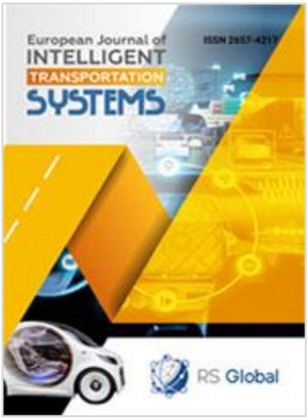

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ENSURING CONSISTENT TRAFFIC MANAGEMENT THROUGH INFORMATION SUPPORT ON ROAD APPROACH SECTIONS TO MAJOR CITIES

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ABSTRACT

An increase in the number of vehicles results in higher traffic flow intensity and density, which affects the emergence of an inefficient, congested and potentially dangerous traffic regime. Under such conditions, the management of individual vehicles does not provide effective control over the functioning of the transport system as a whole. In addition, the modern needs to adapt to growing demand through the implementation of intelligent control subsystems capable of monitoring, analyzing, and performing real-time traffic control.

The growth in the intensity and density of traffic flows affects the likelihood of traffic accidents and congestion and, as a result, increases travel time. Therefore, there is a need to create a specialized control subsystem capable of managing traffic flows, analyzing them, assessing the current state of the transport system, and predicting further developments. To create such a subsystem, it is necessary to analyze and study traffic flows in more detail, create a simulation model to understand the problem and the algorithm of actions to solve it.

The article substantiates the necessity of creating such a subsystem for the sections of highway approaches to large and major cities. The stages of building a traffic simulation model are presented, the principles of the control process of algorithmization are considered, as well as the use of PTV VISSIM software for real-time simulation.

KEYWORDS

Traffic Flow, Traffic Speed, Traffic Intensity, Highway Sections, Major and Most Significant Cities, Intelligent Transportation Systems, Traffic Safety

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Problem statement.

Intensity, density, speed significantly affect the state of road transport infrastructure. Congestion of roads affects the occurrence of traffic jams, road accidents, the environment and the country's economy. Solving such a complex problem requires detailed analysis, research, and modeling of traffic flows, taking into account various situations. Therefore, there is a need to create an automated traffic management system on the sections of highways approaching major and the most significant cities that will carry out real-time traffic management.

One of the most promising algorithms for solving problems related to the rational operation of road transport and improving road safety is the use of modern methods and means of traffic management, primarily automated traffic control systems or intelligent transport systems.

Analysis of recent research and publications.

Many scientists and scholars have been working on traffic management to improve road safety. But given the annual growth of traffic flows, the problem remains unsolved.

The purpose of the study.

To develop a methodology for consistent traffic management through information support on the sections of the approach of highways to significant and most significant cities.

Summary of the main material.

Traffic management is carried out in several stages, including collecting, transmitting and processing information about the state of the road conditions-traffic flows system, assessing the existing state of the system, predicting possible states of the system, selecting the optimal solution, and implementing the selected solution.

Collecting and processing information, making a decision, transmitting and presenting the decision to the automated traffic control system provides the possibility of practical implementation of the control stages, while the mathematical support subsystem solves the most important tasks from the point of view of the control strategy of assessing the state of the control object, its forecast and making a decision on the control method. Therefore, to ensure the possibility of programmatic implementation of operational control in an automated traffic management system, it is necessary to develop mathematical support for traffic management. Consider this issue from the point of view of the general principles of simulation modeling of control systems. [1].

Simulation modeling of traffic flows allows you to explore scenarios of system operation without the need for a full-scale experiment, which ensures safe, economical and prompt decision-making. The simulation helps to form an idea of the process structure, determine its key characteristics, and identify critical points of the system. It is a convenient and easy-to-use tool for understanding and verification. Traffic simulation helps to find optimal solutions for traffic management and provides a clear understanding of the system as a whole and helps to determine and see the level of complexity [2,5].

Within the framework of the functioning of an automated system, modeling is the main apparatus for theoretical description of the traffic control process. If it is practically impossible to conduct experimental studies of the process of operational control in automated systems, then only modeling makes it possible to solve the problems of this study.

When studying any process by modeling, it is necessary, first of all, to build a mathematical model of the process under study. A mathematical model of a real process (system) is a formally described object that can be studied by mathematical methods, including simulation modeling. A mathematical model of the system functioning process is understood as a set of expressions (formulas, equations, inequalities, logical conditions, elements, etc.) that determine the characteristics of the system states depending on the system parameters, input signals, initial conditions and time [7].

Depending on the method of construction, the following groups of models are distinguished: mathematical, simulation, information, situational, linguistic, and physical [5].

