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The Concept of Development of Monitoring Systems and Management of Intelligent Technical Complexes

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Conceptual approaches to improving the system of monitoring and managing the functional capabilities of intelligent technical complexes of buildings and transport and technological machines of mining enterprises are defined. Criteria are proposed for the efficiency of functioning of automatic systems for controlling the movement of transport-technological machines, taking into account the probabilistic nature of system-forming factors. The scheme of scientific and methodological research on the improvement of automation systems and traffic control in the automotive transport is presented.

The perspective directions of the formation of control functions for the movement of vehicles based on the use of intelligent automated systems are substantiated. The stages of the life cycle of technical systems for monitoring the movement of vehicles, taking into account the features of their operation. A technique has been developed for the optimal use of technical means of control in the field of providing control and supervisory functions in the operation of vehicles, and the dependence of determining the financial costs of maintaining their efficiency has been determined.

Key words: motion technical control systems; automobile transport; intellectual technical complexes; monitoring; energetic resources

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Introduction. Automation of technical systems of buildings and transport and technological machines in the world has reached a high level. In Russia, this trend is gaining momentum, including in the mining industry [12, 13]. The relevance of the topic is due to the fact that the use of automation systems to effectively manage the engineering systems of buildings and traffic control systems is in demand both in the restoration of existing electrical installations and in the design of new ones. Effective management of building systems such as lighting, heating and air conditioning helps reduce energy costs, and also contributes to increased comfort during a person’s long stay in the room. The basis of current theoretical studies to reduce the cost of energy consumption in the operation of engineering systems and electrical equipment of intelligent buildings and structures, and as a result, reduce the negative impact on the environment, in conditions of intensively changing quantitative and structural parameters of intelligent hardware changes in the historically established target-forming zones, there have become federal and regional targeted programs for the modernization of the energy system we are in the framework of the program «Smart City».

Formulation of problem. The lack of uniform requirements for technical equipment and the creation of intelligent automatic systems of mining enterprises leads to confusion in concepts simultaneously with the advent of new equipment and software. The task of the need for scientific substantiation and creation of a methodology for innovative technical and technological solutions to reduce energy costs during the operation of engineering systems and electrical equipment of intellectual buildings and structures in the current conditions of changes in quantitative, qualitative and structural parameters in large cities is set by the tasks of federal and regional targeted programs. The main objectives of the programs: improving the balance and efficiency of energy resources management in the operation of intelligent buildings and structures as part of the energy system that ensures the national interests of the country. One of the criteria for the transition to a new level of development of intelligent technical complexes of buildings and transport-

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technological machines of enterprises of the mining industry is the widespread introduction of continuous monitoring systems for their operation under various operating conditions. Such systems provide the possibility of intellectual interaction, for example, with individual vehicles, with a transport stream through information and telecommunication technologies in order to increase the efficiency of use [5, 13].

Based on the study [6], methodological foundations and proposals for the rational use and effective management of complexes of automatic motion control systems were developed based on the formation of a system for evaluating the performance of intelligent technical complexes. In modern conditions, it is necessary to ensure the effective implementation of motion control systems and to obtain a single concept aimed at improving the functioning of technical means of automatic fixation based on an assessment of their effectiveness. The formation of the foundations of the methodological basis and the improvement of technologies for the operation of technical means of control (TMC) at various levels will make it possible to substantiate a conceptual approach, as a result of which it will be possible to build an effective management system for the functioning of intelligent technical complexes.

The developed methods will allow to carry out institutional transformations, further development of the production of high-tech components and materials, introduce state standards that meet international requirements and ensure the improvement of scientific, technical and personnel potential. Operating experience of intelligent technical complexes of buildings and transport and technological machines of mining enterprises in foreign countries shows that the formation and implementation of technical solutions aimed at monitoring intelligent technical systems will increase significantly in the near future [1, 3, 6, 8]. These circumstances create an objective need to integrate technology-oriented management, in particular, the energy networks of buildings and structures of mining enterprises on the basis of a system-oriented approach.

