which proved well at the world's largest corporations;

–   from systems that are based on the "file" and "client-server" technologies — to systems based on Internet technologies (http, SOAP protocols, mark-up languages html, xml, Java programming language, thin client);

–   from isolated railway information systems, from systems that ensure information support for specific directions of activities of JSC RZD and its divisions (for example, financial or personnel management) — to integrated centralized systems which cover the entire life cycle of transportation process.

The unique character of dependability management on railway transport is in the following:

– Many facilities of railway transport are distributed in space and have a hierarchical structure;

– To manage dependability of infrastructure facilities and railway transport in general, it is needed to combine in real time the above two directions: acquisition and processing of statistical data on facility failures, modeling of the dependability of facilities;

– A vast variety of facilities, on the one hand, and essential differences in operational modes and conditions for even same type facilities, on the other hand;

– The extent of impact of facility dependability on transportation process depends on the properties of fail-safety as well as maintainability of facilities and on the properties of transportation process itself (traffic intensity, train speed, duration of delays of trains because of repairs of infrastructure and/or rolling stock).

– The mentioned circumstances have caused the need to develop specialized automated control systems (ACS) on railway transport to manage the processes of gathering data about the schedule of realized train traffic, on the current state of elements of infrastructure divisions (GID-URAL, ASOUP-2, ASU-P, ASU-Sh-2, ASU-E) [9]. These systems provide information about failures in the elements of divisions. However, this information has a disparate character and not systematized by categories and impacts upon train delays. The abundance of automated control systems that have no common interface, insufficiency of information on dependability and safety of facilities represented by them, uncertainty of the information itself, no possibility in these systems to analyze failures, etc. have become the prerequisites for development of a common automated control system for management of acquisition, analysis and pre-processing of data on failures and recoveries of compound elements of railway transport facilities.

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The basis of the information technology that ensures integrated management of transportation process dependability is the "Integrated automated system for accounting, control of fault elimination in facilities and analysis of their dependability" (KASANT). To acquire trustworthy information on the state of facilities and implement the principle of maximum usage of human-independent forms of data acquisition, the KASANT system has been integrated with the existing industrial automated control systems as regards exchange of data on failures. To arrange effective interaction with the KASANT system, the mentioned automated systems has been adapted in terms of storage and access to data for track-recording wagons, results of decoding speed gauges, KLUB-U legal registration units, and other devices for registration of train movement parameters. Due to these works, objective sources form the basis of primary information on the status of technical facilities in the URRAN project.

Based on the real data of the KASANT system, it is possible to acquire summary information on faulty facilities regarding the company in general. The total amount of users of the system by the end of 2014 was 35 thousand employees of JSC RZD [10]. Therefore, in the company now there is already a fully automated process of analyzing failures of technical facilities that impact the stability of traffic.

Based on the achieved positive results, in line with the general methodology of URRAN, Russian experts have started the work related to the analysis of violations of technological processes in the company's divisions. In the long run, this will let us provide economical feasibility of the infrastructure component value in cargo and passenger transportation tariffs through a life cycle cost and ensuring an acceptable risk level, as well as take into account the impact of errors in the planning of traffic, including staff errors.

3.2. Development of the URRAN unified corporate platform

Currently, JSC RZD uses a lot of information systems that cover almost all the sides of the company's production activities and have been developed and introduced into commercial operation for a long time. Under the conditions of structural differentiation by the types of activities, the role of computerization as the technical means of coordination and centralization of control increases. It is needed to perform transition from isolated railway division information systems, from systems that ensure information support for specific directions of activities of JSC RZD and its divisions [11] to the integrated centralized platform that provisions the entire life cycle of transportation process.

The object of computerization for the unified corporate platform of URRAN is business processes of technical maintenance work of JSC RZD's infrastructure.

The enterprises of JSC RZD, subsidiary companies participating in maintenance of the company's infrastructure assets will be able to use data in the unified IT environment, standardized systems of data processing and transmission. It will also allow combining the benefits of the scale and coordination with the benefits of distributed production.

The key groups (complexes) of business processes aimed at the management of the infrastructure maintenance are:
- Strategic management of maintenance of infrastructure facilities;
- Management of monitoring and diagnostics of infrastructure facilities;
- Management of running maintenance and scheduled preventive repairs;
- Management of maintenance of self-propelled vehicles, instruments, machinery and equipment of enterprises, ensuring availability and good condition of engineering means.