Mathematical models are formed in the form of equations and other structures written in the language of mathematics. Simulation models describe the object of modeling in the language of algorithms, which can include both mathematical statements and some informal processes, including decision-making processes.

The mathematical support subsystem makes a decision on the feasibility of using operational control, as well as on the scheme of its practical implementation in given road conditions, and information about this is broadcast on variable information displays in the form of appropriate recommendations.

To implement the decision on operational control at the next stage, it is necessary to develop rational control actions for the given traffic parameters, which should be transmitted in the form of appropriate signals of information display devices at the control points of the automated traffic control system.

To model the traffic in the PTV Vissim software environment of the operational traffic management process, specified by the above information, it is necessary to build an appropriate modeling algorithm. An algorithm is a precise instruction that defines a computational process that starts with arbitrary input data (from a certain set of possible input data for a given algorithm) and is aimed at obtaining a result fully determined by these input data.

Evaluating the feasibility of applying control influences in an automated traffic management system is a critical stage in the decision-making process in the event of critical situations. This stage involves determining whether the detected situation really requires active intervention by the control system, or whether the existing traffic parameters may enable autonomous stabilization of the traffic flow without intervention.

Determining the feasibility of imposing control actions:

$$S(t) = \{q(t), v(t), d(t), w(t)\} \quad (1)$$

where q(t)– lane traffic intensity, cars per hour;

v(t)– lane speed, cars per hour;

d(t)– density of traffic flow, cars per hour;

w(t)– weather conditions

On the other hand, from a mathematical point of view, each of the elements contains a certain independent group (block) of elementary operations, the volume of which can be quite large, after performing these operations, some quantitative indicators should be obtained that are necessary for making a separate management decision or a direct management decision (order, command, recommendation).

The main elements of the algorithm consist of “Assessment of traffic conditions in the operational control area”, “Determination of a critical situation”, “Determination of the feasibility of imposing control influences to resolve this critical situation”, “Selection of a method for implementing operational control in given road conditions”, “Formation of control influences in the automated traffic control system”, “Transmission of commands to the subsystem of operational traffic control”, “Control of compliance by the driver with the management instructions of the automated traffic control system”.

In the further study, simulation models of traffic flows in case of critical situations on the sections of the highway approach to the major and most significant cities of their implementation will be formed for each of the above main stages of the management process.

It should be noted that the tasks implemented at the first stages of the automated traffic control system implementation are more related to the information than to the mathematical support of automated traffic control systems, while the latter includes only algorithms and methods for implementing complex mathematical control methods [1].

In the world practice, well-known software products for simulation modeling in the field of traffic flow organization are widely used. Among such programs are VISSIM, developed by PTV AG from Germany, and GETRAM/AIMSUN. The considered modeling systems perform the function of displaying in real time the reaction of traffic flows to the impact of traffic lights, which is the result of the chosen management strategy. Therefore, the efficiency of organizing uniform traffic on the sections of road approaches to major and the most significant cities was determined in the PTV VISSIM software environment, this product is designed to simulate the movement of individual vehicles and traffic flows in settlements and outside them. PTV VISSIM simulation software greatly facilitates the designer's task by providing a reliable basis for the development of road transport and urban infrastructure projects [4,5].

The main advantages of simulation modeling are: acceleration of problem solving; possibility of solving problems that cannot be solved analytically; research and simulation of traffic flows without field experiments; prediction of traffic flow behavior; obtaining a large amount of various information; study of probabilistic behavior and interaction in the flow of vehicles; possibility of reproducing any situations (real and hypothetical); possibility of studying traffic flows on the approach sections of highways. [3].

As the traffic flow on the approaches to the city approaches urban traffic conditions, i.e., dense traffic flows, the likelihood of road accidents increases. Based on the analysis of accidents in these areas, we can conclude that a significant number of road accidents occur, such as “ Crash” [8,10].

During the study to determine the impact of road conditions on the characteristics of traffic flows on the approach section of the highway M-06 Kyiv – Chop to the city of Kyiv, a simulation model of traffic flows on the section of this road was developed, which will allow determining transport and operational indicators.

A specific section of the approach of the M-06 highway to the city of Kyiv, which is a public road of national importance, was selected for the study.

This section of the road has an asphalt concrete pavement. This section has intersections and junctions at the same level.

