The Dynamic Traffic Modelling System

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Abstract. High rates of growth in the number of the rolling stock in the streets of cities and, as a result, an increase in traffic intensity, set the municipal authorities the task of increasing the efficiency of organizing the transport process. To solve this problem successfully, it is necessary to have complete information about traffic flows on specific sections of the road network. In the introductory part of the article, problematic issues caused by deficiencies in the organization of traffic are considered. The second part provides a brief description of modern methods for determining the intensity of the traffic flow. In the third part, an analytical review of the results of experimental studies on determining the time and speed of movement of vehicles on the busiest section of the road network of the city of Ryazan is presented and the possibility of their use to build a dynamic model of traffic flows in real time is considered. The next part of the article provides an overview of modern scientific research in the field of traffic modeling and optimization of the use of transport infrastructure. The final part presents a conclusion about the promising directions of the use of dynamic modelling of traffic flows in the development and implementation of projects for the organization of road traffic in urban conditions.

1 Introduction

It is difficult to imagine the economic development of a modern city without well-organized transport links [1, 2]. Ensuring a high level of transport mobility of residents is also one of the important social tasks facing the city authorities. Unfortunately, at present, the city people already consider it a habitual situation when in the morning and evening hours on the main transport routes there are difficulties in traffic caused, first of all, by the low capacity of the existing road network. As practice shows, the constantly increasing fleet of cars in cities has led to the creation of a critical situation in which the existing transport infrastructure cannot provide the required level of traffic intensity [3, 4]. Constantly formed traffic congestion entails the emergence of a number of negative aspects: an increase in the duration and cost of transport correspondence, environmental pollution by exhaust gas emissions and decrease in road safety due to an increased number of conflict situations Constantly formed traffic congestion entails the emergence of a number of negative aspects: an increase in the duration and cost of transport correspondence, environmental pollution by exhaust gas emissions and

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decrease in road safety due to an increased number of conflict situations [5–7]. Preventive measures taken by municipal authorities are aimed, as a rule, at restricting the movement of certain categories of vehicles in the central part of the city or introducing paid parking for cars [8, 9], but these measures have a short-term effect and in the medium term the situation remains practically unchanged.

2 Methods

Due to the high cost of road infrastructure construction, more and more often extensive measures for the development of transport systems are used due to more efficient traffic management [10, 11]. This approach makes it possible to improve the quality and reliability of management of the transport system of a large city without capital investments. In this regard, the issue of developing systems for dynamic modelling of traffic flows in real time is becoming topical. Obviously, future management strategies can be characterized as user information systems (primarily dynamic signs and displays) and control systems (reversing lanes, toll collection systems, traffic detectors, adaptive coordinated regulation at traffic lights, access control systems to roadway). In order to achieve high efficiency from the use of the presented traffic control elements, it is necessary to predict the impact of the use of these tools on the formation and elimination of traffic congestion, as well as the overall efficiency of the entire urban system.

Travel time is considered one of the most important indicators of the transport system, since this indicator is easily perceived by untrained people. This data can be transmitted to users through dynamic displays and mobile applications. There are three main ways to obtain travel time estimates:

- “active” vehicles owned by the city administration, which transmit data about the driving time using GPS/Glonass (for example, public transport data);
- a system for matching license plates of cars using image analysis;
- receiving data from “passive” vehicles (for example, Google Maps).

These three main technologies have been the most common means of obtaining travel time information over the past several decades. However, recently there has been an increase in interest in a new methodology for obtaining travel time measurements. The growing popularity of mobile devices, coupled with wireless connectivity in cars, used to connect these devices to each other and the Internet, has led to the development of a travel time tracking method based on the Media Access Control (MAC) address received from the Bluetooth module.

One of the promising ways to obtain information about the traffic intensity is the development of a system for dynamic modelling of traffic flows in real time. Figure 1 shows the main block diagram of the system.