Methodology. The basis of this approach is the provision on the relationship of the work of intelligent hardware and the resulting energy savings and the possibility of joint optimization of these processes. Models that link the work of intelligent hardware and the amount of energy costs are the normative-targeted basis for alternative implementations of scenarios for their improvement. Optimization criteria are based on summarizing technical and energy indicators of this process.

In the process of managing the energy resources of intelligent buildings and vehicles, three hierarchical levels can be distinguished: regional mega level, local macro level and individual micro level (Fig. 1). At each level, the process of managing energy resources is optimized by the following criteria: the volume of automation systems that allow efficient control of technical systems in the fifth period should not contradict the continuing trend of increasing energy consumption in the subsequent period $n + 1$; the amount of energy costs should not be larger than the maximum allowed.

The process of creating and using automatic information and telecommunication systems for controlling the movement of transport and technological machines is inevitably associated with the problem of evaluating their effectiveness. This raises a number of complex issues, due to the specifics of the tasks for which this object is designed. In the course of the study, positive results were analyzed and possible solutions for the identified problems were proposed. Of particular relevance are issues related to the development of criteria for evaluating the management of structures and organizations that ensure the functioning of the TMC on the basis principles and provisions of the theory of decision making. The developed sequence of studies on monitoring and management of automation systems and traffic control in road transport will provide optimal solutions for the effective use of TMC control systems layed on the criteria-based approach (Fig.2). As a result of the effectiveness evaluation, directions are being developed for improving the systems for controlling the movement of vehicles [2, 7, 10, 15].

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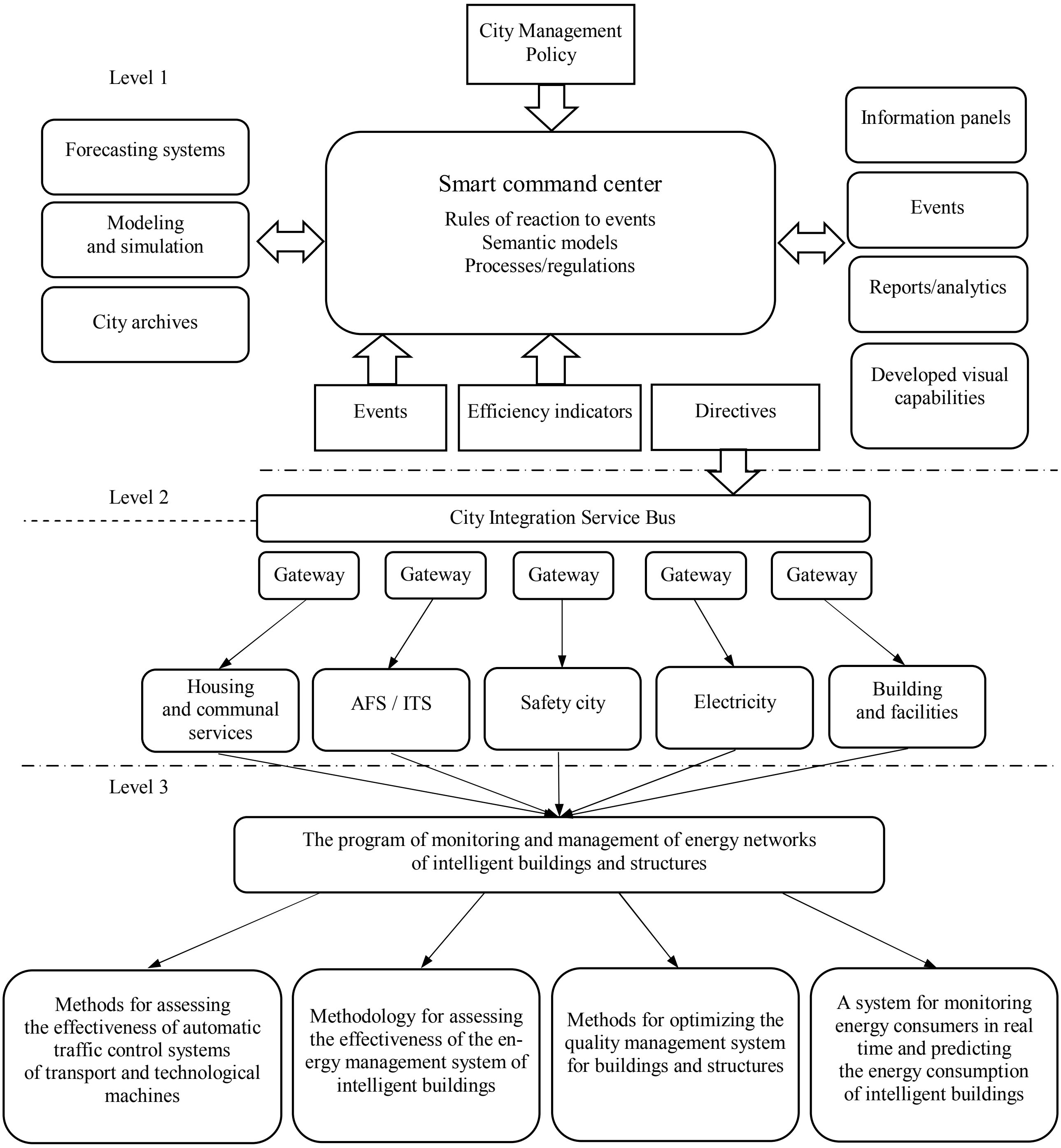