The main transport and operational indicators that describe the conditions of traffic flow on roads are: intensity, traffic flow composition, and speed [6,11,12]. The analysis of the average daily hourly and peak traffic intensity on the road showed that the most congested areas are the sections of the road approach to the city of Kyiv during peak hours. During peak hours, the intensity of traffic flow increases, and the state of traffic flow moves from free conditions to partially bound and bound [9,13]. This affects the likelihood of traffic accidents and, as a result, the formation of traffic jams. It is possible to influence the traffic flow by controlling the speed of traffic on a certain section of the road approach to the city of Kyiv.

In some cases, when modeling a road network with a large number of runs and intersections, the size of the matrices cannot exceed the capabilities of the software. Thus, the capabilities of PTV VISSIM software allow you to generate data with a size of no more than 10000 x 10000 meters.

The initial data for creating the model was the section of the highway approach to the city of Kyiv, which is characterized by: roadway width, m; number of lanes; traffic flow intensity, vehicles/hour; traffic flow composition; presence of intersections and U-turns for oncoming traffic flows (Fig. 1).

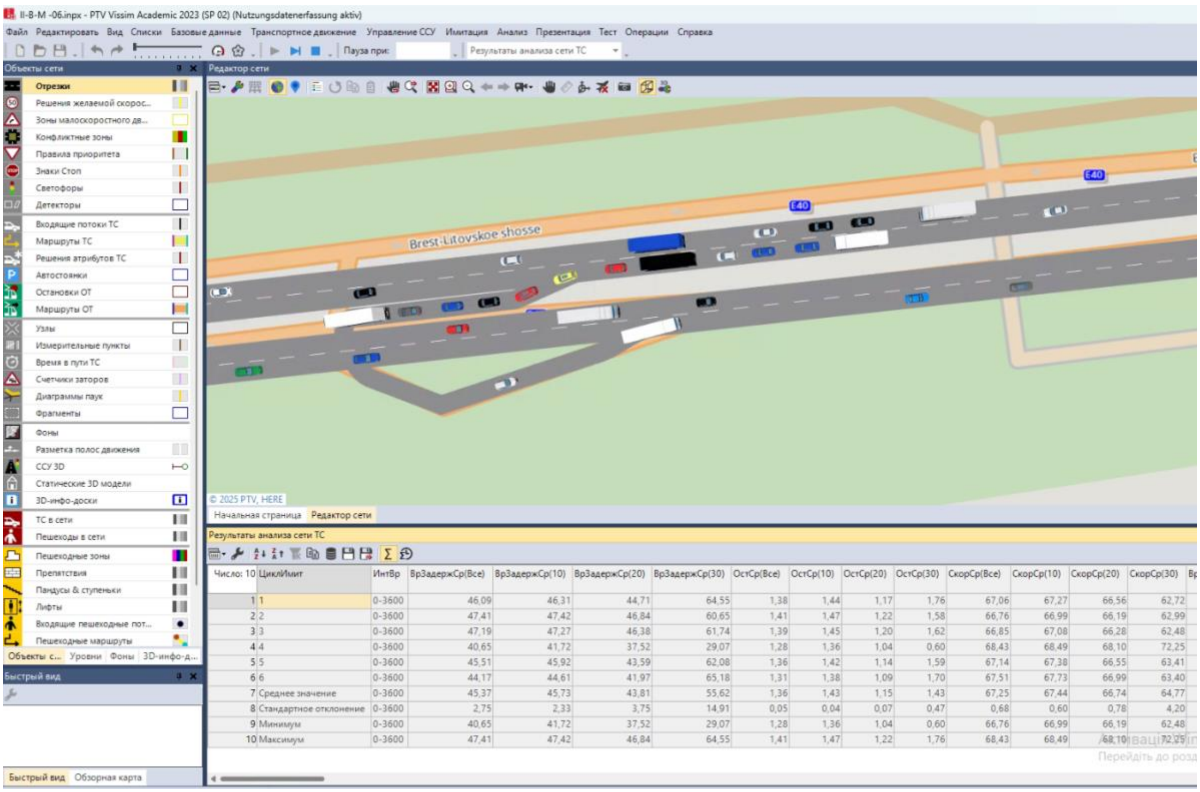

Fig. 1. *Distribution of traffic flows at turning points for oncoming traffic*

The construction of a simulation model on the road approach section to the city of Kyiv in PTV VISSIM is performed in the following sequence:

1. Construction of the road approach section: reconstruction of road segments, intersections, organization of oncoming traffic, creation of places for turning oncoming traffic flows, creation of transitional high-speed lanes, road markings.

2. Entering a traffic flow: setting traffic intensity, vehicle composition, routes of traffic flows; entering priority rules in conflict zones.