The basis for support of the above described management principles and processes are technologies implemented in the UCP URRAN. The structure of the UCP URRAN system is represented in Fig. 3. The UCP URRAN is a system for decision making support whose goal is to aid the top managers making decisions in severe conditions to perform an all-round and impartial analysis of substantive work.
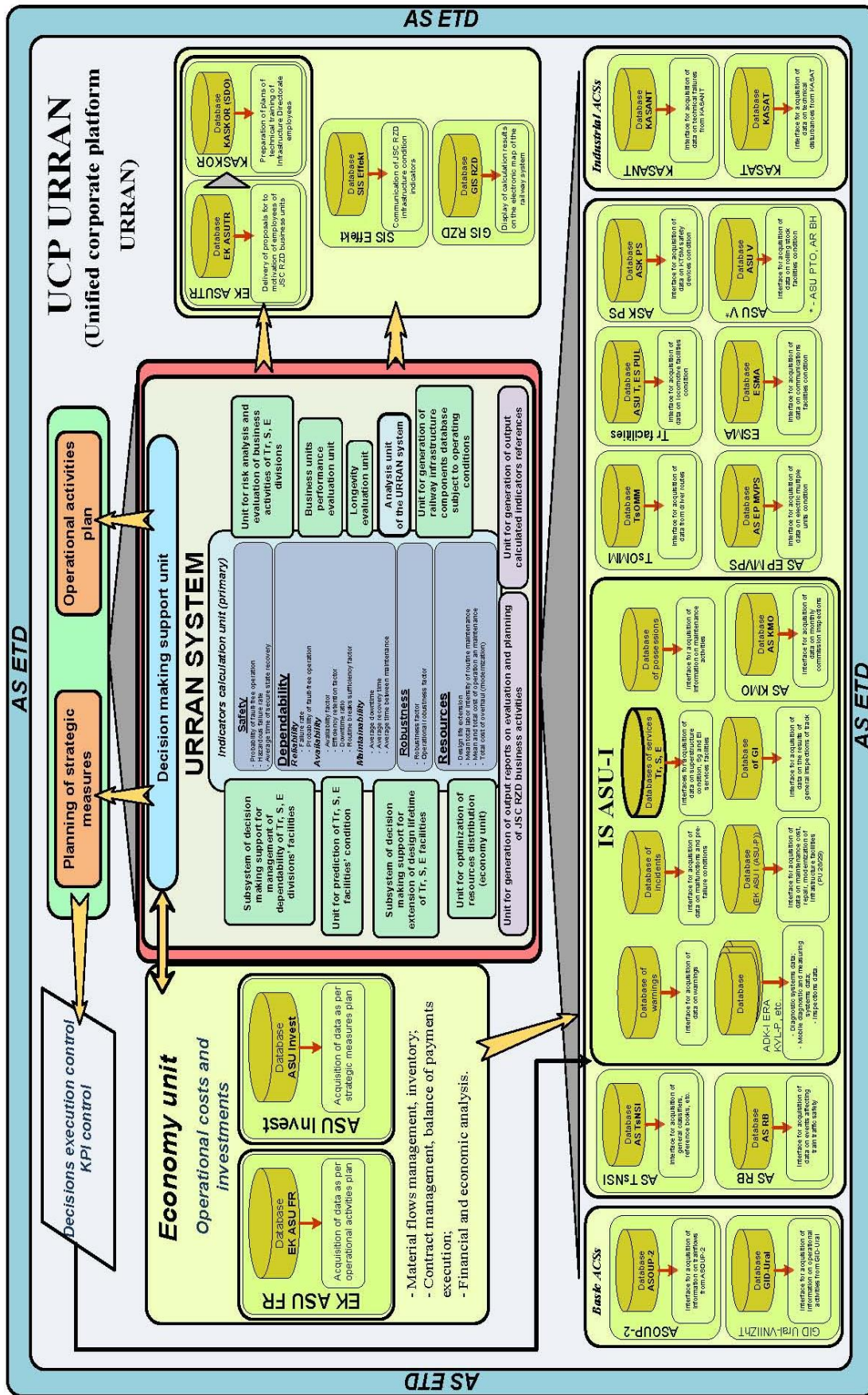
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Fig. 3. Structure of the UCP URRAN system

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With the help of decision-making support for integrated management of dependability, risks, and cost of a life cycle on railway transport, resources' provision of the company's activities is formed: when budgeting, the company's strategic goals and purposes are related to the volumes of funds it currently possesses or will get soon. When planning, the system assists in viewing data from previous years, reveal trends and regularities and use them in preparing a budget, thus making it more well-targeted and accurate.

The UCP URRAN is meant to solve the following problems:

▪ automation of primary processing of statistic data on failures in technical facilities of infrastructure facilities and rolling stock of railway transport;

▪ quantification of indicators for operational dependability and safety of infrastructure facilities;

▪ quantitative evaluation of production activities of infrastructure divisions and rolling stock with regard for failures and maintenance as well as operation of infrastructure facilities;

▪ monitoring, correlation, and motivation for activities of structural subdivisions within divisions based on the indicators of operational dependability and safety;

▪ evaluation of compliance of achieved indicators of operational dependability and safety with set norms;

▪ preparation of estimated data to draw up recommendations for decreasing risk levels;

▪ identification of vulnerable facilities based on risk assessment;

▪ preparation of draft plans for maintenance of infrastructure and rolling stock;

▪ preparation of projects for distribution of investments into the most displeasing facilities of railway transport.

CONCLUSION

The RZD holding is Russia's largest transport business system that offers vast potentials for increasing efficiency in meeting the growing needs of the national economy and population in transport services and delivers quality transport services both at the Russian and international markets.

To achieve this goal is not possible without ensuring a high level of safety and dependability of transportation process, which is a guarantee for safekeeping stable competitive edges of the RZD holding at transport markets.

The URRAN project implies development of an innovative technology for supporting executive decision-making aimed at increasing the dependability and functional safety of Russia's railway transport at all the stages of a life cycle.

Russian experts have developed the key provisions of the URRAN methodology that as an improvement to the European RAMS methodology provides for integrated management of dependability and safety as well as the cost of a life cycle of railway transport facilities with regard for assessment of risks and longevity. The developed system of operational indicators provides estimates of the properties of dependability, safety, life-cycle cost achieved for the railway transport infrastructure with regard for the volume of field operation performed by facilities. Under the scarcity of financial means, the URRAN allows for assigning repairs to the most displeasing sections and ensuring reliable functioning of the infrastructure and traffic safety, managing the maintenance of railway transport facilities based on their current status of dependability and safety, which, in particular, ensures prolongation of a set service life of facilities provided that acceptable levels of safety are maintained. Assessment of risks of hazardous situations on railway transport allows for forecasting occurrence of traffic accidents at sections of railway lines in poor state.

The basis for supporting the URRAN methodology is technologies implemented in the UCP URRAN which is a system of decision-making support in severe conditions, including the conditions of uncertainty.

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