Fig.1. Hierarchical levels of monitoring and management of intelligent technical systems

One of the prospects for the development of the AFS (automatic fixation system) is the introduction of new complexes on the roads of the Russian Federation with high traffic intensity; it is planned to install in addition stationary photo-video recording complexes. In accordance with the system methodology, it is advisable to present traffic control complexes in road transport as intersections of the following systems: technological structure (infrastructure facility); technological system of manufacture (assembly); infrastructure facility – operators; technical maintenance and repair; infrastructure facility – the natural environment; infrastructure facility – vehicle.

To assess the effectiveness of the functioning of photo and video recordings of administrative offenses in the road and transport sphere, when interacting with the objects of the *i*-th system, it is advisable to use the criterion [12-14]

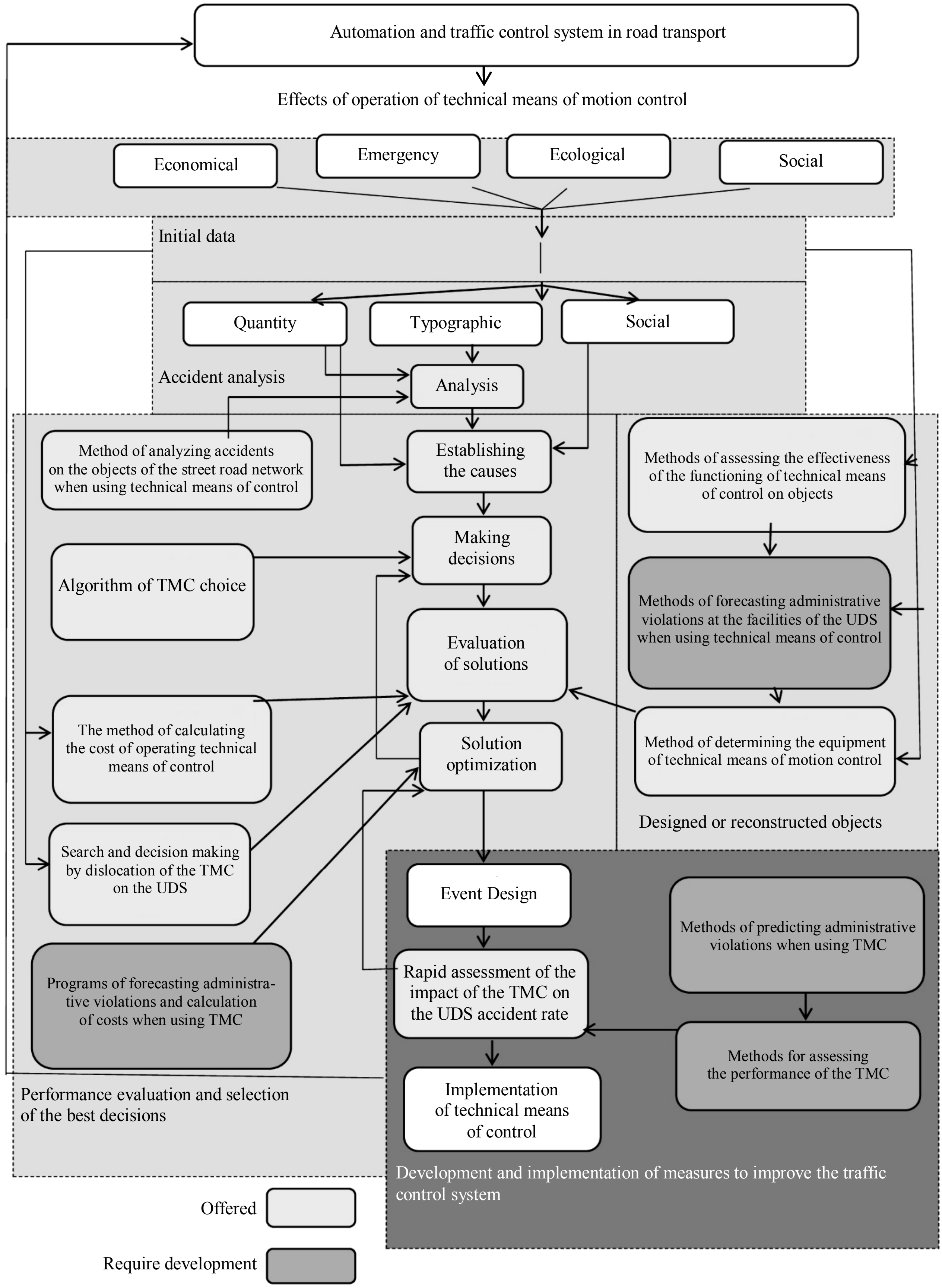

Fig.2. Functional diagram of scientific and methodological studies of monitoring and control of automation systems and traffic control in road transport

$$K_{\mathrm{E}i} = \frac{\{\mathrm{E}(+)_{ij}\}, \{N_{\text{ен}ij}\}}{\{\mathrm{C}_{sij}\}, \{\mathrm{E}(-)_{ij}\}},$$

where {E(+)}, {E(–)} – a set of positive and negative effects from the functioning of the complex at the considered stage, from a systemic point of view, a positive effect is characterized by an increase in the level of monitoring, a negative one by a decrease in the level of vehicle traffic control and, accordingly, an increase in road traffic accidents with all the ensuing consequences; C_s – the aggregate of the system's costs of operating the complex and maintaining it in a workable condition, reduced to the form of an economic indicator; N_{en} – a set of types of entropy of the system, neutralized by traffic control complexes in road transport, i.e. reducing the level of road traffic accidents, reduced to the form of an economic indicator.

The task of assessing the effectiveness of the functioning of traffic control systems on an automobile transport is multicriteria. To solve this problem, it is often used to rank all the criteria presented. In this formulation, the importance of each optimization task should be determined by the degree of its impact on society (increased road safety) and evaluated by an objective indicator – the rank of the influence of the *j*-th private direction of optimization relative to the most priority option R_{sj}/C_1.