3. Displaying the results of modeling analysis. After the model has been reproduced and the traffic flow parameters have been set in the PTV Vissim software environment, a number of data can be obtained to analyze the work performed. That is, you can not only visually evaluate the modeling results, but also obtain data for analyzing the modeling results, on the basis of which you can form reasonable conclusions.

To get the correct data for analysis, you need to configure the model configuration parameters in the Analysis/Configuration tab. Without activating the required option, the analysis file will not be created.

Activate the necessary items in the simulation mode settings window, namely, “Vehicle entry”, “Vehicle network analysis”, “Network travel time”, “Delay time”, “Congestion counter”, “Nodes”, the simulation duration is 1 hour or 3600 s.

After entering the input data, it is important to check the correctness of the model and the information entered before proceeding to the calibration stage. This process is known as verification. The quality of input and initial model configuration significantly affect not only the complexity of subsequent calibration and validation, but also the possibility of performing them at all.

The first variant of the simulation modeling was the traffic flow on the approach section of the highway to the city of Kyiv under existing conditions. A 10 km long section was selected, where the speed limit is 110 km/h, and within this section there is one intersection of traffic flows at the same level and places for turning vehicles. When approaching the intersection and turning points, there are road signs for a gradual reduction in speed of 90 km/h - 70 km/h - 50 km/h.

According to the modeling results, under the existing traffic conditions, the expected average delay time of one vehicle within the control area is 40.84 seconds, the average speed on the area is 63.67 km/h, the average number of stops and parking lots is 8.85, and the total delay time of the entire traffic flow is 184,578 minutes.

The second option was a simulation modeling under the same road conditions, in case of critical situations. This option considered the blocking of one of the lanes as a result of a traffic accident or road repair work, or the passing of columns.

The simulation modeling of traffic flows in case of critical situations on the road approach to the city of Kyiv (option II) provided for similar conditions for the distribution of traffic flows.

According to the modeling results, under this option, the predicted average delay time of one vehicle increases to 45.54 s, its average speed decreases to 63.1 km/h, and the average number of stops and parking increases to 12.89 and the total delay time of the entire traffic flow to 257,940 s, respectively.

The third option was a simulation modeling under the same road conditions, in case of critical situations. This option considered the blocking of one of the lanes as a result of a traffic accident or road repair work, or the passing of columns.

Under this option, management was carried out at the place of the critical situation, while simulation modeling of traffic flows in case of critical situations on the road approach to Kyiv (option III) provided for similar conditions for the distribution of traffic flows.

According to the modeling results, under this option, the predicted average delay time of one vehicle decreased to 45.09 seconds, its average speed increased to 67.31 km/h, and the average number of stops and parking increased to 12.56 and the total delay time of the entire traffic flow to 220,110 seconds, respectively.

The fourth modeling option involved the implementation of management decisions aimed at controlling traffic speed in case of critical situations by placing variable information boards on the studied section of the highway approach to the city of Kyiv.

According to the simulation results, under this option, the predicted average delay time for one vehicle should be 37.57 s, its average speed on the section should be 68.83 km/h, and the average number of stops and parking should be 8.84 and the total delay time for the entire traffic flow should be 123,265 s, respectively. The results of the traffic flow simulation are shown in Table 1 and Figure 2.

Table 1. Results of Traffic Flow Simulation Modeling

	I variant existing traffic conditions	II the possibility of an obstacle to traffic in the existing conditions	III the possibility of an obstacle to traffic and the imposition of management decisions	IV option for implementing the proposed measures
Average speed on the section (km/h)	63,67	63,1	67,31	68,83
Average delay time (s)	40,84	45,54	45,09	37,57
Average number of stops and parking lots (pcs.)	9	13	12	8
Total delay time(s)	184578	257940	220110	123265

