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Systems of Transport Route Development

K. Balsys, D. Eidukas, A. Marma, A. Valinevičius, M. Žilys
Department of Electronics Engineering, Kaunas University of Technology
Studentų st. 50, LT-51368 Kaunas, Lithuania, tel.: +370 37 35 13 89; e-mail: kestutis.balsys@arevita.com

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.

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.

Data collection 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 [1]. 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.

Problems of standard systems

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. These systems are also called the global positioning systems. GPS is currently the most popular global navigation system in the world. Using the global satellite systems, we can easily find out the vehicle coordinates. 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. 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.

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 [2]. According to this algorithm, the routes are invalidated 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 [3].

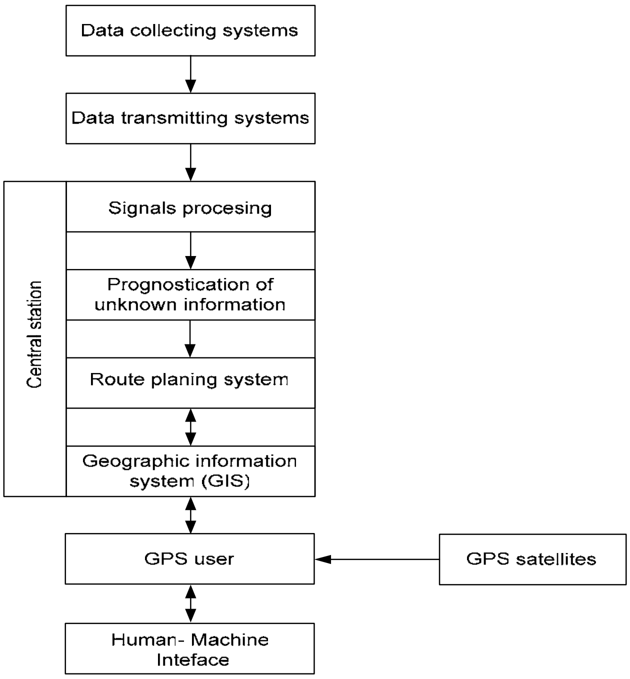

Fig. 1. Structural scheme of integrated transport control system

Kaunas city was selected for the experiment. Totally, 21 busiest crossroads were selected in Kaunas city. These crossroads and roads between them are represented in Fig. 2.

Fig. 2. Crossroads selected for the experiment

The experiment was performed at average crossroad traffic intensity, and at peak hours. 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 hours.

As we can see from the Fig. 3, the number of vehicles crossing the crossroad 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. The least intensity was noted at eighth, sixteenth and seventh crossroads.

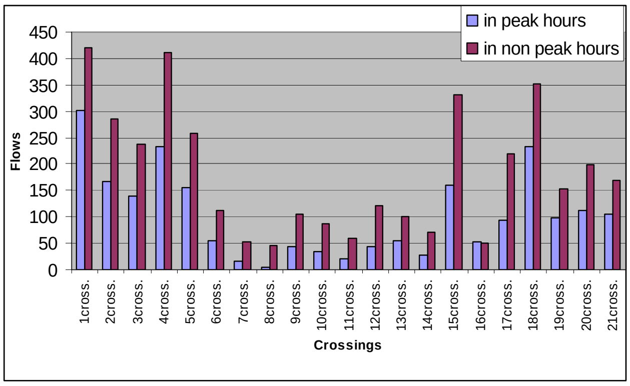

Fig. 3. Vehicle flows at crossroads

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.4).

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.

The weighted coefficient of the direction of each crossing K_s is calculated according to the following formula:

$$K_S = \frac{A_S}{3} \cdot t_{\check{z}} \cdot 100 + \frac{3 \cdot t_r}{100}, \qquad (1)$$

where A_s – vehicle flow; $t_{\check{z}}$ – time of the green traffic-light signal; t_r- time of the red traffic-light signal.

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. 5.

