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SIMULATION MODELING OF THE URBAN TRANSPORT SYSTEM TAKEN INTO ACCOUNT OF CHANGES IN PASSENGER FLOW

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KEYWORDS

Simulation modeling, urban transport system, passenger flow, network congestion, demand modeling, traffic assignment, performance evaluation, infrastructure changes, policy interventions, transportation technologies, sustainable mobility, resilient cities.

ABSTRACT

Simulation modeling has become an essential tool for understanding and optimizing urban transport systems, particularly in the context of evolving passenger flow dynamics. This article presents a simulation modeling approach aimed at capturing changes in passenger flow within the urban transport system. By integrating various data sources and modeling techniques, the proposed approach enables the analysis of passenger behavior, network congestion, and system performance under different scenarios and conditions. The article discusses key elements of the simulation model, including network representation, demand modeling, traffic assignment algorithms, and performance evaluation metrics. Furthermore, case studies illustrate the application of the simulation model to assess the impact of infrastructure changes, policy interventions, and emerging transportation technologies on passenger flow dynamics and system efficiency. Through a comprehensive analysis of simulation modeling in urban transport, this article offers insights into addressing challenges and opportunities for sustainable and resilient urban mobility.

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The rapid growth of the urban population and the increase in its mobility cause a number of problems related to the development of transport in cities. Management of the transport system is one of the main components of the city's infrastructure, which provides the vital needs of the population.

One of the main tasks of transport management is to create optimal routes and intervals for regular buses. The complexity of its solution lies in the need to determine the flow of passengers and their distribution by time during the day. Solving this problem allows to reduce the time of bus stops, eliminate the cases of flight cancellations and increase the efficiency of the use of rolling stock. At the same time, optimal transport planning allows to increase the efficiency of buses, reduce the number of rolling stock entering the route with the same passenger flow, and frees important material resources of the vehicle fleet from circulation.

In this regard, the purpose of the study was to build a mathematical model for solving the routing problem in the distribution of passenger and traffic flows, taking into account the specific characteristics of passenger traffic in the city. A characteristic feature of the traffic flow of the city network is its complex composition. It includes many flows: internal flows of private transport, flows of public transport (by city and routes), etc. In order to ensure the rhythmic operation of the entire transport system of the city, it is necessary to take into account the influence of one flow on another and their interaction with the external environment. A characteristic feature of the passenger flow is its variable volume at each point of the city network. At the same time, transport networks are objects of a graph structure, so graph theory methods are used to study them. But the algorithms and models built on the basis of these methods do not allow to take into account dynamically changing characteristics and random factors in the operation of transport systems.

It is proposed to use the AnyLogic simulation modeling package to determine the most reasonable option for the organization of the urban public transport network and to study the flow of passengers in the urban network.

Accordingly, in order to form a reasonable network of city public passenger transport routes, it is first necessary to determine the size and characteristics of the flow of passengers moving through the city.

When studying the flow of passengers, the main parameters (factors) that directly affect their change are:

1. Hour of the day;
2. Day of the week;
3. Month of the season.

"Hour of the day" parameter takes the hours of the day when the city passenger transport operates. The ranges of variation of the factors are very important, which leads to the appearance of a large number of options for different combinations of parameters. Thus, obtaining statistical materials on changes in the flow of passengers across the city is a complex, time-consuming task. Solving this problem with a continuous survey is practically impossible due to the high labor intensity and therefore the high cost of the research. Thus, a mathematical model that adequately describes ongoing processes and allows obtaining the necessary statistical material with minimal labor is needed [4].

The developed model has a high level of detail and takes into account the logic of each subject of the transport process. The model takes into account the following model parameters: route length, number of stops on the route, distance between stops, number of buses on the line, number of trips per day, passenger flow, passenger turnover.

The simulation program is divided into the following types:

1. Aimsun simulation software

Aimsun is a full-featured set of tools for traffic flow and traffic analysis. It enables planning, detailed modeling and research of transport requirements and operating conditions. Thanks to the integrated platform, Aimsun provides not only statistical, but also dynamic modeling capabilities. The product has the ability to import and process data from various geographic information systems, including ESRI, Tele Atlas, NAVTEQ, and others. The program can read CAD graphic data and raster images, which simplifies the task of editing and presenting project documents. The product supports data formats and other applications, such as EMME/2, CONTRAM, SATURN, TRANSYT- 7F, TRANSYT/12, VS- PLUS. The Aimsun 6.0 system provides download of sensor data (stored in databases and received in real time) for modeling, planning or visualization. Aimsun 6.0 is an extensible software environment whose architecture allows for an unlimited number of components implemented by TSS, third-party developers or users themselves. The user has fully programmable access to Aimsun tools and their customization tools like system builders.

Aimsun software is divided into Micro and Macro simulation system:

Aimsun Micro implements the principles of simulation modeling at the micro level; during the simulation, the movement of each vehicle on the road network is continuously simulated, taking into account the defined behavior models. In the process of meso-imitation, the car is also considered as a separate object, but the behavior models are simplified with a slight loss of realism, but the main focus is on adequately replicating what is happening in the car.