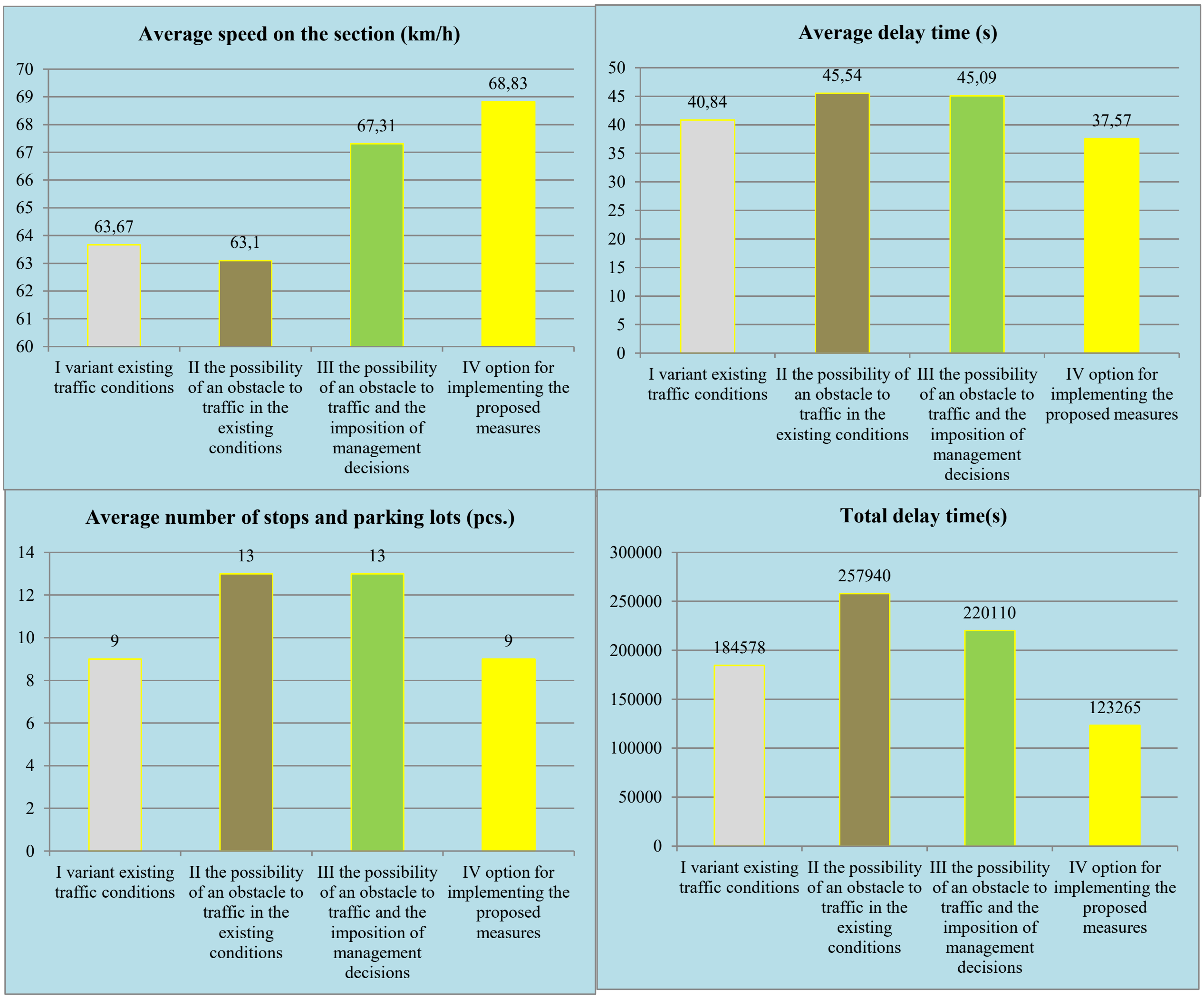

Fig. 2. *Results of simulation modeling of traffic flows*

In the context of existing conditions, it was found that the average speed is 50 km/h and the average delay time is 20.46 seconds. However, when an obstacle is encountered, the average delay time increases significantly to 156 s and the average speed decreases to 37 km/h.

Conclusions.

The results of the study have shown the effectiveness of using simulation modeling to substantiate and evaluate measures for operational traffic management in critical situations on the sections of the road approach to large and major cities. The proposed methodology, which is based on the use of information support within the automated traffic management system, ensures a reduction in traffic delays, an increase in the average speed of traffic and a more rational use of the existing road infrastructure.

The results of the study indicate the effectiveness of using simulation modeling to analyze traffic flows on the approach section of the M-06 highway to the city of Kyiv. The study included four variants of simulation modeling: traffic flows under existing conditions of the transport network (variant 1); in case of critical situations under existing conditions (variant II), in case of critical situations under existing conditions and imposing management decisions (variant III), and in case of implementation of the proposed measures (variant IV).

Simulation experiments performed in the PTV Vissim environment confirmed that the implementation of the proposed measures to control traffic speed in critical situations leads to an improvement in key transport and operational indicators: the average delay time decreased by 19%, the average speed increased by 5 km/h, and the total traffic delay time was significantly reduced compared to the baseline scenario.

Thus, the application of the developed methodology makes it possible to increase the efficiency of the “road conditions - traffic flows” subsystem in real time, which is an important component of the implementation of intelligent transport systems. Further research should be focused on formalizing algorithms for managing critical situations and their integration into software and hardware of the ACSDRS in order to ensure adaptive, dynamic and safe traffic regulation.

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