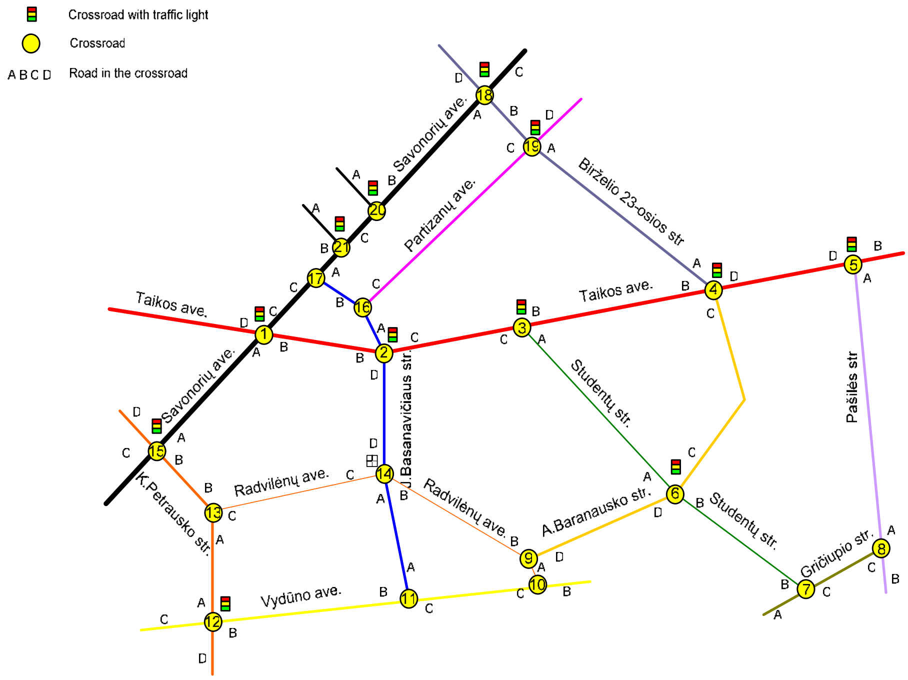

Fig. 4. Graph of city roads and crossroads

In the uncontrolled crossings the number of the vehicles has been calculated per time unit – 60 s.

$$K_S = \frac{A_S}{3t \cdot 100}, \qquad (2)$$

where K_s – weighted coefficient of the vehicle flow; A_s – vehicle flow; t – time (60 s).

The total flow weighted coefficient of the road section between the two crossings (S_s) has been received by summing the flows, coming from the first and second crossing.

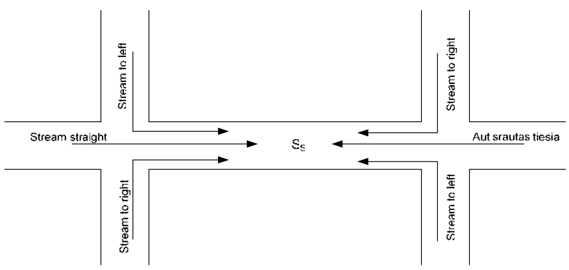

Fig. 5. Summarized weight rate of crossroads

The final weighted coefficient K_g of the road section between the two crossings is received according to the following formula: $K_g = S_S + K_k$, where S_s – total flow weighted coefficient; K_k – weighted coefficient of the road.

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. 6), the route from the crossroad 1 to crossroad 5 is being searched at medium traffic intensity.

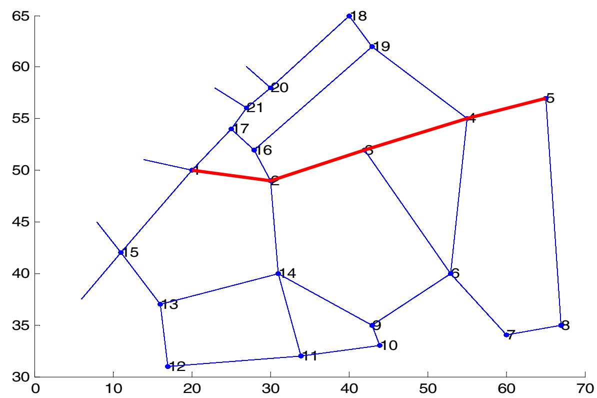

Fig. 6. Finding the route from the vertex 1 to the vertex 5, at low traffic intensity

