ANALYSIS OF THE TRAFFIC MANAGEMENT SYSTEM IN URBAN NETWORKS

АНАЛИЗ СИСТЕМЫ УПРАВЛЕНИЯ ТРАНСПОРТНЫМИ ПОТОКАМИ В ГОРОДСКИХ СЕТЯХ

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Abstract: In the article is considered traffic management system in urban networks. Presented analysis of the criteria in the transport network management techniques. Showed results achieved in the implementation and management of traffic flows in the cities, their advantages and benefits. Development of mathematical dynamic models for calculating working parameters of the transport unit allows to create a well-functioning traffic management system. These systems allow to solve optimization problems, to regulate traffic flows in populated areas, thereby allowing the full potential of the existing route network, as well as it will ensure an adequate level of safety, convenience and efficiency of transportation with the least environmental impact.

KEYWORDS: TRAFFIC MANAGEMENT SYSTEM, URBAN NETWORKS, TRANSPORT CONTROL DEVICES, OPTIMIZATION

1. Introduction

Starting from the second half of the eighties a number of dynamic systems that calculate the parameters of a transport node (a cycle or composition of phases of traffic lights based on actual changing traffic conditions) is developed. However, the quality of dynamic management, as we know, determined by the quality of the model traffic flow. There are also limitations, due to the fact that the developed model is usually not prepared for extreme changes of the condition of a traffic flow. Nevertheless, the issue of dynamic control of the node or node group is not simple considering that on a simple crossroads may be 12 directions of movement of vehicles, i.e. for a simple network formed by ten nodes, we are talking about 120 directions. The output of the regulatory process should be to minimize delay to 120 destinations, and the traffic intensity varies in time and space [1], [3].

Development of mathematical dynamic models of calculation of parameters of a transport hub will create well-functioning of traffic control system. These systems will allow to adjust traffic flows in built-up areas and in undeveloped suburban areas, thereby will allow to use the full potential of the existing route network, as well as significantly reducing the influence of the number and consequences of road accidents on the functioning of the transport system of the city.

2. Analysis of publications

Traffic control device used to manage the transport network in the city. Usually it is equipped with sensors to monitor the presence of vehicles or pedestrians. The executive elements are the signal lights (traffic lights), CCTV cameras, GPS sensors, which provide information to the driver or pedestrians. The control device can work in isolation without communication with other control devices or with a central station that can be installed in a coordinated line or may be managed by the control center. From the management point of view, there are two basic states: managing the transport node and the transport network (area) [2].

3. The aim and task

The aim of this publication is the analysis of the traffic management systems. Modern systems of traffic management can be divided into static and dynamic (traffic-dependent). For control systems of the traffic flows the big interest has transport-dependent control device. In case of transport-dependent control available detectors before the stop lines that capture the instantaneous presence of vehicles, and control device thus responds to the instantaneous conditions in the node, for example, increasing the duration of the green signal. These changes are transmitted to the Central management node, which makes subsequent adjustments to the device nodes of the road.

Therefore, we are talking about traffic management in the transport nodes in the used grid time (which is line management), and also all traffic.

Consequently, the biggest interest have the systems which are working in real traffic conditions.

4. The main section

Consider existing systems of traffic control [1], [2].

The modern system of traffic control management is equipped with a control device characterized by control devices (nodes). They are controlled: 1 - on a fixed schedule; 2 - on a state of a transport stream (transport-dependent).

Traffic management in transport nodes is divided in the following categories:

• time-dependent control – transport status is determined on the basis of statistical analysis of historical values of the characteristics of traffic flow (traffic intensity) and on the basis determined by the output values of the regulatory process;

• transport-dependent control (in real time) – management, the intervention of which is calculated on instantaneous traffic situation. Methods of real time (online) provide work in real-time, every second make changes and optimize the control parameters, i.e. duration of the green signal in the corresponding direction.

