Modeling tracking the influence of factors on functioning of transport nodes

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Abstract. The research focuses on simulation modeling of the influence of factors on transport nodes. The utilization of electronic devices and sensors to track factors that are difficult to take into account by conventional methods is considered. The research emphasizes the importance of simulation modeling for the analysis of complex systems and offers the concept of applying modern technologies to accurately collect real data and create more realistic impact models. In the course of the research, current theories and developments concerning modern trends in simulation modeling were analyzed, areas that require clarification and additions were identified. In the experimental part, a simplified electronic circuit of a device for generating pulses, which is sensitive to the readings of real-time sensors, is proposed. The use of such devices can facilitate the collection of primary information about operational changes in the city's road network, the formation of data arrays for traffic management systems. The development is of significant importance for identifying stochastic factors in certain areas and transport hubs, as well as determining the intensity of stochastic effects.

1 Introduction

Simulation modeling of traffic flows is a complex multi-level process that should be based on a deep analysis of existing theories and practical developments. Improving the construction of effective models requires simplifying the arrays of incoming information and accelerating the reading of indications about the real situation at transport nodes and on main highways.

One of the options for such a simplification, which allows us to quickly assess changes in the road network and make management decisions based on the data obtained, is given in this research.

2 The main part

2.1 Analysis of research and publications

A significant contribution to the formation of modern theories of transport modeling was made by the work "Modelling and simulation of urban traffic systems: present and future" by F. Qiao et al. [1], which focuses on the use of simulation modeling to analyze congestion of the main transport lines of large cities. The authors examine the impact of infrastructure parameters, such as traffic light locations, on travel time and throughput.

One of the main aspect of research is partially highlighted in the work "From Sensors Data to Urban Traffic Flow Analysis" by L. Po et al. [2] the specifics of the practical use of modern electronic devices and computing facilities are studied. The authors emphasize that accurate and current data play a crucial role in creating realistic models of factors' impact on transport nodes.

In "Agent-Based Modeling" by A. Crooks et al. [3], the authors investigate how simulation modeling can reveal the interaction of various factors and management strategies in the context of transport nodes. "Integration of Public Transportation in Smart Transportation System (Smart Transportation System) in Jakarta" by R. Oktorini, L.S. Barus [4] discusses the use of sensors to track vehicle movement and control traffic flows. The importance of such technologies for enhancing the efficiency of transport nodes is noted. Further analysis is conducted in the study "Traffic Management system and Traffic Light Control in Smart City to Reduce Traffic Congestion" by W. Ali et al. [5]. Through simulation modeling, the authors identify optimal control strategies that contribute to improving the functioning both individual nodes and the road network as a whole.

It is also worth mentioning promising studies of Ukrainian scientists. This includes, among others, such works as "Peculiarities of using modeling methods of traffic flows in the city street network" by O. Stepanchuk et al. [6] and "Effective use of approaches for simulation modeling of logistics processes" by V. Samostyan [7], which add depth to the overall body of sources and lend additional weight to the discussed research. In "Peculiarities of modeling group movement of vehicles in cities" by L. Abramova [8] the author scrutinizes the influence of diverse factors on the interaction of transport flows in urban settings, investigating the potential of simulation modeling.

Comprehensive research work in the field of improving the modeling of traffic flows was also carried out by scientists from the Priazovskiy State Technical University. The results of this work are reflected, in particular, in such publications as:

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"Peculiarities of the use of simulation modeling in the analytical component of the information-analytical system for monitoring means of transport" by M. Volodarets, I. Gritsuk, Y. Ukrainskyi [9] – indicated that most of the tasks to improve the management of vehicle performance have an informational aspect. Assessment of operating conditions, analysis of plans and profiles of highways are mainly carried out manually in paper form, which complicates management and optimization tasks. The author proposes to use simulation modeling in the analytical part of the information and analytical system for monitoring transport.

"Development of the analytical system for vehicle operating conditions management in the V2I information complex using simulation modeling" by M. Volodarets, I. Gritsuk, Y. Ukrainskyi et al. [10] – a research article discussing the integration of vehicles, infrastructure, and humans into a single information network within the context of active development of information systems in transport. The focus is on the V2I (Vehicle-to-Infrastructure) system of information analysis for monitoring and controlling vehicles in operating conditions.

"Mechanism for assessing the transit potential of the nodes of the transport network of the industrial area" by A. Lyamzin, Y. Ukrainskyi, T. Ukrainska [11] focuses on the study of individual sections and nodes of the road network, operating in difficult conditions and requiring special attention in modeling.