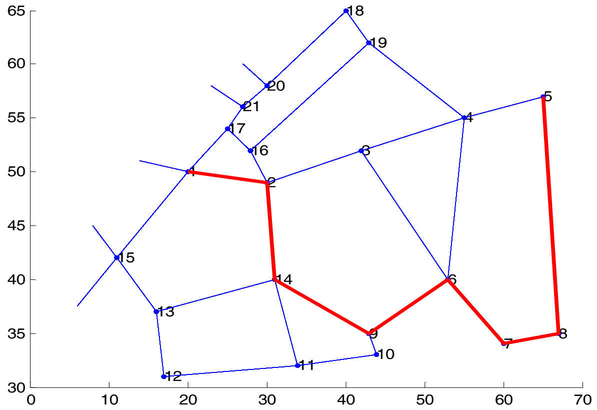

Fig. 7. Route from the crossroad 1 to crossroad 5 at medium traffic intensity

Fig. 7 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.

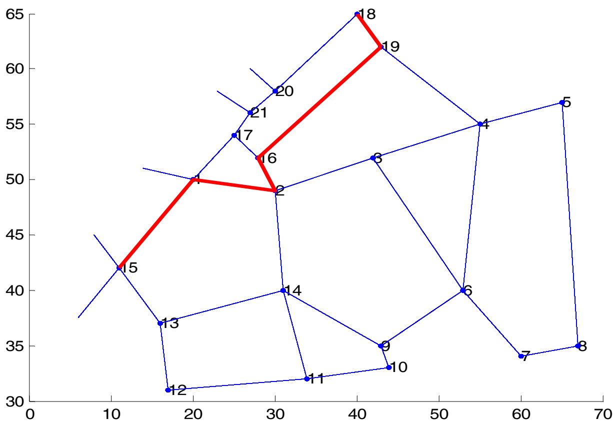

Fig. 8. Finding the route from vertex 18 to vertex 15 at medium traffic intensity at roads and crossroads

In the provided sample of finding the optimal route (Fig. 8), the route from the crossroad 18 to crossroad 15 is being searched at medium traffic intensity

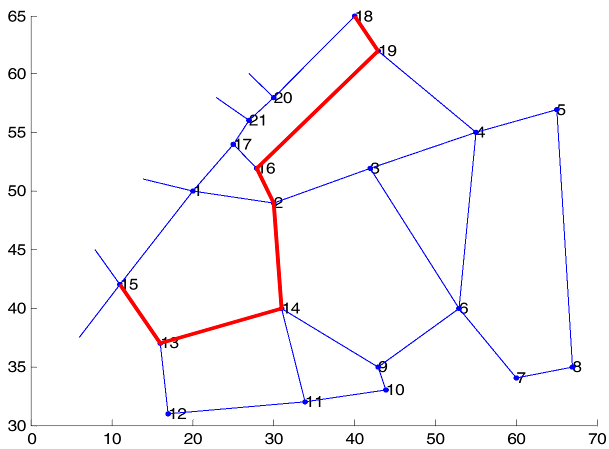

Fig. 9. Finding the route from vertex 18 to vertex 15 at maximum traffic intensity

Fig. 8 and 9 represent the route from the crossroad 18 to crossroad 15 at non-peak and peak hours. At medium traffic intensity, the selected route crosses the crossroad 1, and at peak hours this crossroad is avoided. On peak time this crossroad is eliminated from the route because it has a very intensive traffic and traffic jams.

Some routes were checked by using the vehicle. After checking the routes it was identified that the modelled route saves 15% of time in comparison to the selection of straight route crossing the major crossroads.

Modelling of transport flow forecast system

In other 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 modelling.

The least square method is used for the evaluation of model structure and parameters. This 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 [4]. 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 polynomial assessing only the members in linear dependability from factors will be applied in the work. Such a model is linear both in regard of parameters and independent variables. For the evaluation of unknown model parameters, we shall apply the matrix form of least square method. The following equation is used in calculations of linear parameters of the matrix of least square method form:

$$A = (F^T F)^{-1} F^T Y, \tag{3}$$

where F is a matrix of independent variables.

