Modelling of Intraurban Traffic Control Systems

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Abstract. This paper explores the possibility of intraurban traffic control systems modeling. The crossroad flow forecast model was developed. Applying such model the problems related to implementation of expensive data collection systems can be solved. The developed model of finding the shortest possible route is based on the solution of solving the single-source shortest path problem for a directed graph with non-negative edge weights. By applying the Matlab program, according to the experimental data, the program for finding the shortest possible route was designed.

Keywords. System of transport route development, data collection systems, modeling, transport flow.

1. Introduction

System of transport route development can assist in reducing of problems arising as a result of increasingly rising numbers of transport means in urban areas. This system would enable the driver to reach a certain location of city within the shortest possible time, avoiding jams on the roads. Implementation of such system in transport means would be highly beneficial for logistic companies, special services, public transport and for every driver. Implementation of such system covers the renovation of old traffic-lights and installation of new, implementation of the priority system of public transport, installation of the transport sensors and controllers, information of the drivers with the help of the display panels, monitoring of the condition of the traffic flows at the critical networks points, by using the video cameras, as well as implementation of full intraurban traffic system control information system.

In order to avoid the installation of data collection systems of transport flows at all city crossroads, the crossroad flow forecast model was developed. It enables to forecast the car flows. Such model is very important and useful in installation of transport control systems. After applying such model for the forecasts of car flows, the problems related to implementation of expensive data collection systems can be solved. Such systems would be installed only in the streets at main crossroads, where the transport flows are the biggest; and therefore, the transport flows in smaller streets and crossroads could be forecasted [5].

Overall operation of all the systems is coordinated from the central monitoring and control center. All information from the data collection as well as video surveillance systems accesses the central control center. Central monitoring and control center carries out the following functions:

- Calculation of the traffic control plans;
- Calculation of the traffic control zones within the given periods of time;
- Selection of the strategy of control signals: automatically, as per operator’s instructions, as per pre-set schedule;
- Interzonal traffic coordination;
- Implementation of the priority system of public transport;
- Response to the danger-signals;
- Flow forecast;
- Storage of information.

2. Problems of standard systems

While developing the transport control systems, it is an imperative to know the transport flows in city streets. The following methods are most often used for calculations of transport flows:

- Visual monitoring systems with computer-aided image processing;
- Sensor-based technologies of information processing and communication;
- Vehicle detection technologies;
- Collection of experimental data based on human monitoring.

One of the most efficient data collection technologies is the visual monitoring system.
This system enables to monitor the transport flows. Main component of the visual monitoring system are video cameras and special cards for the processing and transferring of video signal that are installed at certain sections of the road or at crossroads [4]. It enables to receive real information about the traffic conditions in target road sections, and to use all this information for the control of transport flows. All signals from video cameras are transferred into the central stations analysing the transport flows.

For the planning of transport routes it is very important to know the real-time location of vehicle on the road. This information is given from the vehicle location identification system. GPS is currently the most popular global navigation system in the world. Using these systems, the driver can easily identify a certain location in the city, and also reach it in the shortest possible route. But in the standard system, the driver can select only the shortest route by length. Such selection can be useless as it may include the busiest streets of the town. The problem can be solved by developing the integrated systems (Fig. 1). Such system finds the shortest route by evaluating the traffic intensity in the route [1]. The integrated transport management system consists of certain components:

- Data collection systems;
- Data transfer systems;
- Data processing;
- Transport flow forecast;
- System of shortest route development;
- Geographical information system;
- Global positioning system;
- Others

![Figure 1. Structure of integrated transport control system](image)

3. Modelling of route planning system

The developed model of finding the shortest possible route is based on the solution of solving the single-source shortest path problem for a directed graph with non-negative edge weights. Dijkstra algorithm is applied for solving the problem. According to this algorithm, the routes are evaluated by certain edge weights. Weight rate consists of the road length and vehicle flows crossing the crossroad. By calculating the weight rates, we can include into them not only the transport flows or road lengths, but also the number of pedestrian crossings, numbers of uphills and downhills, lanes etc. In order to calculate the weight rates, data about the transport flows is needed. In a real system, the data about the transport flows would be obtained from the data collection systems discussed above.

Data collection was made by monitoring the transport flows. Kaunas city was selected for the experiment. Totally, 21 busiest crossroads were selected in Kaunas city.

The experiment was performed at average crossroad traffic intensity, and at peak time. For comparison, we provide a chart representing the summarized number of vehicles crossing the crossroad recorded during three measurements of the crossroad, at average crossroad traffic intensity and at peak time. Fig. 2.