The main elements of the system are:

- a module for calculating traffic flows along the road network in the form of correlation matrices;
- a module for describing traffic flows, in the form of a special mathematical model;

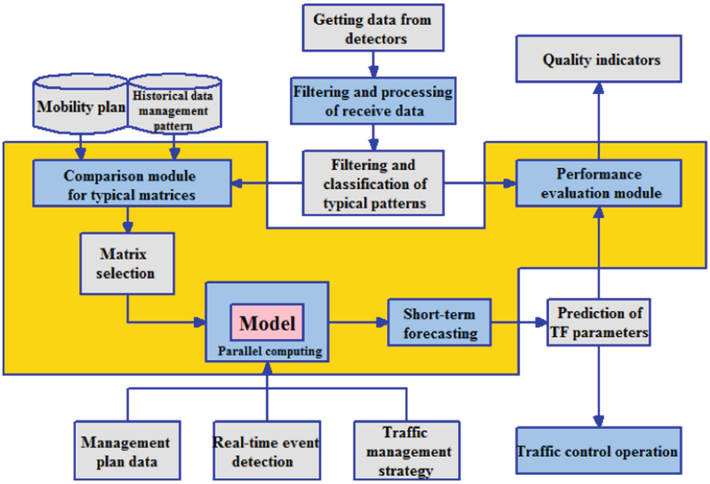

Fig. 1. The scheme of the system of dynamic modelling of traffic flows.

– a module for working with initial data received from external devices (traffic flow detectors).

To ensure high efficiency of the proposed modelling system, it is necessary to provide the most accurate data on the intensity of the traffic flow on the corresponding section of the road network [12, 13]. If traffic data is collected accurately, then this contributes to an increase in the level of model building and allows to correctly assess the prospects for the implementation of design decisions made on the basis of building a dynamic model of traffic flows. Currently, data collection is carried out by using detectors of various operating principles (inductive loop detectors, infrared, video, ultrasonic and acoustic detectors) [14–16]. Let's take a quick look at some of these ways to get traffic information.

Video detectors allow automatic analysis of video images with high accuracy when cars pass under them (Fig. 2). The images obtained with the help of video cameras allow to record various parameters of the traffic flow: the presence of a car, speed, lane occupancy, the lane, flow rate, etc.

Traffic monitoring can be done with inductive loop detectors that can detect the presence of a vehicle (Fig. 3). One loop installed under the road surface can count vehicles. Dual loops in the same lane, separated by a fixed distance, can measure a vehicle speed. When the vehicle's speed slows down below a certain threshold, loop detectors can signal traffic congestion.

As noted above, the range of technical devices that allow the collection of information about the traffic intensity on a certain section of the road is quite wide.

The choice of this or that method of obtaining data for the system of dynamic modelling of traffic flows depends on specific conditions of the road network and the

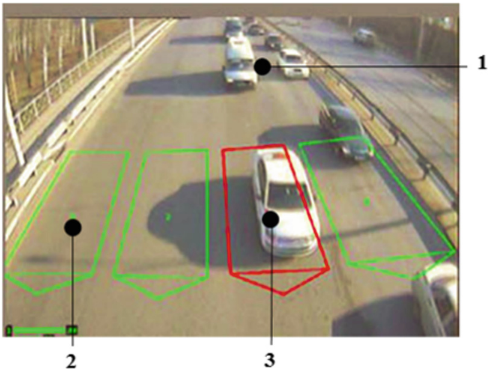

Fig. 2. Video detector of transport: 1 - incoming traffic; 2 - detection zone ("free" mode); 3 - detection zone ("active" mode).

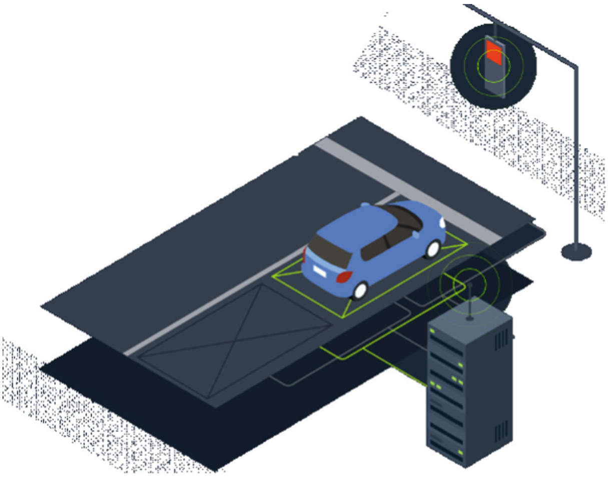

Fig. 3. Inductive loop detector operation diagram.

possibility of installing detectors on the simulated section. In the future, the possibility of monitoring traffic flows based on scanning Bluetooth MAC addresses is being considered.