"Forecasting the impact of traffic flows on the street and road network of an industrial city" by O. Lyamzin, I. Nikolaenko [12] explores approaches to solving problems of short-term forecasting of traffic flows in an urban environment using modeling tools and graph theory. This makes it possible to evaluate the reverse influence in the "transport-network" system, without which a full-fledged simulation of flows would be impossible.

Of course, this is not a complete list of studies that can serve as a theoretical basis for further developments in the field of building simulation models. This issue is widely discussed in the scientific and professional community; however, the practical application of developments is often stopped due to the complexity and high cost of their implementation.

In modern conditions, it is more important than ever to find a simple and effective way to organize transport management, including the operational redistribution of traffic flows. And this requires an efficient model that can quickly take into account changing external conditions, but not overloaded with an excess of computing modules.

2.2 Setting objectives

Modern researchers offer many automated traffic control systems, and high-precision sensors are developed aimed at recording-controlled indicators of traffic flows, such as the intensity and speed of traffic, the number of vehicles on a certain section of the road, etc. However, stochastic factors in transport are almost not subject to real-world research – their influence is taken into account only in the form of global indicators or, more often, correction coefficients.

This approach complicates the forecasting of critical conditions at transport nodes and at "bottlenecks" of the city's street-road network. At the same time, the number of transport units in cities is steadily increasing, creating significant problems for planning the transport process and operational flow management. All this creates a need for a quick analysis of stochastic conditions at the most stressful intersections with the possibility of promptly providing the received data to computer systems.

To solve these problems, it is necessary to provide computational-analytical systems with large arrays of operational information, which would be not only accurate and objective, but also presented in a convenient form. This creates a need for simple but efficient signal generators that are sensitive to the readings of sensors of different types and principles of operation. At the same time, it is critical that the output signal is understandable not only to the machine, but also to the operator – this will allow you to quickly intervene in the operation of automated traffic control systems if necessary.

Signal generators should be placed in all loaded transport hubs and in dangerous sections of the city's road network for constant monitoring of the situation. The complex of their sensors should support the possibility of modification and upgrade if necessary.

2.3 Presentation of the main material

2.3.1 The essence of simulation modeling

Simulation modeling of traffic flows is a method of research and analysis of vehicle traffic dynamics in the context of road traffic, based on the creation of a virtual environment for the reproduction and study of various traffic scenarios. The main fundamental component of simulation modeling is the representation of individual vehicles as "agents" equipped with specific characteristics that determine their behavior and interaction with other agents and the road environment [7].

The scientific goal of simulation modeling is to reproduce the complex dynamics of the movement of vehicles based on detailed models of their behavior and interaction. The basis of this method is the breakdown of the analyzed system into separate components – agents that realistically reproduce the movement and interaction of drivers on the road. This allows taking into account a wide variety of influences and factors, such as the individual structure of driver behavior, response to changes in road conditions, road infrastructure limitations, etc.

The simulation takes place in discrete time intervals, where each agent makes decisions based on available information and chooses actions that maximize its own objective, such as minimizing travel time. The interaction of agents and their reactions to changes in the environment allow to investigate emerging traffic jams, the effectiveness of different traffic management strategies, and to evaluate the impact of new infrastructure projects on traffic flows [6-7].

The collected data after simulation allows for quantitative analysis of various parameters such as
2.3.2 Proposed similarity theory

Collection of the necessary information can be carried out by means of simulation modeling, basing them on the assumption that the movement of transport units is similar to the movement of an electric current. Stochastic factors can be conditionally divided into two groups:
1. Those that affect the movement of a separate transport unit. In the simulation model, their role will be played by resistors R.
2. Those that affect a group of vehicles at the same time. The effect of these factors is similar to the action of capacitors C.

Taking into account the nature of traffic at intersections, we will get the need for an electrical circuit that generates rectangular pulses of different frequencies depending on the current stochastic state. A symmetrical multivibrator can perform this function. Its principle diagram is shown in Figure 1.

\[ t_n = \ln 2 \cdot RC \]  

(1)

- \( t_n \) – the time during which there is a signal at the nth site, s;
- \( R \) – resistance of the resistor, Ohm (Ω);
- \( C \) – capacitor capacity, F.

If necessary, additional sections \( R_nC_nQ_n \) can be included in the scheme. In any case, the total frequency of oscillations in Hz will be calculated by the formula:

\[ f = \frac{1}{2\pi t} \]  

(2)

- \( f \) – total frequency of oscillations, Hz;
- \( n \) – the number of sections in the chain;
- \( t \) – duration of a separate signal, s [14-15].