Then the efficiency of using the optimization resource (no worse than usual) and aesthetic (compliance of the complexes with the applicable standards) expediency can be assessed by dependence:

$$f_{0,1t}, \Sigma = \left\{ \begin{array}{l} \sum_{i=1}^{n_{tk}} \left[K_{efi} C_1 \to \left\{ 1 - \sum_{i=2}^{4} R_s C_j / C_1 \right\} (\max C_1) \right] \\ K_{ef} C_2 \to R_s C_2 / C_1 R_\alpha C_2 (\max C_2) \\ \sum_{i=1}^{n_{op}} \left[K_{ef} C_3 \to R_s C_3 / C_1 R_\alpha C_3 (\max C_3) \right] \\ K_{ef} C_4 \to R_s C_4 / C_1 R_\alpha C_4 (\max C_4) \end{array} \right\},$$

where n_{tk}, n_{op} – number of communication channels with functional objects and operators; $R_\alpha C_i$ – indicator characterizing the efficiency of using the optimization resource in the *i*-th direction.

As optimization resources, various schematic solutions are considered, involving the use of mobile and stationary photo-video recording, the choice of location, etc. The rank of social influence of the *i*-th direction (level of accident rate reduction) optimization is determined by the dependence

$$R_S C_i = \frac{N_s C_i \eta_s C_i}{N_s C_1 \eta_s C_1},$$

where $N_s C_i$ – the number of social groups affected by the level of efficiency of the *i*-th functioning of traffic control complexes in road transport; $\eta_S C_i$ – specific share of the impact on the interests of a member of a social group on the level of effectiveness of the *i*-th functioning of the TMC system

$$\eta_S C_i = \frac{V^j_{\Delta K_{ef}} C_i}{\Sigma v^j},$$

where *j* – determining factor of influence (economic, social, etc.); ΣV^j – a set of impacts to reduce accidents during the implementation of *j*-events (for example, for a year).

These impacts are realized through economic indicators: $V^j_{\Delta K_{ef}} C_i$ – impact volume, depending on the level of TMC functioning efficiency; $N_s C_i$ – social group quantity; $\eta_s C_i$ – specific share of the impact of technological impact areas of optimization, for which $R_s C_i = 1$, determined by an expert survey of specialists.

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To assess the influence of various factors of functioning of mobile and stationary complexes of automatic motion control systems on the efficiency of use in individual regions of the Russian Federation, a multiple regression analysis was performed. The analysis shows that the most influential factors are: population of the region ($x_{11}\cdot10^6$, ppl.), from which on 88,4 % depends on the efficiency of the TMC; traffic density in the region (x_9, pc./km^2); road length (x_{10}, km) and territory of the region (x_{12}, km^2). Some factors are correlated, for example, the amount of fines paid ($x_2\cdot10^5$, rub.) and a specific indicator characterizing the ratio of the number of vehicles to the number of administrative offenses issued (x_1, vehicles per unit.), have a relationship estimated value of 0,96. Almost all factors have a positive correlation with the performance parameters of the TMC.

Factors number of mobile TMC (x_6, pc.); road length (x_{10}, km) and territory of the region (x_{12}, km^2) have a negative correlation with the performance parameters of the TMC, their increase leads to a decrease in the number of road accidents. An analysis of the influence of factors was carried out in the Statgraphics program: population density in the region (x_8, ppl/km^2), traffic density in the region (x_9, pc/km^2) and territory of the region (x_{12}, km^2) on the performance of the TMC. All coefficients are statistically significant and 94.4 % describe the effect on the dependent variable. As a result, a mathematical model was defined as:

$$y = 1326.05 - 1.09546x_8 + 10.5527x_9 + 1033.04x_{11}.$$

The degree of influence factors have the following hierarchy: x_{11}, x_9, x_8. The impact on the efficiency of the functioning of the TMC of the factors of the specific indicator characterizing the ratio of the vehicle number on the number of administrative offenses issued (x_1, vehicle per unit), amounts of fines paid ($x_2\cdot10^5$ rub.), the number of stationary TMC (x_3, pc.) and population density in the region (x_8, ppl/km^2) simulated by dependence:

$$y = 2379.24 + 1543.63x_1 - 3.9134x_2 + 9.4035x_3 + 1.0307x_8.$$

The statistical parameters of the resulting model are presented in the table.