Traffic light control in real time is well known and is used as a standard under the name transport-dependent control or dynamic control. Its principle is that the node is usually equipped with two types of sensors: sensors intervals and call that are in most cases inductive loop. The transport device control program that continuously tests the state of the traffic flow over separate sensors and on the basis of pre-defined algorithms increases the duration of signals, modifies the phase sequence or phase invests on call. These changes are usually carried out within a predetermined time cycle and predetermined maximum values, the duration of green signals.

Sensor intervals, located approximately 30-50 m before the stop line, got its name due to the fact that it continuously measures the time intervals between vehicles and if they are less than a given value (usually 3-5 seconds), it increases the duration of green signals up to a predetermined maximum. Such a measurement method called "Management by measurement of time interval". In addition, the duration of green signals may also be increased on the basis of the measurement conditions of the sensor, which essentially represents the relative time during which the sensor is located above the vehicle, and based on this value, expressed as a percentage, extends or shortens the duration of the green signal. Sensor call is located before the stop line or in more remote locations, where can irregularly be formed congestion. In both cases, depending on the control algorithms embedded phase, is identified if the employment of a sensor of the vehicle.

Certainly, it is possible multiple grouping controls in a line and method of management in the system, also called “green wave”. Methods of calculation are well known and come from the calculation of the coordination parameter, which is the time shift.
The latter on the basis of the distance between the intersections and depending on the velocity of the vehicle determines the time delay of the signal "travel allowed" at the next intersection for vehicles traveling from the previous node. The second possibility of traffic management is that individual nodes are connected to the traffic management center traffic flows, which coordinates and manages the nodes at the district level. There are following modes to control the scope:

- time-dependent control – information about the characteristics of traffic flow conditions in the area are obtained by statistical analysis of data on the characteristics of traffic flows. Based on this, is determined the mode of operation of the transport control device, after which they are introduced into the control device, depending on the time of day or day of the year. In the calculations, optimized the duration of the green signal, the cycle duration and the time shift;

- transport-dependent control – characterized by the fact that for the different states of traffic flows in the network system pre-calculated signal plans stored in the control devices or in the centre of traffic management of traffic flows.

If the network is not classified traffic flow conditions, only one parameter is used for describing, which is the intensity of the movement. Transport-dependent control is used in the real time scale and every second receives the signals of the selected sensors. However, the switching signal of the programmes is carried out with a certain hysteresis to ensure stability in the transport network. In practice, this means changing the program of the control device in the grid several tens of minutes.

The instant response to the situation based on the creation of the state of traffic flow in a node or in a network based on the measured transport parameters. Therefore, this system is always equipped with sensors and is more expensive. The measured data are included in the model of traffic flow, which performs optimization.

Optimization in autonomous mode gives the possibility to calculate the basic adjustable parameters: cycle time, phase sequence, the time shift and the duration of green signals for the historical data. These data are obtained by long-term measurements by means of transport detectors or, not very well, replaced by local tracking and account. On the basis of long-term recorded data is usually developed statistical model for the intensity of the movement, usually gives the opportunity of determining on typical weekdays and weekends, resulting in severely restricted change of variables.

The implementation of these control devices have been applied in developed and presented models of traffic management.

Improving the efficiency of road usage is the main objective, the implementation of which will ensure adequate levels of safety, convenience and efficiency of transportation with the least impact on the environment. Implementation is possible only with widespread usage in transport devices of a dynamic and modern systems of traffic management - intelligent systems that evolve in many branches of economy of the leading countries in the world. The use of such systems for transportation can significantly increase the efficiency and safety of transport, provide the service to users of transport on a higher level.

The main tasks of such systems are:
- increasing capacity of the transport network;
- improving the safety of traffic participants;
- reducing the time of travel of vehicles;
- optimizing the use of road capacity;
- reducing the amount of congestion;
- reducing the amount of fuel consumption; and
- reducing the amount of emissions.

