E3S Web of Conferences **376**, 04001 (2023) https://doi.org/10.1051/e3sconf/202337604001
ERSME-2023

UC aims system in the management of the economic activities of the track complex of JSC "Russian railways"

N. Kovalenko[1], *I.* Rosenberg[2], and *V.* Tsvetkov[3*]

[1]Russian University of Transport (MIIT), 9, p., 9, Obraztsova str., 127994 Moscow, Russia
[2]Research and Design Institute of Russian Railways JSC "NIIAS", 27, building 1, Nizhny Novgorod strt., Moscow, Russia
[3]Research and Design Institute of design information, automation and communication on railway transport, 27, bldg 1, Nizhegorodskaya Str. 109029 Moscow, Russia

Abstract. The analysis of the structure of the UC AIMS and the interrelation of its subsystems is carried out. The perspective of the development of the UC AIMS system by creating a Situational Control Center for ordering and consolidating the interaction of various control subsystems included in the overall structure is considered. The activity of the situation center allows to reduce the workload of employees of departments and the audit apparatus, resulting in a reduction in production costs, improvement of quality indicators, as well as obtaining a certain economic effect. The UC AIMS information and analytical system is aimed at improving the level of technical condition of the track and infrastructure in good condition. The creation of a unified information environment is aimed at increasing reliability and optimizing costs when planning travel work. The creation of a Situational Center is aimed at dividing the initial information into true and false at the stage of its preliminary analysis before the start of calculations. This separation will allow us to consider the stage of preparation for computational iterations in automatic mode. This can significantly reduce the number of calculated iterations performed (approximately by 3-5%), by reducing the time for processing the array of source data and increase the efficiency of the information and analytical unit of the UC AIMS system (approximately by 6-10%). Keywords: Unified information environment in Russian Railways; automated infrastructure management system; subsystems and components; situation center; information is true and false; the reduction of production costs; qualitative indicators of informatization.

1 Introduction

Infrastructure management is a complex task that requires a whole range of solutions. The model of effective management of infrastructure maintenance processes consists in the coordinated work of all components.

* Corresponding author: cvj2@mail.ru

The Unified Corporate Automated Infrastructure Management System (UC AIMS) is a human-machine system that ensures the effective functioning of an object in which information is collected and processed using automation and computer technology. UC AIMS is a hierarchy of subsystems that is focused on achieving certain goals.

UC AIMS is a single information model for all infrastructure facilities, including track facilities and structures.

The main function of managing the maintenance of the infrastructure of JSC "Russian Railways" is to ensure the operable condition of structures, devices, mechanisms and equipment that are safe for train traffic with economically rationally justified train speeds and axial loads with an optimal ratio of operating costs for maintenance.

Currently, in the infrastructure of JSC "Russian Railways", the cost of maintaining fixed assets reaches 30% of the total amount of all railway transport expenses. Therefore, optimization of infrastructure maintenance costs is one of the key tasks. An important circumstance of the current state of the infrastructure is caused by the results of many years of underfunding, which led to an increase in the depreciation of fixed assets.

A significant increase in the prices of materials affected the increase in the cost of repairs.

To improve the efficiency of management and improve the quality of work of structural units, an urgent task is to improve the management system of the operational work of the infrastructure. One of the solutions is the use of modern information technologies and the development of an automated control system.

2 Materials and methods

The UC AIMS as a system is designed for the operational solution of management tasks and information support of business projects for the maintenance of infrastructure facilities of JSC "RR" (fig. 1).