3 Results

To develop a dynamic model of traffic movement in real time, high-quality data on traffic flows are required. In the course of experimental studies, data were obtained on the congestion of sections of the road network in the central part of the city of Ryazan. Figures 4 and 5 show the results of measuring the time and speed of movement along the tracks of Moscovskoye highway in Ryazan. The measurements were carried out during the week from 25 to 31 January 2021. The graphs shown in the figures allow us to estimate the degree of uneven loading of the studied area in different periods of the week. We can see that the highest congestion is observed on Monday (red chart). On the rest of the weekdays, there is a decrease in the traffic load of the road network to the average indicators (blue graph), and on weekends, the traffic intensity significantly decreases and reaches the minimum values (green graph). It should be noted that at the entrance to the study area and at the exit from it, practically comparable indicators of driving time and speed of cars for all days of the week are recorded, and the peak values are reached in the middle part of the study area.

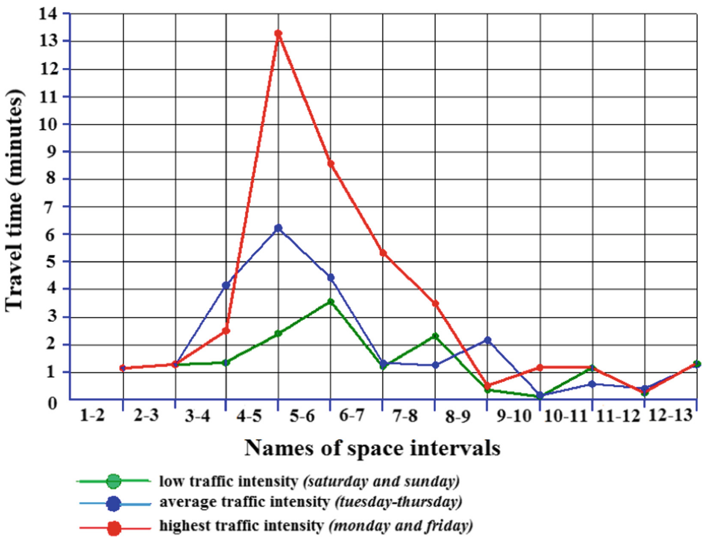

Fig. 4. The graph of the distribution of the average travel time on space intervals.

During the measurements, significant deviations in the average travel time during peak and inter-peak hours were revealed. In fact, there was a critically low efficiency of the system during the hours of greatest demand.

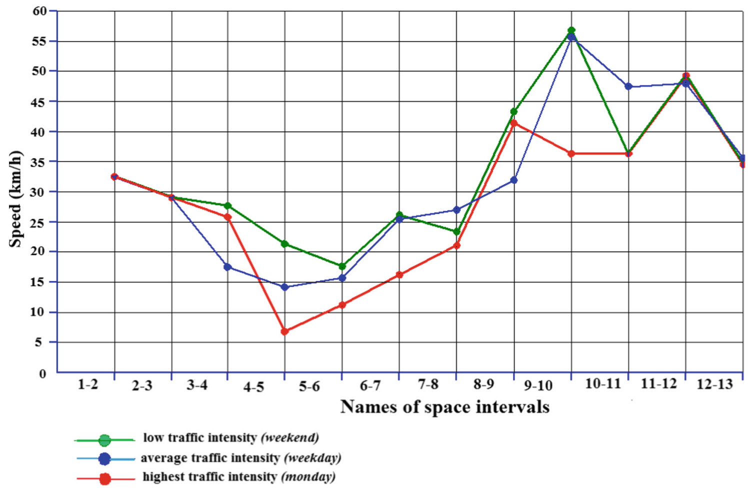

Fig. 5. The histogram of the speed distribution on space intervals.