In the modern understanding, the transport management system of cities is not only a system of traffic control at intersections with traffic lights. These systems are equipped with other systems and devices. For example, information displays along with communication give drivers the opportunity to choose alternative routes of movement, with special attention paid to the elimination of the consequences of traffic accidents, congestion, etc.

One of the biggest implemented European projects for traffic control of a large urban area was the Munich COMFORT project [4]. It was the first project that coordinated management of traffic flows in the downtown, and took into account planning the motorway network in the suburban area. Control algorithms evaluated the condition of traffic flow, optimized the traffic light predicted the development of the transport load and directed vehicles out of the field, which often had traffic jams.

This system achieved the following:
- the investment paid off within 2 years;
- decreased raids by 35%;
- reduction of traffic accidents by 30%;
- decreased the amount of congestion by 31%.

Depending on the implementation of the complex of the main works and purpose of traffic management distinguish the following subsystems (Fig. 1):

3. Information and navigation.
4. Management depending on traffic loading

![Fig. 1. Traffic management subsystems](image)


Transport data from the sensors installed in transport hubs can be used for the primary traffic management. However, integrated system of traffic management in urban networks requires more detailed information about the situation of the network, as demonstrated in projects such as QUARTET PLUS and EUROSCOPE. In the context of the widely adopted concept of "mobility management" and the close linkages between the monitoring and management of traffic flows, these projects have experienced in practice new system based on videodetective (use as sensors, stationary cameras). In these projects, for the first time in practice, were tested new algorithms to determine time of movement, speed on the lanes and in the network and algorithms to determine the points of origin and destinations. Especially important for transport information system is data of points of origin and destination. Projects also were tested forecasting algorithms that could be used for short-term (1-20 minutes), intermediate term (11-12 hours) until long-term forecasts (1-2 days). Both projects helped to identify inaccuracies and limitations that characterize the forecasts of parameters of functioning of the transport network, and identified areas for further development, one of which is the use of data from propel labs, live traffic flow (floating car) – project CAPITALS.

Private, but very important area of using the results of data analysis is the region of establishment (detect or detection) of the traffic accidents occurrence.
Timely detection of incidents can begin the process of taking the necessary measures, which include the strategy of traffic management in this situation, informing drivers of the situation and a rapid response of the rescue services. The project IN-RESPONSE, in addition to detecting incidents, have been developed that model to predict road traffic accidents.

2. Automatic identification systems of road traffic accidents.

The subject of several European projects have been addressing the issues of management of the liquidation of consequences of road accidents. Traffic management system in the cities of UTC (Urban Traffic Control), are using special modules ensure the detection of incidents and their impact on traffic flows. Projects, such as IN-RESPONSE and IN-EMERGENCY, demonstrated the variety of equipment, including high-speed warning system designed for rescue services, and tools that support decision making by operators of the rescue service.

3. Information systems and navigation.

Systems for informing drivers using on-Board units or controlled road signs and displays that are located along roads, have ever-increasing importance for traffic flows management on road networks. Information about possible problems greatly reduces the congestion due to the fact that the driver is informed and can choose other options to the path of motion or the suitable parking lot or just parking.

At the time, such systems, as TFIS (Traffic Flow Information System), information system impacts on traffic flow), were often used in different European projects.

The use of information and navigation systems in the framework of the European projects are presented in such systems of following cities:

- Bristol (CONCEPT) – TFIS for the best use of Park and Ride system;
- Brussels (CAPITALS) – TFIS as part of a master control system of traffic in tunnels on the inner ring of the city;
- London (CLEOPATRA) – determination of the influence of TFIS, when identifying locations of traffic accidents, the choice of drivers on the road to the road network and the efficiency of the transport network;
- Lyon (CLEOPATRA) – information strategy for TFIS in the automatic mode using data derived from measurements conducted on road network;
- Munich (TABASCO) – TFIS for the best use of Park and Ride system;
- Piraeus (COSMOS) – a strategy for changing the movement direction of vehicles in the area of the seaport;
- Southampton (EUROSCOPE) – integrating the impact of road traffic accidents and control sites;
- Toulouse (CLEOPATRA) – strategy of changing the direction of movement of transport streams;
- Turin (CLEOPATRA) – TFIS strategy with the strategy of traffic management in the city.