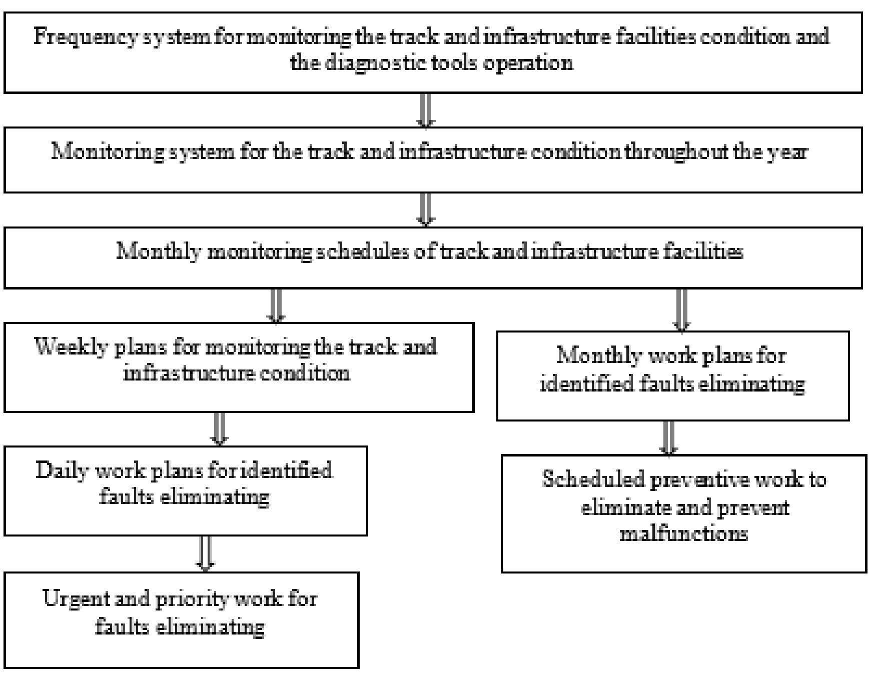

Fig. 1. The production plan structure of the infrastructure division of the track complex in JSC "RR".

Fig. 2 shows the current work distribution at the infrastructure facilities of JSC "RR". The supporting materials indicates that about 50% of the work (46%) are carried out according to the monitoring results. Consequently, their implementation timeliness, quality and validity of their production depends on the received information reliability.

The following were considered as the target tasks for the UC AIMS system creation:

- supporting for the infrastructure complex of JSC "RR" reforming;
- increasing the economic efficiency of infrastructure maintenance by automating and optimizing the planning and accounting functions for all types of resources;
- management processes optimization by creating a unified source of information on the functioning of infrastructure processes;
- ensuring transparency of processes by creating a unified source of information on the maintenance of infrastructure at all levels of activity;
- increasing the manageability and efficiency of management decisions;
- improving traffic safety by systematically monitoring their requirements.

The system is built on the platform of IBM's software product - IBM Maximo and implements its functions using subsystems and components closely related to each other. Consolidation of hundreds of workstations into a unified modern solution provides effective support and infrastructure development.

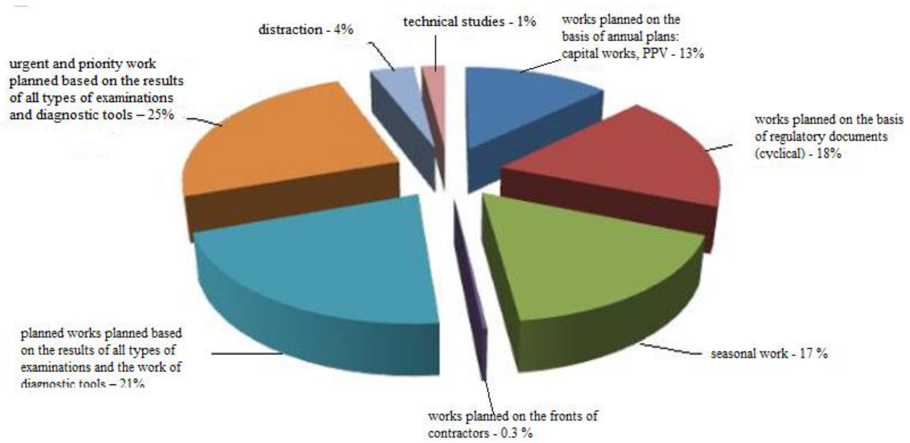

Fig. 2. Diagram of the labor costs distribution by activity type at infrastructure facilities of JSC "RR" (railway track, turnouts, man-made facilities, roadbed, right-of-way lines).