The obtained mathematical dependences show the relationship between the number of traffic accidents and the various factors x_1, $x_2...x_n$. These factors affect managerial, technological and methodological aspects of the problem of increasing traffic safety. The analysis of the model obtained shows that the main contribution to the accident rate is made by the number of registered vehicles in a particular region x1. This factor is taken into account in the model through the standard indicator – the number of vehicles per one automatic device of the motion control system. The recommended provision of the region with TMC vehicles is one complex for 6.5 thousand registered vehicles [15].

Research results. The operation of the TMC covers several stages, the totality of which is called their life cycle. In the general case, the term life cycle refers to a certain evolution, a period of time and a set of activities that change the state of the system under consideration from the start of operation to the end of its operation. At each stage of the developed TMC life cycle, a certain set of tasks, methods for their solution and a set of technical solutions arise. In this case, for each stage, the initial are the circuit solutions adopted in the previous study. The life cycle schedule of the functioning of the TMC includes four stages (Fig.3):

I. «Local Impact», on which the number of TMC complexes increases and their work is debugged. At this stage, there is a noticeable increase in the identified administrative violations in the road transport sector, while simultaneously reducing the accident rate at the installation sites of the complexes [2, 10, 15].

Statistical parameters of the mathematical model

Parameters	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	2379.24	377.889	6.29614	0.0243
x_1	1543.63	193.139	7.99232	0.0153
x_2	−3.91341	0.472106	−8.28924	0.0142
x_3	9.40355	3.09578	3.03754	0.0934
x_8	1.0307	0.153725	6.70487	0.0215

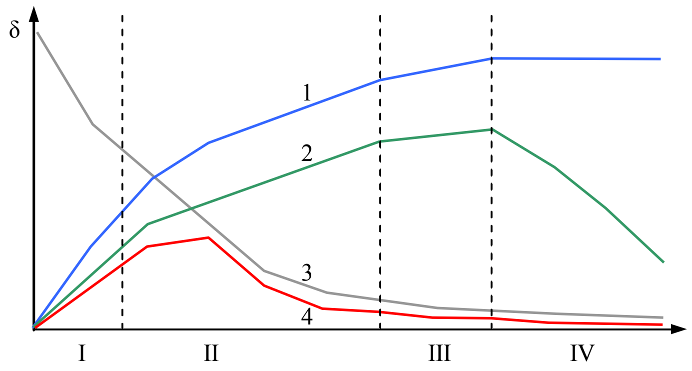

Fig.3. Schedule life cycle of the functioning of the TMC

1– AFS; 2 – the number of decisions by the Center for automated fixation of administrative offenses; 3 – δ coefficient; 4 – accident rate

II. «The beginning of systemic influence», where the TMCs go to a stable level of functioning. The number of automatic systems is constantly increasing. To improve the performance of the TMC, it is possible to install dummies and signal simulators, while in the places of their use it is necessary to periodically use existing photo and video recording complexes.

III. «The period of growth of systemic influence of automatic motion control systems». After a certain increase, a gradual decrease in the number of detectable administrative offenses begins, as the level of awareness of drivers about the ubiquitous control over the movement of vehicles increases. The increase in the number of TMC continues.

IV. «Period of stable operation of the TMC», during which stabilization of all indicators of the functioning of the complexes occurs. The number of TMC reaches the optimal value and the further increase in the number of complexes is impractical. The objectives and goals of their application, as well as the functionality of these complexes, must change. Of great importance is the further development of the interaction of TMC with intelligent onboard vehicle systems (IOVS).

Based on the analysis, the proposed development scheme for multi-purpose systems for the automatic control of vehicle movement, which can be represented as the following formalization [11]:

$$W_1 = \longrightarrow W = f(F_1, F_2, F_3, F_4, F_5, F_5, \; F_6, \ldots, F_n),$$

where W_1 – function of current parameters; W – function of those parameters that you want to strive for (prospective).