This formula enables to unambiguously identify the values of unknown model parameters A [5].

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 where monitored at the same time. Totally, 12 experiments were performed. The experiment results are given in the Table 1.

Table 1. Experiment results

Experiment number	Experiment time	x1	x2	y
1	7.50 hour	254	276	321
2	11.00 hour	186	101	259
3	12.45 hour	212	134	270
4	14.00 hour	266	172	330
5	**14.30 hour**	**235**	**137**	**304**
6	**15.30 hour**	**283**	**154**	**329**
7	**16.00 hour**	**292**	**197**	**345**
8	17.00 hour	318	244	368
9	20.10 hour	180	89	221
10	20.40 hour	175	92	201
11	23.00 hour	69	27	83
12	01.30 hour	15	8	18

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 x_1 and road x_2 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 [7-14]. This data was reserved for the verification of the model functionality. Results of modelling and experiments are given in the Fig. 10.

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 included 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 included into the model. As we see in the provided chart, these unknown results are quite precisely forecasted by the model.

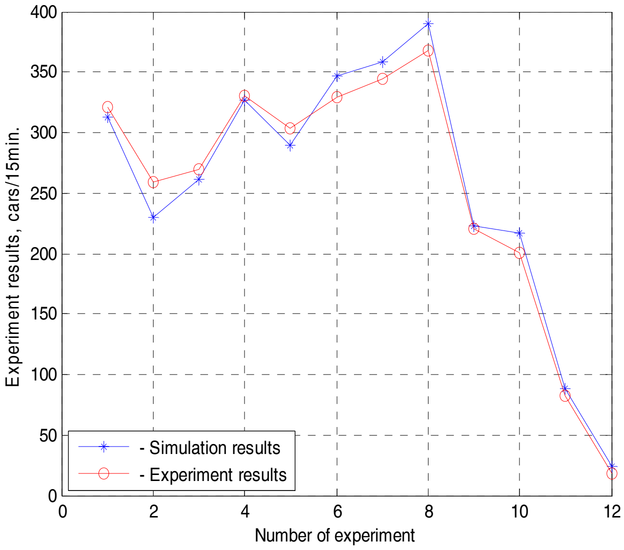

Fig. 10. Results of experimental modelling and simulation

Conclusions

1. The experiments were performed in the crossroads and roads of Kaunas city. According to the received experimental data, the following weight rates were calculated:

-Weight rate of the road length K_k;
-Weight rate of the vehicle flow K_s;
-Summarized weight rate of flows S_s;
-Final weight rate of the road K_g.

2. 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%.

3. 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.

4. 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.

5. 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.

