The Use of GIS Technologies in the Management of the Urban Transportation System

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***Abstract*: The article describes the practical and theoretical aspects of using GIS technologies with respect to urban transport networks, as well as considers the developed generalized algorithm for GIS-processing technology of the urban transportation network parameters. The authors suggest the algorithm of information models of urban transport network elements taking into account the importance of set tasks and the developed method to optimize parameters of the elements of GIS of urban transport network in terms of optimization of urban public transport operation parameters, as well as the structure of the standard information model of the urban transport network element named "Urban public transport route".**

Index Terms*: *GIS technologies, urban transport network, geometric network, public transport, geoinformation system.

I. INTRODUCTION

At the present time, due to the rapid development of computer technology, there are many opportunities to build an effective automatic public vehicle traffic models using specialized software, such as for example geographic information system (GIS) [1]. In terms of purpose, GIS is an information system that provides the collection, storage, processing, access, display, and dissemination of spatially oriented data (spatial data) [2]. In terms of software and information implementation, GIS is a set of electronic maps with symbolic indication of objects, databases with information about these objects, and software for easy work with maps and databases as an integral whole. Databases can be both internal (integrated into specialized geographic information software packages (GIS packages) that work with electronic maps) and external (implemented in other software packages and formats) [4]. Typically, GIS contains an internal database and provides integration with external databases. The GIS technology, i.e. the technological basis for GIS creation, allows realizing the functionality of GIS.

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The purpose of the present study is to analyze the use of GIS technologies in urban transport system management.

II. EXPERIENCE OF USING GIS TECHNOLOGIES WITH RESPECT TO URBAN TRANSPORT NETWORKS

According to the researchers, the urban transportation system represents a geometric network (GN), i.e. a certain set of vector object classes, which form part of an inextricable network consisting of threshold elements, transitions, and turns [5]. The world practice has proved that using GIS technologies is the most optimal way to store parameters and process indicators of the GN, including transport system (TS) [13, 64]. Many foreign and domestic institutions and enterprises, such as Environment Systems Research Institute (ESRI, USA), Intergraph Corporation (USA), Pitney Bowes (USA), Mappl (Russia), JSC CB Panorama (Russia), Moscow Automobile and Road Construction State Technical University (MADI) (Russia), and others are engaged in solving problems related to the use of GIS technologies for modeling parameters and road networks optimization. The traditional approach to the processing of GN indicators is identifying and storing their attribute parameters in the database, which reflect only the presence and nature of certain relationships (relations) among elements. Certain spatial elements of GN are displayed on the GIS map as corresponding geometric objects, which are topologically linked into a single network entity. Modern GIS software packages allow taking into account some topological relationships among objects: the possibility of crossings, the presence of common points, etc. When using GIS for transport systems, one usually focuses either on building and optimizing just the street and road network model, or only on modeling traffic flows at intersections, or on the study of only passenger traffic, etc. At the same time, it is important to create and use GIS automated processing of the entire set of parameters of the TS for integrated management of urban traffic flows and networks. Unfortunately, the existing GIS and software packages do not allow fully analyzing and solving the entire complex of transport problems. In addition, their mathematical apparatus is somewhat limited, and contains not all the main known approaches to the automated processing of GIS data parameters related to the urban TS. Having analyzed the known systems, one can draw the following conclusions: when

processing GIS data parameters with respect to urban TS, the system should contain the following information components:

1. A database containing information about the TS [6], [7].
2. GIS map, which will be used for spatial processing and visualization of the TS.
3. The software modules for information analysis and processing, which allow solving many applied problems.
4. Decision supporting software modules, which, depending on the set task, will allow forming a set of optimal solutions to the optimization problem of the of GIS data parameters concerning TS.

III. METHODS

The research results consist of the development of a generalized algorithm of using GIS technology to process the urban TS parameters. Based on the analysis of the available mathematical capabilities in solving problems of urban traffic management [9], [10], the capabilities of GIS technologies and the specifics of the problem in general, the authors propose the following concept of processing GIS parameters for the urban TS management.