![Figure 2. Vehicle flows at crossroads](image)

As we can see from the Fig. 2, the number of vehicles crossing the crossroad at average traffic intensity and at peak time increases in about 46%. The maximum traffic intensity was noted at the first, fourth and eighteenth crossroads. It happens because these crossroads are the biggest, and the traffic intensity in them is also highest. Smallest intensity was noted at eighth, sixteenth and seventh crossroads.
Using the graph theory the roads and crossroads are represented as graph elements. City roads are represented as graph edges, and city crossroads as graph vertices (Fig. 3).

The weighted coefficient of each road consists of the certain values, such as the length of the road and the load of the crossing. To this end, all the distances between the crossings have been measured. In order for the length of the road in the gross weighted road coefficient to have the sufficient weight, as compared with the crossing load coefficient, the length of the road is divided from the road coefficient k, which is equivalent to 45.

Summarized weight rate of the road section between two crossroads (Ss) was obtained by summarizing the flows incoming from the first and second crossroads, Fig. 4.

Fig. 6 represents the optimal route from the crossroad 1 to crossroad 5 at peak time. As we can see from the sample, the route is selected in a way to avoid the busiest crossroads with intensive traffic. At low traffic intensity, the selected route crosses the crossroad 3 and 4. At peak hours this crossroad is avoided. On peak time these crossroads are eliminated from the route because they have a very intensive traffic and traffic jams. As we can see from the Fig. 2

4. Results of modelling

By applying the Matlab program, according to the experimental data, the program for finding the shortest possible route was designed. The program for finding the shortest possible route finds the optimal route according to the calculated weight rate.

In the provided sample of finding the optimal route (Fig. 5), the route from the crossroad 1 to crossroad 5 is being searched at medium traffic intensity.
the crossroads 14, 9, 6, 7, 8 have less intensive traffic.

5. Modelling of transport flow forecast system

In order to avoid the installation of transport flow data collection system in all city crossroads; the model of transport flow in the city was developed. Statistical mathematical models are made based on the experiment results, therefore it is very important to perform the experiments in a way that ensures the maximum informative mathematical modeling. The least square matrix form is used for the evaluation of model structure and parameters:

\[ A = (F^T F)^{-1} F^T Y \]  

where F is matrix of independent variables.

The least square method enables to make evaluations of the selected structural model parameters according to the experimental data. The least square method can be applied both for the identification of linear and non-linear mathematical models [7]. This method is most efficient when the model is linear in respect of the parameters. Frequently, polynomials of different types are used as the statistical models.

The described model is applied in forecasts of vehicle flows. Such mathematical model of forecasting the vehicle flows is the most useful in development of route creation systems and other transport management systems. Such model enables to forecast the transport flows in other streets, given the known traffic intensity. Certainly, in order to obtain the reliable model, one must perform experimental flow measurements. The more vehicle flow measurements are performed, the more exact the model is. If such model is applied in practice, the data compilation systems could be installed in the busiest and major city streets, and flows of less busy streets could be forecasted by the model described above.

The experimental research was performed in one of the Kaunas crossroads. During the experiment, the vehicle flows in both directions, in three crossroad roads, where measured for 15 minutes. Flows in all three streets were monitored at the same time. Totally, 12 experiments were performed. Experiment performance diagram is showed in figure 9.
The model was implemented in Matlab program [6], where, based on the least square method, the unknown model parameters are calculated. The vehicle flows from the road x1 and road x2 were used in the model inputs, and in the output the vehicle flow y was used. Data of the 5, 6 and 7 experiments was not applied in the model development. This data was reserved for the verification of the model functionality. Results of modeling and experiments are given in Fig. 9 [3].

As we can see from the provided comparison of experimental and modelling results, these values are very similar. As it was already mentioned, the experiments 5, 6 and 7 were not incorporated into the model development. In order to ensure that the developed model meets the actual experiment results, the unknown 5, 6 and 7 experiments results were incorporated into the model. As we see in the provided chart, these unknown results are quite precisely forecasted by the model.

6. Conclusions

The experiments were performed in the crossroads and roads of Kaunas city. According to the obtained experimental data it was identified that the traffic intensity in the crossroads at peak time, in comparison to the non-peak time, is increasing in about 46%.

The route finding system, built according to the Dijkstra algorithm, is accessing the traffic intensity on the roads. The model is implemented with the aids of the the program Matlab.

After the inspection of results of the shortest possible modelled route, it was identified that the driver saves about 15% of time when riding the selected routes.

The experiment of vehicle flow calculation in one of the Kaunas crossroads was performed. Based on the obtained data, the model of the vehicle flow forecast was developed. The model was implemented in the Matlab program.

7. References