An algorithm has been developed for assessing the impact of means of automatic fixation of traffic violations on accident rates (Fig.4), where the following notation is used: C_{mt} – the cost of maintaining the performance of the TMC, rub.; C_m – the cost of one TMC movement, rub.; η_{mt} – rate of deductions for maintenance and technical repair of TMC per year, %; AS_{ku} – assembly, installation and configuration of TMC, rub.; Sal_{op} – operator salary, rubles.; Sal_{tech} – technicians salary, rub.; Sal_{dr} – drivers salary, rub.; P – number of TMC, units.; C_{inst} – the cost of installation works, including labor costs and other expenses, rub.; C_{am} – annual maintenance cost, rub./year; i – interest rate, %; n – service life, year; SI_{CLCT} – specific capital investments for the construction of the line of control traffic, rub.; $SI_{inst\ afs}$ – specific capital investments for installation of TMC, rub.; k_2 – cost increase ratio for TMC; C_{rs} – the cost of a road sign, rub.; $C_{inst\ rs}$ – the cost of installation of a road sign, rub.; m – number of road signs, units. D^s_{acc} – damage from an accident before the start of the operation of the TMC, rub.; N^s_{acc} – the annual number of accidents before the start of operation of the TMC, units.; D^{in}_{acc} – damage from an accident after the start of operation of the TMC, rub.; N^{in}_{acc} – the annual number of accidents after the start of operation of the TMC, units; δ_1, δ_2, δ_3 – coefficients that take into account the effect of TMC on traffic safety.

The introduction of a «correlation fixation system» allows us to evaluate in practice the effectiveness of using different TMCs, as well as the degree of their influence on the accident rates. The formulated scientific and technical problem is solved using methods and software tools that implement the developed system criteria [9].

Conclusion. With a comprehensive solution to the problem of reducing costs, there is a need to assess the effectiveness of the functioning of intelligent technical systems., both in the process of operation of engineering systems and electrical equipment of intelligent buildings of mining enterprises, as well as transport and technological machines based on the construction of three-level op timization models. A unified database is needed, formed in terms of the subject area at all levels