References

1. **Balaišis P., Eidukas D., Valinevičius A., Žilys M.** Informacinių elektroninių sistemų efektyvumas. – Kaunas: Technologija. – 2004. – 358 p.
2. **Plukas K., Mačikėnas E., Jarašiūnienė B., Mikuckienė I.** Taikomoji diskrečioji matematika. – Kaunas: Technologija, 2005. – P. 34–160.
3. **Jurkauskas A.** Viešasis transportas. – Kaunas: Technologija, 2004. – P. 54–237.
4. **Dumčius A., Eidukas D.** Eksperimento metodologija ir planavimas. – Kaunas: Technologija, 2004. – P. 41–49.
5. **Mayers H. R., Montgomery C. D.** Response surface methodology. A Wiley Interscience Publication. – JohnWiley & Sons, Inc. – 2004. – P. 1–28.
6. **Kildišas V., Tekorius T.** Valdymo uždavinių sprendimas taikant MATLAB sistemą. – Kaunas: Technologija, 2005. – P. 5–26.
7. **Eidukas D., Valinevičius A., Žilys M., Marma A.** Intelektualiosios transporto valdymo sistemos // Elektronika ir elektrotechnika. – 2004. – Nr.6 (48).
8. **Eidukas D., Valinevičius A., Kilius Š., Plėštys R., Vilutis G.** Analysis of Communication channels of the Dwelling Control System // Proceedings of 28th International Conference on Information Technology Interfaces ITI 2006. – June 19–22, 2006, Cavtat/Dubrovnik, Croatia. – P. 513–518.
9. **Marma A.** Efficiency of intelligent transportation systems. Zeszyty naukowe Politechniki Sląskiej: Transport. ISSN 0209-3324. – Gliwice: Wyd. Politechniki Sląskiej. 2005. – Z. 59, nr. Kol. 1691. – P. 289–297.
10. **Marma A., Eidukas D., Žilys M., Valinevičius A.** Intelektualiųjų transporto valdymo sistemų efektyvumas // Elektronika ir elektrotechnika. ISSN 1392-1215. – Kaunas: Technologija, 2005. – Nr. 6(62). – P. 61–66.
11. **Valinevičius A., Žilys M., Eidukas D., Kilius Š.** Modeling of the Integrated Security System //18th International Conference of Production Research. ISBN 88-87030-96-0. University of Salerno-Campus of Fisciano – Fisciano (SA) Italy. – July 31 – August 4, 2005.
12. **Valinevičius A., Žilys M., Eidukas D.** Information Flow Model of integrated Security System // Proceedings of 26th International Conference on Information Technology

Interfaces ITI 2004. – June 7–10, 2004, Cavtat/Dubrovnik, Croatia. ISSN 1330-1012. – P. 567–572.
13. **Valinevičius A., Eidukas D., Žilys M.** Modeling of the Integrated Security System // NETTIES 2004 Conference, Budapest, Hungary. 2004. – P. 31.
14. **Žilys M., Valinevičius A., Eidukas D.** The simulative Model of The Integrated Security System // 16th International Conference on Production Research ICPR-16 (29 July-3 August 2001) Proceedings. ISBN 80-02-01438-3. – Prague, Czech Republic, 2001. – P.1–14.

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Improvement of the global position system (GPS)-based navigation systems, data collecting systems, data transmission systems allows the speedy development of the traffic control systems. The implementation of the traffic control systems can help solving such motor transport related problems as environmental pollution, gridlocks, car thefts, road safety. The main goal of this paper is create the road formation system model, which determines the shortest distance between the crossings and create prognostication of unknown information system. Ill. 10, bibl. 14 (in English; summaries in English, Russian and Lithuanian).

К. Бальсис, Д. Эйдукас, А. Марма, А. Валинявичюс, М. Жилис. Системы формирования транспортного маршрута // Электроника и электротехника. – Каунас: Технология, 2007. – № 3(75). – С. 17–22.

Быстрое усовершенствование глобальной навигационной системы (GPS), системы сбора данных, системы передачи данных позволяет быстрое развитие систем управления движения. Усовершенствование систем управления движения автомобильного транспорта может помочь решить таких проблем как экологическое загрязнение, заторы, воровство автомобилей, дорожная безопасность. Описываются методы создания модели системы формирования маршрута, которая определяет самое короткое расстояние между дорогами, и модели прогнозирования неизвестной информации. Ил. 10, библ. 14 (на английском языке; рефераты на английском, русском и литовском яз.).

K. Balsys, D. Eidukas, A. Marma, A. Valinevičius, M. Žilys. Transporto maršruto valdymo sistemos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 3(75). – P. 17–22.

Lietuvoje sparčiai plintant tokioms sistemoms kaip globalinė paieškos sistema (GPS), duomenų surinkimo bei perdavimo sistemoms, atsiranda naujos galimybės plėtotis transporto valdymo sistemoms. Tobulinant transporto valdymo sistemas galima spręsti su transportu susijusias problemas, tokias kaip avaringumas, transporto spūstys, ekologija ir kitas. Aprašomas sukurtas maršrutų sudarymo sistemos modelis, kuris gali padėti surasti trumpiausią maršrutą tarp sankryžų, bei nežinomos informacijos prognozavimo modelis, kuris gali būti taikomas transporto srautams prognozuoti. Il. 10, bibl. 14 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).