Implements a 4-level planning paradigm for transport operations in a single integrated environment. Performs a balanced distribution of user tasks, supports requirements analysis and exchange of network models and relevant traffic flow data with the microsimulator. Facilitates the combined use of macro and micro analysis tools (for example, in a task involving detailed simulation of a limited sub-network as part of a larger strategic network).

The main system of the simulation program is PTV Vissum. VISUM is a software that allows you to display all types of private and public transport in a single model. It is complemented by the microscopic traffic simulation system VISSIM. Both programs together form the PTV VISION system. With VISUM, you can manage basic data of transport information systems and planning. Unlike conventional GIS systems, VISUM has the ability to obtain information about the complex interrelationships within one or more transport systems and thereby create an optimal transport model.

A transport model is usually a transport demand model,

It consists of a VISUM-based network model and various influence models.

The transport demand model contains information about the demand for transport. Knowing the transport demand in the area where transport planning is carried out is an indispensable basis for the assessment of transport networks. Through data collection, traffic correspondence matrices can only be partially determined. Therefore, in order to show the real demand relationship, it is necessary to calculate the traffic flows between the regions of the planning area on the basis of structural data and information on how the population uses transport, as well as information on the spatial location of the infrastructure and the available transport supply. mathematical models are used.

A standard 4-step model is integrated into VISUM, with which correspondence matrices can be created in the program.

The network model contains information about the traffic offer. It consists of transport zones (transport cells), nodes, stops, road and rail sections of the road network and routes with timetables. In VISUM, traffic data can be visualized and interactively processed in various ways.

VISUM offers a choice of different impact models for analyzing and evaluating transport proposals. The user model simulates the nature of passenger traffic and the vehicle-driver pair. In this case, load indicators and user-related parameters (for example, travel time or transmission frequency) are calculated. The carrier model calculates OT operational metrics such as business trip kilometers, number of public transport units, operating hours or operating costs. Based on the transport demand data, the revenue from the sale of tickets is calculated, based on which the revenue estimates for the various routes are made, and therefore the profitability of the routes is evaluated. If it is necessary to show the environmental impact of motorized personal transport, there are also different calculation methods.

VISUM displays the calculation results in the form of graphs and tables. For example, nodes can display and analyze interconnected traffic flows, "bundles" of flows, isochrones, and traffic flows. Travel time, length of sidewalks, transmission frequency, service frequency and many other parameters are shown in the form of cost matrices.

Like all models, the transport model is an abstraction of the real world. The purpose of modeling is to model system analysis, impact predictions, and real-world decisions.

VISUM is the world's leading traffic analysis, forecasting and GIS data management software for the transport and transportation industry.

VISUM calculates the impact of an existing or planned transport offer, which may include both a private road network and a scheduled route network.

Possible uses for planning tasks in the field of public transport:

- planning and analysis of route networks;
- development and analysis of tables;
- assessment of the need for drivers and vehicles;
- conducting a cost-benefit analysis;
- display public transport characteristics (in graphical or tabular form) (number of tickets sold, estimated number of passengers entering/exiting, flow of school children per zone or stop);
- analysis and presentation of the number of passengers and other indicators by different transport systems, segments, stops, routes and carriers;
- create presentation tables to view different planning options;
- calculation and forecasting of cost and profit indicators for individual regions and carriers;
- production indicators to calculate the profitability of routes;
- generate network fragments with corresponding correspondence matrices.

Usability for planning tasks in the field of personal transport:

- analysis of traffic and construction activities, predicting the resulting traffic loads and their impact;
- predicting the impact of the toll;
- analysis of the capacity of transport nodes;
- separate consideration of different systems of individual transport;
- adaptation of correspondence matrix to current calculation data;
- detection of noise and/or release of harmful substances;
- generate network fragments with corresponding correspondence matrices.

With PTV VISSIM, you can do the following:

- assessment of the impact of the type of road intersection on mobility (uncontrolled intersection, controlled intersection, roundabout, railway crossing, intersection of different levels);
- design, testing and evaluation of the effect of traffic light operation mode on the character of traffic flow;
- evaluation of the transport efficiency of the proposed measures;
- analysis of the organization of traffic on highways and city streets, control of traffic directions both in individual lanes and in the entire traffic section;
- analysis of the possibilities of giving priority to public transport and measures aimed at the priority passage of trams;
- analysis of the impact of traffic control on the situation in the transport network (regulating traffic flow, changing the distance between mandatory traffic stops, checking entrances, establishing one-way traffic and lanes for public transport);
- analysis of the capacity of large transport networks (for example, a highway network or urban road network) during the dynamic redistribution of traffic flows (this is

necessary, for example, when planning stops) ;

- analysis of traffic regulation measures in railway transport and organization of waiting areas (for example, customs points);
- detailed simulation of the movement of each participant in the movement;
- modeling of public transport stations and subway stations taking into account their interaction;

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