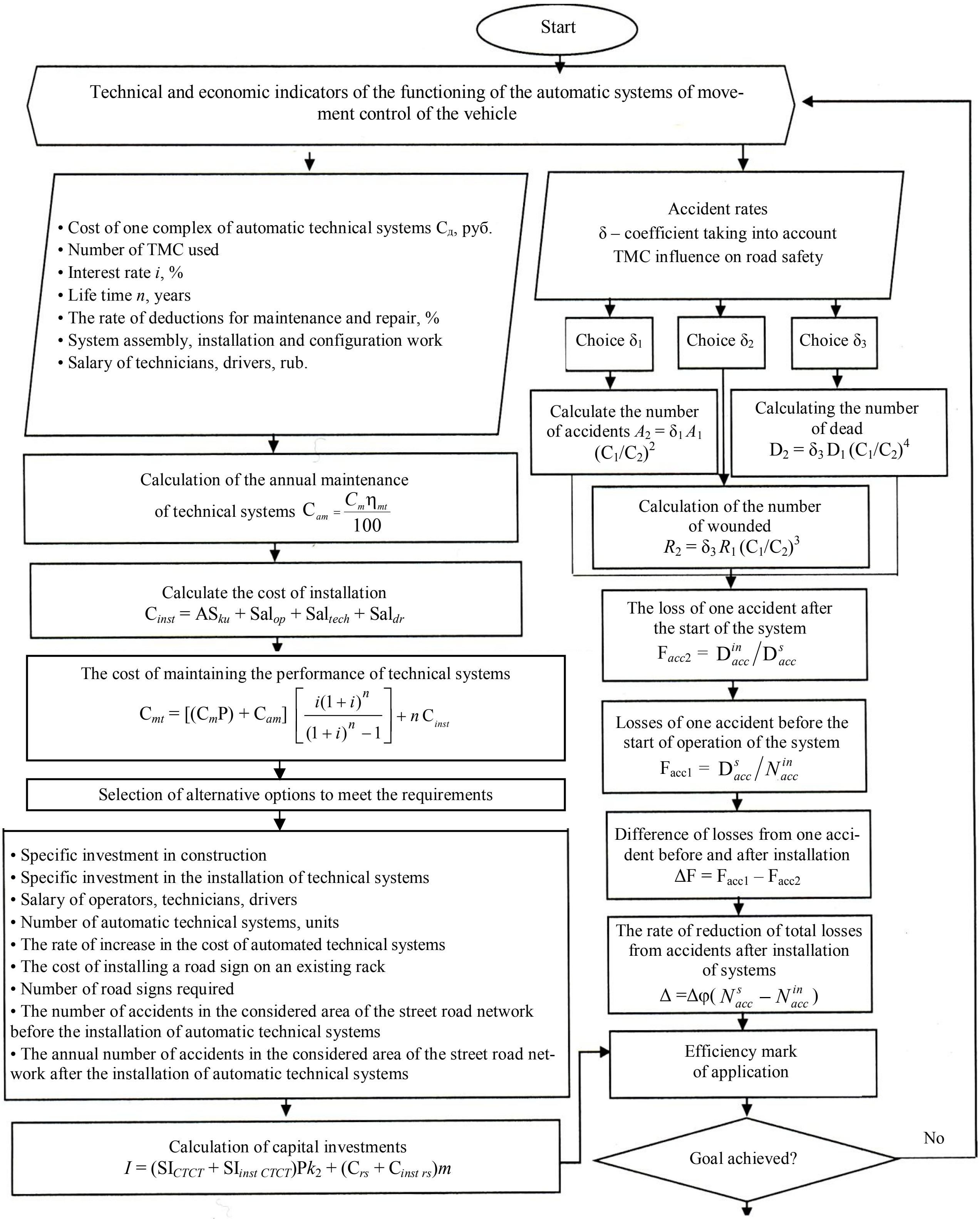

Fig.4. Flowchart for assessing the effectiveness of the use of automatic TMC

of the management process, providing an opportunity for a systematic analysis of the situation development. The formed server center for reducing the costs of energy consumption during the operation of engineering systems and electrical equipment of intelligent buildings, monitoring the technological process of applying intelligent technical systems as part of the automated information system (IAS) of a single database should ensure the possibility of collecting generalized information and its formation in the three-level domain concepts process of energy management and system analysis of the cost and situation and in the region both in the process of operation of engineering systems and electrical equipment of intelligent buildings of mining enterprises, as well as transport and technological machines based on the construction of three-level optimization models. A unified database is needed, formed in terms of the subject area at all levels of the management process, providing an opportunity for a systematic analysis of the situation development. The formed server center for reducing the costs of energy consumption during the operation of engineering systems and electrical equipment of intelligent buildings, monitoring the technological process of applying intelligent technical systems as part of the automated information system (IAS) of a single database should ensure the possibility of collecting generalized information and its formation in the three-level domain concepts process of energy management and system analysis of the cost and situation and in the region.

Output. As a result of the research, targeted approaches to improving the functionality of the monitoring and control system of intelligent technical systems of buildings and transport and technological machines of enterprises of the mining industry have been identified. Criteria are proposed for the efficiency of functioning of automatic systems for controlling the movement of transport-technological machines, taking into account the probable nature of the system-forming factors. The characteristic of the stages of the life cycle of the automatic systems of motion control systems, taking into account the features of their operation, which predetermined the method of optimal application of technical means of control in the field of providing control and supervisory functions during the operation of vehicles, resulted in a relationship to determine the financial costs of maintaining the complex during the entire service life. The scheme of scientific and methodological research on the improvement of automation systems and traffic control in road transport is substantiated in order to determine the promising directions for the formation of control functions during the movement of vehicles based on the use of intelligent automated systems.

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