The key subsystems and components of the UC AIMS:

- Unified technological base of infrastructure facilities (UTB);
- Unified system for infrastructure facilities monitoring and diagnosing (UC AIMS MD);
- Typical Infrastructure Incident Management System (TSI);
- Typical management system for the current infrastructure maintenance (TS-2);
- System for assessing and predicting the state of infrastructure facilities (SAPS);
- System of consolidated corporate reporting (SCR);
- Technological automated control systems (ACS) of facilities;
- Geographic information system (GIS);
- ESB - a unified service bus, middleware providing an exchange between information systems;
- Electronic archive of technical documentation (EATD);
- System of central storage and provision of reference information (CISR);

The basis for the functioning of the UC AIMS system is the Unified Technological Base of Infrastructure Objects (UTB), designed to store explicit characteristics of infrastructure objects and their connections at the physical and logical level, in line with the information model. Each user of the UTB system has his own area of responsibility covered by his powers.

The UTB allows to solve problems in the following areas:

- general information model forming and maintaining of the operational infrastructure;
- unified description of objects and connections between them developing;
- unified regulatory reference information and geoinformational component forming and maintaining;
- unified interface for manual or automated data maintenance developing.

The functional diagram of the UC AIMS is shown in fig. 3.

The unified system for infrastructure facilities monitoring and diagnosing (UC AIMS MD) was created to monitor and diagnose infrastructure facilities.

The data sources for the work of the UC AIMS MD are:

- systems for centralized monitoring of the objects state;
- on-board systems of mobile diagnostic tools (track measuring cars, defectoscopic devices, laboratory cars);
- various inspections of the infrastructure facilities state;
- automated traffic safety management systems (AS TS);
- automated systems of commission monthly examinations (AS CME);
- automated systems of drivers' comments (AS DC).

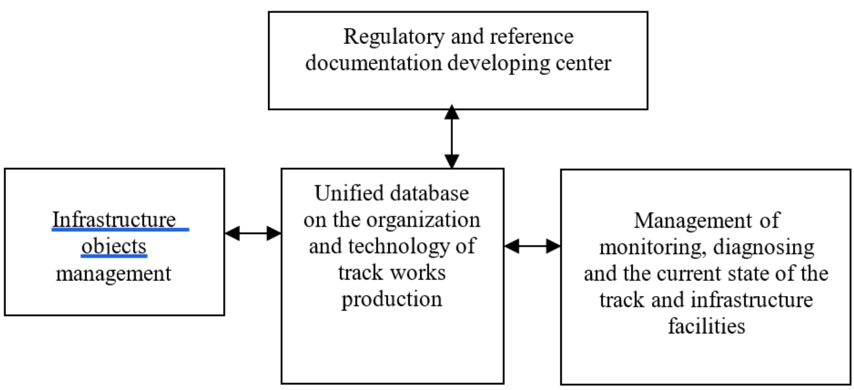

Fig. 3. Functional diagram of the UC AIMS.

The scheme of interaction of the ETB with external systems is shown in fig. 4.

The standard incident control system (SICS) is designed to automate the management of troubleshooting and pre-failure conditions (incidents) at infrastructure facilities.

The objectives of the subsystem are the processes of activities of the infrastructure branches relating to work management on faults and incidents elimination.

The SICS objectives are:

- incidents registration in ETB and TS-2;
- providing executors with information on incidents elimination;
- organization of incidents elimination, and their registration;
- monitoring of the work state to restore the objects operability;
- providing facilities with information on the status of the incident eliminating process.

The typical management system for the current infrastructure maintenance (TS-2) is designed to automate the management of the current maintenance of the infrastructure objects and the production of scheduled preventive maintenance.

By applying this system the following tasks are solved:

- maintenance of regulatory reference information, as well as maintenance of technological maps by work type;
- annual, monthly and operational planning of work on the current maintenance;
- work management at operational facilities;
- personnel management (formation of the need for labor costs;
- assignment of personnel to work; actual accounting of labor costs when performing work);
- management of material and technical resources (MTR);
- forming reports on objects.

The system for assessing and predicting the infrastructure facilities state (SOPS) helps to form an economically optimal work plan for the current maintenance of infrastructure facilities.