A. Algorithm

Phase 1. Collecting source data and choosing the main elements of the TS and options for the structure of information models of their elements.

1. Searching or forming the updated GIS of the street and road network (based on urban plans or schemes, or data of remote sensing of the Earth).
2. Identifying the main places of urban attraction and collection of information about their functioning patterns (during the day, week, and seasons of the year).
3. Conducting full-scale observations of real traffic flows in the city using video surveillance at different times of the day, and days of the week, in the most problematic points of the city.

Phase 2. Identifying information models of urban TS elements.

1. Creating a road network model using GIS technologies. The model should be flexible, and able to edit existing models, create new objects, and use new methods and optimization algorithms.
2. Identifying the model of the main places of attraction of the city and carrying out corresponding modeling and forecasting of the main urban traffic flows using well-known methods and algorithms.
3. Refining the synthesized urban traffic flow model based on the video surveillance and field observations of real urban traffic flows.

Phase 3. Optimizing parameters of GIS elements of the urban TS.

1. Analyzing existing and developing optimal modes of traffic light phases at intersections to ensure the maximum traffic capacity of urban streets in priority directions according to the model of places of attraction; considering the feasibility of introducing traffic lights, and developing optimal regulation modes at unregulated intersections.
2. Analyzing the arrangement of road signs regulating the traffic flow, developing guidelines to establish new or eliminate old signs that in conjunction with traffic lights will allow increasing the traffic capacity of urban streets in priority directions.
3. Studying the possibility of increasing the traffic capacity of urban street and road network through optimizing the network using various short- and long-term measures. In case of practical implementation of actual changes, one should turn to phase No. 1.
4. Implementing visualization of all scenarios of changing the parameters of the street and road network and measures for traffic flow management both at present and in the future using GIS technologies. Predicting all possible consequences of such changes, indicating areas, in which improving the functioning of the road transport network is possible.
5. Creating information portals to inform the population about the optimal and erroneous transportation routes to reach certain places of attraction, taking into account the current condition of the roads.
6. Returning periodically to each of the phases and updating information and calculations.

IV. DISCUSSION

Parametric optimization of urban GIS TS elements will be demonstrated on the example of parametric optimization of the urban public transportation (UPT) operation. When scheduling UPT timetable, the main quality parameter of the calculation is the interval between the public vehicles on the route. Ideally, the interval should remain unchanged. But movement interval can change when stopping for lunch, adding additional public vehicles at peak time, or returning to the depot. When conducting calculations, one must achieve uniformity of intervals, often, in case of a different number of public vehicles on the route. In order to obtain an interval, which would change smoothly, the number of public vehicles per route, as well as single-shift exit of public vehicle, should not exceed 40% of the number of exits of public vehicles operating in two shifts.

In practice, several types of exits to the route are used:

– single-shift exit with a lunch break;
– single-shift exit without a lunch break;
– double-shift exit;
– double-shift exit without a lunch break in the second shift;
– through the exit (when working in two shifts, though used only in the morning and evening peak hours, while the rest of the time vehicle stays in the depot).

The main task of the calculation is building arrival and departure timetable for the same route vehicles with reference to the end terminals. This table can be adjusted by the operator, changing the information depending on the circumstances. Before starting the calculation, one always checks the availability of data necessary for the calculation, which includes the following:

– analysis of the matrix, in which the codes of regime marks are entered indicating movement of the public vehicle on a half-hour scale;
– arrival and departure terminals of each public

vehicle, as well as route code;

– the length of the turnaround and zero routes (turnaround route is a route that is made by the public vehicle departing from a certain end terminal and arriving at the same terminal; while zero trip is a trip from the depot to a certain end terminal);

– time of crossing reporting points (designated stops on the route).

Codes of regime marks are special digital marks indicating a place, in which a public vehicle should be within a certain period of time. These codes indicate whether the public vehicle is on the route, in the depot, or on a lunch break.

