SYSTEM ANALYSIS AND MODELING OF TRANSPORT AND PASSENGER FLOWS

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ABSTRACT

The article analyzes approaches to modeling of transport and passenger flows for optimizing and improving the efficiency of functioning of existing routes and interchange nodes. A technique for estimating traffic flows in a large city system based on a transport model is presented. Key indicators to provide interaction in the process of control of transport and passenger flows are identified. A systematic approach is described in analyzing the possibilities of integrating parts (elements) of an intelligent transport system.

Keywords: intelligent transport model, system approach, transport flow control, passenger flow control, optimization, information model, interaction of transport and passenger flows.

Background. *Constantly increasing load on the transport network and interchange nodes of the city leads to the fact that the intensity of transport flows increases substantially, and it is often no longer possible to expand the ways and increase the number of access lines. In these conditions, the ability of the system to increase the capacity of stations and stopping points with minimal changes in architectural and planning decisions, without capital reorganization, with the help of internal resources of transport facilities acquires special significance.*

The task is to optimize traffic flows, increase the efficiency of functioning of existing roads, maximally save material resources for expensive reconstruction, and also save streets from traffic jams and congestion that take a lot of time and nerves for drivers and passengers and also seriously pollute the environment.

The solution of the task of increasing the capacity with the current transport infrastructure can be found in a detailed study of transport flows, vehicles, passengers, their interaction with each other and the elements of the transport network, the conditions and logic of flow control.

Objective. *The objective of the author is to consider the issues of a system analysis and modeling of transport and passenger flows.*

Methods. *The author uses general scientific methods, comparative analysis, economic evaluation, simulation modeling.*

Results.

1.

What parameters determine the transport flow? Is this set of cars on the road a traffic flow or not? From how many vehicles does the flow start? These questions have never been purely speculative.

One vehicle is not a flow, and two are probably already able to be (for example, in the «follow-behind-the-leader» model, two transport units are considered). That is, the notion of a transport flow is defined within the framework of that theory or model of transport processes and systems in which it is used. And for each type of a model and a level of detail, the flow will have its own character and motion properties.

For example, in the abstract theory of transport processes and systems based on the use of a mathematical model that can be conditionally called a transport machine by professor V. V. Doenin [1], the transport flow (TF) is a set of transport objects passing through a given point of the network in a certain point in time. The transport process and the account of the influence of factors of the interaction of objects on the nature of its development can be carried out using the model of the movement of objects [2]:

$$\begin{aligned} &z_v^i = f_z^i\left(x_v^i, s_v^i\right),\\ &s_{v+1}^i = f_s^i\left(x_v^i, s_v^i\right),\\ &d_{v+1}^i = f_d^i\left(x_v^i, s_v^i\right),\\ &x_v^i = f_x^i\left(z_{v-1}^1, z_{v-1}^2 \ldots, z_{v-1}^k, t_v\right),\\ &t_v = t_{v-1} + \Delta t, i = 1, 2, \ldots, k, \end{aligned} \qquad (1)$$

where z_v^i – function of the reaction of the transport object at v-th moment of time; s_{v+1}^i – state of the object at v + 1 moment of time for the considered i-th process; d_{v+1}^i – location of the object in the medium at v + 1 moment of time for the i-th process; x_v^i – variable indicating the presence of a place in the zone along the object's movement for the i-th process; Δ – discrete step of changing time t.

The model (1) reflects the fact of influence of each of k objects of the system on the considered i-th process, which manifest itself through the change of input actions x_v^i as a result of formation of a set of reactions $z_{v-1}^1, z_{v-1}^2 \ldots, z_{v-1}^k$. Relying on this model, it is possible to provide an analysis of the properties of dynamical systems of any kind intended for moving objects of various kinds.

According to another version [3], TF is a set of vehicles moving along the roadway. Here, depending on the number of lanes and the permitted directions of motion, the traffic flow is divided into one-sided, two-sided, three-sided (and more).

The definition of a passenger flow in the abstract theory of V. V. Doenin is generalized by the concept of an intelligent transport flow. And it is formulated as follows [1]: an intelligent one will be called a discrete transport flow, the control of a transport process in which is realized either by an external transport operator (centralized control) or by intellectual transport objects independently (autonomous control), or by both (combined control). The most important characteristics of transport flows in this case are controllability, stability and convergence of transport processes.

In another source [4], passenger flow is defined as a set of trips united by a single direction and performed during the period of time under consideration.

