The software adaptive system for managing the heavy cargo transportation process based on the automated vehicle weight and size control system

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Abstract: The article presents the results of research on the software adaptive system for managing the transportation of heavy loads through the automated weight and size control in order to minimize the adverse impact of motor vehicles on the roads by creating an information center for managing heavy loads, identifying factors at all stages of the transportation process, searching for an optimal solution for every stage, automating the heavy load transportation planning process and reducing the impact on roads.

1. Introduction
A significant factor affecting the efficiency of transportation of heavy and (or) bulky cargo (HBC) is a significant number of restrictions on highways related to the cargo weight and size. The Federal target programs, the List of orders of the President of the Russian Federation and road maps of the Government of the Russian Federation created the objective need for scientific substantiation and creation of an adaptive weight and size control system based on innovative technical, technological and optimization solutions for the delivery of heavy cargo in order to reduce the cost of transportation and adverse impacts of vehicles on highways.

2. Materials and methods
The modern approach to optimizing the planning of HBC transportation by road vehicles is based on the complex interrelation of many factors. Mathematical modeling (MM) of these processes is the basis for the software-adaptive control system for the transportation of heavy cargo, which is based on the systematic approach (Fig. 1). As information on the bearing capacity of the road, vehicle design features and other factors affecting the efficiency of the transportation process becomes available, the model is optimized. The limiting conditions for the development are the cost and time factors [1,2].

At the stage of technical solutions and recommendations for the formation of a software-adaptive control system for the transportation of heavy cargo, the study of the correspondence between the bearing capacity of the road surface of the AD and the design parameters of the vehicle is carried out. At the same time, the calculation and refinement of the route are carried out based on the differentiated amount of damage, calculated from the real impact of the vehicle on the HELL in order to check the feasibility of the principles substantiated at the previous stage. Taking into account the results of mathematical modeling of the influence of factors on the efficiency of the transportation of...
heavy cargo, the route along the roads with the highest strength parameters and the smallest values of road damage is determined.

Figure 1. The generalized model of the software-adaptive control system for the transportation of heavy cargo based on the automated weight and size control of vehicles
3. Results and Discussion

![Theoretical calculation of axial loads](image)

Figure 2. Interface of the software computing module for calculating the amount of damage

The interface of the information system is shown in Figure 2. To identify vehicles in control systems of technical means, it is necessary to combine real-time systems into a single system. This circumstance determines the hardware structure of the system, methods of ensuring reliability and survivability, and resource allocation. Difficulties arise in the implementation of real-time systems when integrating them into a single system, which provides the simultaneous solution of a large number of dissimilar problems when the vehicle is moving, which determines the requirements for the automation systems used for controlling the movement of vehicles in real time. It is necessary to develop automated control systems based on the microprocessor technology. This allows us to automate technical processes in road transport, integrate control systems of technical means for controlling the movement of vehicles, and solve a wide range of tasks for the rational use of robotic and traditional vehicles:

- adaptive control in real conditions;
- development of proposals for the optimal control of technical means in normal and extreme conditions, etc.

The existing methods of identification of a motor vehicle have a number of drawbacks. Therefore, a new identification method based on the developed system of automatic control of vehicle movement the QR code matrix (application for invention No. 2018114847 of 22.10.2019 Bul. No. 30) is required. It can solve the problem of segmentation of license plates and plates of different formats (signs such as a QR code with a different number of characters). There are two main goals: to recognize segmented characters from the same input sets of the same size without overlapping letters and sets of numbers; to recognize non-standard characters based on the mixed method of templates, the degree of compliance). By testing 100 samples of patterns and signs, experiments and photographs taken in real conditions, this method gives a recognition accuracy of 80.4%; for work with a mixed type it takes 1.7 seconds, and for matching patterns - 0.75 seconds to perform the recognition operation when determining the factors of adequacy of the mixed method. The block diagram of the system is shown in Figure 3.
The system of automatic control of vehicle movement uses a matrix QR code, in which a converter, an interrogator and a transceiver are sequentially connected between the Internet output of the vehicle identification system camera via the selected radio channel to the Internet with the subsequent prompt delivery of transmitted information to users. The system of automatic control with a matrix QR code can be used to transmit operational information about the vehicle axle load during movement, available permits, the current route, road payments.

Among the optimal transportation plans, there is a support solution to the system of constraints using the simplex method. If the optimal plan is unique, it coincides with a support solution. Based on the previously found support solution, we calculate a new support solution, on which the value of objective function $F$ is not less than on the old one. They do the same with a new admissible basic solution until they find a solution that is optimal [5,6]. The linear programming task is to find the values of $n$ variables $x_1, ..., x_n$ that provide the extremum of the function.

When solving the system of equations of the simplex method, it was found that the cost of the transportation process along the route specified by the system is 61% less than the cost of the transportation process along the rejected route (in the absence of a control system). During the transportation process with a traffic control system, the ATC transport operation also has less flight time than in the absence of a system, that is, productivity increased by 57%.

To reduce the adverse impact of vehicles on highways, it is proposed to create an information center for managing heavy cargo transportation, which has a single database - a server center for reducing the adverse impact of vehicles on highways for monitoring road HBC transportation (Fig. 2). The center should collect generalized information, its formation in terms of the subject area of three levels of HBC transportation and systematic analysis of the amount of damage to the road network[3,4,5].

The information for SCNVAD AKTP as a component of the intelligent transport system can be collected using data of regular inspections of the technical condition of the vehicle, upon receipt and renewal of the route license based on the results of operational monitoring of the highways by mobile laboratories, control of HBC transportation using the navigation information of the GLONASS / GPS system. The accumulation of such data is required for the implementation of many types of transport planning. It can improve the validity of management decisions and predict the effect of implementation of oriented technologies into the HBC transportation process.
Baseline parameters for assessing adverse impacts of road vehicles and criteria for evaluating the efficiency of transportation of large heavy cargo (intensity of traffic flows, mass and characteristics of large heavy cargo, vehicle, driver's staff)

Figure 4. The structural and functional diagram of the automated information center for managing the transportation of large heavy cargo

4. Conclusion
The method for controlling motor vehicles solves the problem of increasing the efficiency of vehicle movement monitoring by ensuring the transfer of variable data from the vehicle to the multifunctional automated control system. Compared to other methods, which are not able to recognize all types of license plates and symbols, the method is capable of recognizing all types of signs. The method of the automatic identification system shows high performance for the real-time recognition system. Most of the previous works were based on one method: template matches or neural networks, which are ideal for recognizing some species, but do not recognize other ones. The quantity and quality of recognition should affect the identification performance. The model of the software adaptive control system for the transportation of heavy cargo made it possible to establish the main factors that have a serious impact, search for an optimal solution and automate the planning process, as well as to use innovative methods in organizing transportation, to predict the effect of oriented technologies implemented into the HBC transportation process. Thus, when implementing the software-adaptive system for managing the HBC transportation process, it is expected to improve the quality of services, reduce the cost of HBC transportation on federal and regional highways that meet the international standards and rules and decrease operating costs by 25-30%.
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