The SOPS, based on the collected data on infrastructure facilities and modern reliability management methodologies, allows for a comprehensive analysis and assessment of the state of the infrastructure, forecasting and determining the probability of failure-free operation, as well as the risks of failure.

The system allows you to move from a maintenance strategy based on scheduled preventive maintenance to a more modern maintenance system based on the actual state of objects, which significantly reduces maintenance costs.

Further arrangement and consolidation of the interaction of various control systems that are part of the general structure of the UC AIMS, at the present stage, is possible and most effective, by creating a Situational Control Center.

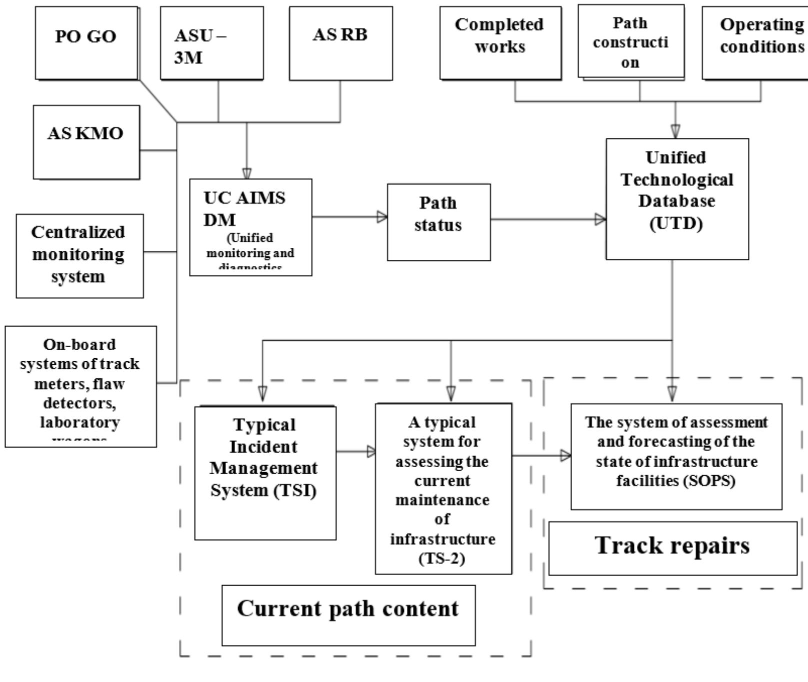

Fig. 4. Scheme of interaction of ETB with external systems.

The Situation Center functioning allows to reduce the workload of the departments and auditing office employees, therefore an indirect reduction in production costs is achieved, quality indicators are improved, also determining the receipt of a certain economic effect. All indirect effects that occur when using the Situation Center of the Central Regional Hospital of JSC Russian Railways can be divided into two groups: 1st - quantitative: cost reduction in solving complex problems; and 2nd - high- qualitative: improving the work quality, reducing the tension in the work of operational dispatchers and analysts.

The technological direction of situational management consists in the development of methods and technologies for analysis and management, which reduces the load on the decision maker (hereinafter, the DM). This direction uses an informational approach based on information management methods. In addition, geoinformatical methods are becoming an integral part for JSC "Russian Railways" in this direction.

The control system of the situational (dispatch) center provides an integrated interaction of all elements of the situational analysis. The high complexity of the situational center systems requires constant maintenance and improvement.

3 Decisions analysis

When analyzing the decisions we consider the qualitative, logical, quantitative and systemic levels. The analysis of the decisions made, as a rule, is based on the analysis of a situation or several related situations. Therefore, in essence, such an analysis is situational.

As a matter of form, any analysis, including logical, includes two stages.

The first stage consists in the construction of formal information structures in the form of related sequences and qualitative assessment. These constructive sequences can subsequently be described by logical expressions, mathematical formulas or topological constructions.

The second stage of the analysis includes a detailed study of the qualitative content of the constructive sequence and the application of mathematical or logical analysis to it. However, it may happen that a qualitative assessment already allows a decision to be made or to begin to form it.