The construction of the arrival and departure table begins with the first exit of the public vehicle to the route. First, one takes the exit time to the route, data on zero and turnaround routes, and builds part of the table for the morning period with regard to the first exit. Then the interval in the morning hours is determined and the arrival-departure time for each exit to the route is calculated. After that, the interval for the next period of time is calculated, and the next part of the table is built taking into account new parameters. All other parameters are determined based on the table data. The structure of the standard information model "Urban public transportation route" is shown in Table I.

Table I. The structure of the standard information model of UPT route

No	Model parameter	Meaning
1.	Parameters and characteristics of the TS	N_i - the number of the route; L_i - the length of the round-trip route from terminal A to the same terminal A; t_i - route time; t_{exit} - exit time to the route; t_{return} - return time to the depot; T - the current time of the day; I_i - the interval between the arrival of the public vehicles to the transport stops; n_{id} - the number of public vehicles on the route *i* (d = 1, h, where h is the total number of public vehicles in the depot; at that, it is assumed that the maximum number of public vehicles on route *i* is d_{imax}); S_j - season of the year (j = 1,2, 3); D_k - time of the day (K = 1,...,4); t_q - time interval (q = 1, ..., 5). The route time of the same length changes depending on the season of the year, time of the day, and the time interval determining the number of vehicles on the route.
2.	Complication options	Change of traffic routes caused by road repairs, road accidents, etc.
3.	Route direction	Is determined by the route number
4.	Factors	Time parameters of the public vehicle motion
5.	Model parameters identification methods	Figure 1 shows a graph to determine vehicle traffic parameters depending on the season of the year, time of the day, and time interval. Calculation of traffic parameters is conducted depending on the season of the year, time of the day, and time interval for a particular route. In this case, the generalized selection model of motion parameters looks like as follows: $\{ n_{id} , t_i , I_i \} = f (S_j , D_k , t_q)$
6.	Conditions of topology matching with other models	It is consistent with the street and road network, depending on the route type, as well as with the UPT stops.
7.	Conditions of matching UPT influence on other objects	Affects the parameters of traffic flows, congestion of streets, and parking spaces.

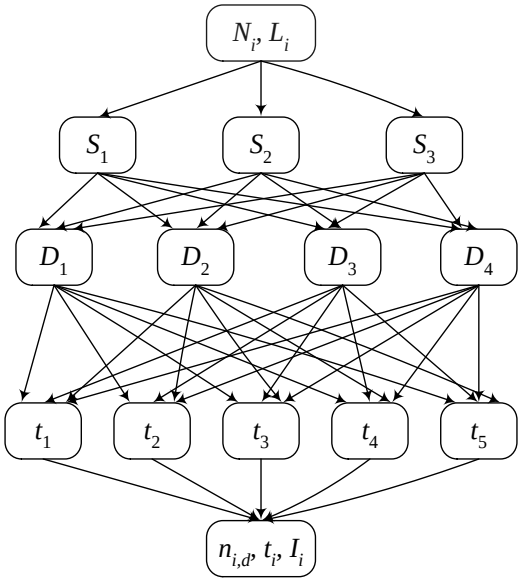

Fig. 1. Graph to determine public vehicles traffic parameters

After calculating public vehicles' service timetable for an individual route, it is adjusted to the timetable for other routes, i.e. a combined schedule for all routes is drawn up. For the convenience of information processing, the combined schedule is made for individual control point in a certain direction. This is made for more consistent determination of a number of public vehicles on routes and an interval between them. This is important for a uniform and more or less full load of vehicles.

V. CONCLUSION

Summing up the above, we can note the following.

At present, the tasks of operational (real-time) monitoring of the public vehicle's movement along with the planning of urban transport are very relevant. With the proper use of information support and modern information technologies, including already developed GIS technology for solving transport and navigation problems, one can save a lot of money, which now is spent on the design of the urban transport systems. These systems will give an insignificant effect if their justification and selection will not be based on analysis of the particular street and road network in general as well as proper traffic flows.

The proposed algorithm of using GIS technology to process parameters of the urban transport network can be widely applied when processing data and optimizing UPT.

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