However, despite the diversity of interpretations and the multivariate approach to the concept, the analysis of transport flows remains a complex stage of traffic control and can be based on:

- *statistical data, based on the transport survey, the use of automated traffic counters by transport detectors, expert assessments made using a transport model;*
- *modeling of road and transport situations through special computer support;*
- *integrated approach.*

An integrated or combined approach, when aggregating statistical data collected by all available methods, and modeling results, usually yields the best solutions.

According to the analysis, the methods of simulation modeling are universal for the modeling of transport flows and the ability to reproduce the aggregate of both the individual parts of movement and the system process as a whole.

2.

With the help of simulation methods, it is possible to use a multi-approach option, which allows to build a transport model for analyzing the properties and behavior of individual objects (using agent modeling) and for system synthesis. When describing a system involving transport processes (using discrete-event modeling) or global dependencies (using system dynamics), a combination of such approaches is also quite possible.

The primary task of the analysis of transport flows on the basis of the transport model is the formulation of tasks to develop activities aimed at optimizing road traffic, among which may be:

• reconstruction of the street-road network, territory or architectural layout of the station, transport hub;

• optimization of the available technical means of traffic organization (information boards, traffic lights, etc.);

• preparation of new ITS-solutions.

The information characterizing transport flows is usually heterogeneous and consists of large amounts of data. Effective analysis is possible only if the simulation model is constructed and specialized software is used that can:

• provide data in a standardized and clear manner;

• compare structures and arrays of data;

• verify the information for reliability.

Long-term experience of scientific research and practical observations of transport flows allowed to identify the most objective indicators. Among them: intensity of the transport flow, its composition according to vehicle types, flow density, speed of movement, delays in movement.

The intensity of the transport flow is the number of vehicles passing through the cross section of the road per unit time. As the estimated period of time year, month, day, hour and shorter intervals (minutes, seconds) are taken to determine the traffic intensity, depending on the task and measurement tools.

The density of the transport flow is a spatial characteristic determining the degree of constraint on the road. It is measured by the number of vehicles per 1 km of the length of the road. The maximum density is achieved when the car column is stationary, located close to each other on the lane. For the flow of modern passenger cars, the theoretical limit value is about 200 cars / km.

Delays in movement are an indicator that should be paid special attention in assessing the state of the road traffic. Delays should include the loss of time for all the stops of vehicles not only before crossings, railway crossings, traffic congestion, but also due to a decrease in the speed of the transport flow compared to the current average speed of free motion on this road section.

To characterize passenger flows, the following key indicators are used:

• transport mobility;

• interchange rate;

• time of movement along the route;

• power or tension;

• costs for an interchange (time, work);

• volume of passengers;

• intensity of the flow;

• density of the flow;

• direction of the flow;

• replacement rate of passengers.

Let's clarify some key indicators:

– power of passenger flows is the number of passengers passing at a certain time on a given section of the route in one direction;

– volume of passengers is their quantities, transported for a certain period of time (hour, day, month, year);

– replacement rate is defined as the ratio of the length of the route to the average range of travel of passengers.

The concept of a system approach to the transport system is primarily the interconnection of the city's territorial-network parts or transport subsystems. Currently, transport systems are not efficient enough, because they cannot link existing parts or steps (functions) into a single mechanism. As a rule, the functions of preparing cargo for transportation are carried out without proper coordination with loading operations, and the latter with the needs and requests of recipients, etc. Separation of individual functions into independent industries and the inability to unite the parts into a single whole are due to various reasons, including the narrowness of the views of specialists, shortcomings in organization and transport planning, etc. But in all cases this emphasizes only one: the need for a more rational solution of the transport problem and optimization of transport processes in general.

Conclusions. *Analysis and synthesis of parts of a complex system, to the category of which, undoubtedly, the transport system of a large city belongs, imply the use of a systematic approach. It allows organizing and redistributing, multiplexing flows, providing the city's population with transportation services with minimal delays and maintenance costs. Due to a detailed study of the interaction of all transport units and transport infrastructure among themselves, and also in conjunction with passengers involved in the transport process, the emergence of the system is achieved, helping to optimize capacity and increase transport accessibility of the network. And in this case it is easier to evaluate and, if possible, improve the routing of the city's transport system at any interchange node or intermodal station, without a major change in architectural and planning decisions, by economically reorganizing the existing transport infrastructure and more rational traffic control of transport and passenger flows.*

The implementation of the system approach in solving such control tasks can be provided by scientific modeling of transport and passenger flows, provision of transport services to customers of transport services with the possibility of analyzing and constructing routes using combined use of various modes of transport, which becomes real on the basis of simulation models and data integration of all systems and modules in intelligent transport system.

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