The hypothesis of the event {A} (formula 1) means such an event {B}, which implies their complete coincidence:

$$(B \to A) \equiv 1 \tag{1}$$

The construction of a hypothesis in the analysis is based on the use of the condition of causal completeness. That is, plausibility is achieved against the background of a decrease in facts and hypotheses with estimates of "uncertain". The verification of this condition is interpreted as if the hypotheses obtained explain the studied situation with a smaller number of parameters, taking into account all the estimated indicators. That is, there is casual completeness and the hypothesis is complete. There are particular hypotheses about the possible causes of the properties or states of objects. They can explain the presence or absence of property (Pj) in objects for which it was not initially known that they possess or do not possess property (Pj) in the current situation.

The purpose of testing the condition of causal completeness is to determine whether the hypotheses obtained as a result of the method work can be accepted. If the condition of causal completeness is not met, then it is necessary to change the applied cognitive technique. For example, choose a different way of coding paralinguistic units or a different set of information units.

As an example of the applicability of this analysis in the UC AIMS system, we can consider the system for monitoring the state of the railway track geometry (hereinafter, RTG) using various instruments and equipment. In particular, the sufficiency of the use of more simplified and less expensive equipment for monitoring the RTG of low-intensity sections of the track (for example, track measuring trolleys and hand-held devices). The use of more complex and more expensive equipment for monitoring the RTG lines of 1 - 3 classes (for example, track measuring cars with the CMLR system). And, finally, the use of high-precision and expensive systems (for example, ERA, INTEGRAL) for high-speed traffic areas.

The hypothesis of events {A} is called simple and causally complete if it is a conjunction of the situation parameters or their negations, but after discarding any of its factors it ceases to be a hypothesis of the event {A}. The parameters of the situation can be negative and positive. A standard situation contains positive parameters and negation of negative parameters. For example, a simple hypothesis can be represented in the form of formula (2):

$$B(x_1 \wedge x_2 \wedge x_3 \wedge x_4 \wedge \neg x_5 \wedge \neg x_6 \wedge \neg x_7 \wedge x_8 \wedge x_9) \equiv 1, \quad (2)$$

In this case, the hypothesis includes all the parameters of the situation, the number of which is 2. It is identically equal to 1 (true), which determines the fulfillment of the condition of casual completeness. The exclusion of any parameter violates the condition of casual completeness and translates the hypothesis into "not a hypothesis". Its interpretation is presented in the form of formula (3):

$$B(x1 \wedge x2 \wedge x3 \wedge x4 \wedge \neg x5 \wedge \neg x7 \wedge x8 \wedge x9) \neq B, \quad (3)$$

The hypothesis emphasizes the obligation and complementarity of the parameters. For example, expression (1) can describe a normal situation.

The negation of any parameter in the expression leads to an abnormal situation:

$$B_{Н}(x1 \wedge x2 \wedge x3 \wedge x4 \wedge x5 \wedge \neg x6 \wedge \neg x7 \wedge x8 \wedge x9) \equiv 1, \quad (4)$$

In expression (4), the negative factor x5 is present in the situation, while in expression (2) it is absent. Expression (4) describes an abnormal situation of the appearance of a negative factor (for example, obtaining inadequate information on the assessment of the RTG by track measuring trolleys and hand-held devices) for assessing the state of the RTG in high-speed traffic areas. The consequence of the event {A} is understood as the event {C}, in which equality (5) is identically fulfilled:

$$(A \to C) \equiv 1 \quad (5)$$

The corollary specifies the possibility of combining parameters and admits their complementarity or non-complementarity. The event {A} is called simple if it is a disjunction of the situation variables or their negations, but after discarding any of its terms it ceases to be a consequence of the event {A}. For example, a simple consequence in the form of combinations (6):

$$C\ (y1 \vee y2 \vee y3 \vee y4 \vee \neg y5 \vee \neg y6 \vee \neg y7 \vee y8 \vee y9), \quad (6)$$

Subsequently, it can be transformed into a new combination in the form (7):

$$CC\ (y1 \vee y2 \vee y3 \vee y4 \vee \neg y5 \vee \neg y6 \vee \neg y7 \vee y9 \quad (7)$$

The new combination obtained in this way is no longer a consequence of (6).