2.3.3 Conducting an experiment

During the initial experiment, computer software was used to read the simulation of the signal supplied to the oscilloscope by the R1Q1 section with a resistance of resistors R2 and R3 of 10 kΩ and a capacity of capacitors C1 and C2 of 10 µF. The result is shown in Figure 2.

By doubling the specified indicators on resistor R2 and capacitor C1, but leaving them unchanged on R3 and C2, we got the following changes in the signal character (Figure 3).
Analyzing the primary research data, we can come to the conclusion that by installing sensors capable of changing the values of \( C_1, C_2, R_2, R_3 \) under the influence of stochastic factors, we will receive two interconnected rectangular signals that will indicate the level of stochastic influence on the section of the street-road network, which is being investigated.

Now, it is expedient to introduce sectors favorable to the presence of certain stochastic factors and their physical values into the schematic diagram of the device. The adjusted scheme is shown in Figure 4.

![Diagram](image)

**Fig. 4a.** Corrected scheme with indicated positions of connection of sensors

2.3.4 Development of a sensor system

Certain sensors are selected individually for the section or intersection where measurements will be made. The list of recommended phase control sensors includes:
- a sensor for the presence and nature of precipitation (contact closure and pressure are read at the same time);
- sensor of excess water level on the road (closing of contacts);
- overspeed sensor (opto-isolator system);
- sensor of overall vehicles (opto-isolator system);
- sensor of dangerous driver behavior (opto-isolator system or video recording).

Smooth adjustment is provided by sensors:
- air temperature (thermistor);
- coating temperature (thermistor);
- air humidity (barometer);
- wind speed (anemometer);
- traffic intensity (opto-isolator system);
- illumination of the site (lux meter);
- air pollution (air analyzer).

Mixed regulation, as well as external corrections, can be carried out by directly providing the system with information on road accidents, repair works, global states and other stochastic factors by the responsible person.

The final signal can be analyzed by two methods: manual and automated. The first involves the participation of an operator who receives a printed graph, analyzes its frequency characteristic, peak height, time and reasons for their occurrence. The second one places this work on software that can work with the signal in real time or analyze a scanned copy of the graph.

2.4 Discussion of research results

Automation of tracking of controlled and stochastic effects on traffic flows is advisable at the busiest sections and intersections. It can be carried out with the help of a rectangular signal generator supplemented by a complex of smooth and phase adjustment sensors, which is confirmed by means of simulation modeling. The received information can be read both directly by the operator and automatically.

As follows from the information obtained in the practical part of the research, a rectangular signal generator with the ability to correct for the R and C branches is able to effectively use the incoming data, despite the simplicity of the design and the availability of components. The change in the distances between the peaks on the oscilloscope monitor, the height and length of these peaks serve as a fairly clear means for compiling a basic assessment of the traffic situation at the point or section of the road network where the control device is installed.

It is advisable to use the results of the signal analysis for planning the operation of the transport system, as well as making operational changes in traffic modes.

It is important to note that before the introduction of the proposed complex into the system of operational management of traffic flows, classical transport simulation should be carried out, as well as computer
simulation for each type of corrective influence when the sensor readings change. Having thus determined the constants for each type of influence, it is possible to achieve the most accurate and informative display of the oscillogram. The improvement of these operations; the determination of optimal limits for constants; the complication of the complex of sensors; the conduct of point field observations on the road network using a model of a control generating device have a significant interest for further research.

3 Conclusions

Modeling the movement of traffic flows is a complex and multi-level process that requires a deep analysis of existing theoretical concepts and practical developments. In order to improve the process of building effective models, an important aspect is to simplify the processing of large volumes of input data and to quickly obtain information that reflects the real situation at transport nodes and main highways.

One of the approaches to the specified simplified model is defined in the use of simulation models, which provide an opportunity to quickly assess the dynamics of changes in the road network and make reasonable management decisions based on the obtained results. The proposed theoretical concept of similarity makes it possible to study traffic using analogies with electrical circuits, which opens up opportunities for analyzing traffic conditions and their impact on road infrastructure.

In addition, the research notes the importance of using sensors and electronic devices to read data that reflect traffic and road flows. These technologies demonstrate significant potential for increasing the efficiency of transport nodes and rational traffic management. The use of accurate and actual data collected with the help of sensors is a key factor for creating realistic models of the influence of factors on transport nodes, which contributes to the improvement of the quality and efficient functioning of the transport infrastructure.

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