Figure 6 shows a model of the operation of the transport system of the central part of Ryazan during the morning peak period. The model made it possible to determine offline important indicators of the transport system operation (density, speed, intensity, congestion level), using the results of experimental studies as input data.

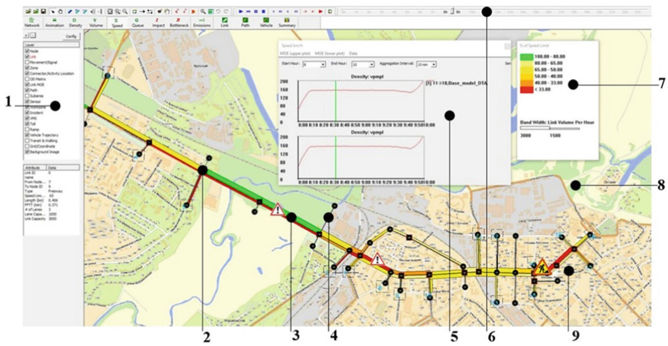

Fig. 6. Complex mathematical offline mesolevel model (on the example of the city of Ryazan): 1 - panel of GIS properties of software DTALite/NEXTA; 2 - nodes of the mesomodel; 3 - calculated velocity diagrams; 4 - a segment of the mesomodel graph; 5 - output of density parameters (graph of flux density); 6 - timeline; 7 - legend of indicators of velocity plots, %; 8 - cartographic base; 9 - accounting for the impact of incidents on the network.

4 Discussion

Currently, there are many ways to obtain mobility plans. They can be roughly divided into static and dynamic plans. Static plans are based on demand models used in predictive modelling systems, based on special transport surveys and collected statistics on places of residence and employment. These plans are very coarse and do not allow analyzing the periods of unevenness when traffic congestion occurs. Dynamic plans are the ones usually obtained from various peripheral devices offline and online. The study of dynamic mobility plans has acquired an active phase in recent decades. The calculation of dynamic plans is based on a set of traffic data received from traffic detectors.

The authors of [17] propose a detailed dynamic decision-making model to determine the degree of risk of congestion on roads and predict their impact on the future traffic flow. It was established that the use of dynamic speed control systems increases the throughput, maintains a stable speed, and increases road safety [18]. Italian researchers [19, 20] consider the possibility of using data from a microsimulation model of road traffic to carry out everyday traffic simulation in an urban environment. Others focus on investigating dynamic platoon dispersion models which could capture the variability of traffic flow in a cross-sectional traffic detection environment [21].

The article [22] presents a mathematical model of the zonal control system for the city's transport processes, which provides an opportunity to organize optimal control with adaptation to changes in the external environment and make timely decisions in emergency situations based on knowledge about the dynamic state of the control zone.

An analytical model of traffic for uncontrolled intersections is presented in one more work [23], which considers microscopic interactions of vehicles and allows traffic forecasting and optimization of road infrastructure. The issues of the influence of various characteristics of traffic flows on the traffic intensity in urban conditions are considered in other works [24].

The presented review of scientific research has shown that there is a wide range of directions for using the modelling of traffic flows in the field of optimization of traffic management.

5 Conclusion

Experimental studies carried out on a section of Ryazan road network made it possible to form a dynamic mobility plan and develop a complex computer offline model of the mesoscopic level, using which it is possible to analyze parameters of the effectiveness of existing and projected activities in the field of traffic management.

An intelligent dynamic platform for aggregation and modelling of traffic flows in real time will allow to approach the operational planning of traffic management in any large city at a qualitatively new level. The system can also be used as an analytical center in intelligent systems projects aimed at improving the efficiency of using road transport in urban environments. The use of traffic flow modelling systems in the development of traffic management projects is one of the ways to avoid mistakes at an early stage of design.

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