Information before the trip and information on the stops of urban public passenger transport have a significant impact on the behavior of most passengers, so it turned out that they, ultimately, caused a small but significant increase in the number of passengers. Integration of transport management in the city, urban passenger public transport and information systems in Turin has reduced travel times on urban passenger transport by 14%, in passenger cars – 17%, which, in turn, led to the growth of urban public passenger transport by 3% and overall improvement of traffic in the city. Investments in the subsystem identify the locations of road accidents in the transport management system in Southampton have paid off within one year, however, payback significantly depends on the method and speed of identification of road traffic accidents.

4. Management systems depending on traffic loading (intelligent systems).

In the city, management depending on the traffic load, as a type of control, has a growing importance for maintaining satisfactory mobility, as it uses different subsystems for traffic management. The application of this program contains, for example, the office at the entrance to the Central area of the city (CAPITALS project) and techniques of artificial intelligence, by combining control on entry and management using the traffic lights system of providing information and assistance to drivers and subsystems with the provision of transport information.

Practical results of the use of traffic control systems in the United States and Canada [5], [6] are the following:

- Toronto (Canada): all 75 objects managed by the system SCOOT (Split, Cycle and Offset Optimization Technique system of movement control), using this system allowed to reduce the number of stopped vehicles by 22%, delays of transport vehicles – by 17%, the average fuel consumption by 5.7%, which had a positive impact on the environment.
- Los Angeles, CA: new management and tracking system has more than 1150 traffic lights and 4600 detectors used to optimize the management process. The result was reduced consumption of fuel by 13%, by 41% decrease in the number of stopping vehicles and by 16% decreased loss of time.
- Chicago, Illinois: project of optimization of urban public passenger transport based on coherent benefits to buses at intersections, resulting in the speed of buses increased by 25-50%. As a result, significantly increased the attractiveness of urban public passenger transport and at the same time, decrease of environmental load (through reducing the number of buses while maintaining intervals).

Positive effect of introduction of transport flows management systems in urban networks is determined by the fact that in their information environment, transport and heads of administrative bodies have the opportunity to get the most rapid and objective data about the passenger and other transport modes, and the ability to quickly monitor and therefore manage the safety of transport systems.

Analysis of the use of the traffic management system in the cities shows that there have been positive results in the areas of:

- increasing the capacity of the transport network by 25-35%;
- reducing traffic delays by 30-40%;
- reducing the number of road accidents by 20-25%;
- reducing the number of vehicles stopped by 20-35%;
- reduction of time travel on urban passenger public transport and passenger cars by 15-20%;
- reduction of the environmental load (reduction of pollution and noise).

5. Conclusions

Model traffic flow, which carries out the optimization should be able to manage the macroscopic offline. It is based on a deterministic simulation of algorithms and optimization, as calculated by the signal plans for the space-time vector of the intensity data for previous periods. Their advantage is that they are based on well-known mathematical models and can be implemented deterministic process control. Developed algorithms on data nodes and management models allow to create transportation management systems. These systems significantly improve the efficiency and safety of transport, help to ensure service users transport at a higher level.

For Odessa, with its level of development of the transport network, the problem of automated traffic management is highly relevant. A superficial assessment of the situation in the transportation network of Odessa, leads to the conclusion that the implementation of the management system will enable flexible management of traffic flows depending on their intensity. Based on the above, we can conclude that for using foreign experience of working with management systems must be performed a complex of works on increasing the efficiency of use of the transport network of the city, which, in turn, will pave the way for use of intelligent transport systems in Ukraine.
6. References

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