It is important to note that: if {A} is a hypothesis of event {B}, then A∧C is also a hypothesis of event {B}; if {A} is a consequence of the event {B}, then A∧C is also a consequence of {B}; if {A} and {B} are hypotheses of the event {C}, then A∧B is also a hypothesis for {C}; if {A} and {B} are consequences of {C}, then A∧B is also a corollary of {C}.

Logical analysis allows not only to evaluate an event for truth and falsity in a logical chain, but also to show the fundamental possibility of obtaining a result from a set of events without making the calculation (conclusion) itself. In (Alyabyeva, 2017; Vereshchagin, 2012), it is noted that semantic following is equivalent to deducibility. This is emphasized by the similarity of the symbols. There is a symbol ├ meaning deducibility and a similar symbol ╞ meaning logical succession. Proof of deducibility or follow-through is included in logical analysis.

In the presented example of a system for monitoring the state of the RTG using various instruments and equipment, the presented monitoring results using hand-held instruments and equipment will be true for low-intensity sections of the track and will be false for sections of high-speed train traffic.

The UC AIMS contains information on more than 15 million infrastructure facilities and their condition, incidents and works, with which more than 20 thousand users work. The UC AIMS is one of the largest infrastructural automated control systems in the world today.

Further development of the UC AIMS presupposes:

- creation of a unified mobile workstation of the UC AIMS using modern mobile devices;
- development of a standard solution for managing field inspections;
- creation of a unified solution for diagnostics and monitoring;
- automation of production planning and the creation of a system for assessing the results of the work of infrastructure enterprises using KPIs ("Key performance indicators" - key indicators);
- development of a system for assessing and predicting the state of infrastructure using mathematical modeling.

4 Result

Separation of the initial information into true and false even at the stage of its preliminary analysis before the start of calculations can significantly reduce the number of calculated iterations (approximately by 3-5%), by reducing the time for processing the array of initial data and increase the efficiency of the information and analytical unit of the system. The UC AIMS (approximately by 6-10%).

It can be concluded that the implementation of the information technology strategy of the JSC "Russian Railways" will create a promising high-tech digital platform that provides a unified information space for doing business.

The separation of the initial information into true and false will allow us to consider the stage of preparation for computational iterations in automatic mode.

References

1. *Unified corporate automated infrastructure management system (UC AIMS). Concept. Order of JSC "Russian Railways"* (2011)
2. V.G. Alyabyeva, *Mathematical logic. Tutorial* (Perm State National Research University, Perm, 2017)

3. V.G. Bondur, Educational resources and technologies **3(15)**, 79-88 (2016)
4. I.P. Deshko, *Information Engineering: Monograph* (MAKS Press, M., 2016) ISBN 978-5-317-05244-7
5. B.A. Levin, V.Ya. Tsvetkov, Science and technology of railways **2(2)**, 2-10 (2017)
6. A.L. Okhotnikov, *Information situational management in transport* (Saarbruken, Palmarium Academic Publising, 2018) ISBN 978-613-9-82104-4
7. D.A. Pospelov, *Situational management: theory and practice* (Nauka, Moscow, 1986)
8. I.N. Rosenberg, V.Ya. Tsvetkov, Science and technology of railways **2.4(8)**, 3-10 (2018)
9. I.N. Rosenberg, V.Ya. Tsvetkov, Railways Science and Technology **2.2(10)**, 3-16 (2019)
10. V.Ya. Tsvetkov, Information Constructions. European Journal of Technology and Design **5(3)**, 147-152 (2014)
11. N.K. Vereshchagin, A. Shen, *Lectures on mathematical logic and theory of algorithms. Part 2. Languages and Calculus* (MTsNMO, M., 2012)
12. B.A. Volkov, N.I. Kovalenko, A.Yu. Dobrin, A.N. Kovalenko, J. Path and track facilities **6**, 13-18 (2019)
13. B.A. Volkov, N.I. Kovalenko, A.Yu. Dobrin, A.N. Kovalenko, J. Path and track facilities **5**, 23-26 (2018)