INVESTIGATION OF RIGA TRANSPORT NODE CAPACITY ON THE BASIS OF MICROSCOPIC SIMULATION

Irina Yatskiv
Elena Yurshevich
Michael Savrasov
Department of Computer Science and Electronics
Transport and Telecommunication Institute
Lomonosova Str.1, Riga, Latvia
E-mail: ivl@tsi.lv

KEYWORDS
Transport system, microscopic simulation modelling, transport node capacity, forecasts, regression models, experimentation

ABSTRACT

The aim of this paper is to describe the example of usage simulation modelling approach for analysing the capacity of transport node in Riga, the capital of Latvia. At first, the simulation model for this node using package VISSIM was constructed. This model was based on the real traffic measurements in this area. Further, the experiments with the model were undertaken on the data prognosis of this traffic for 5 years. The load capacity of three junctions according to the ICU classification was investigated.

INTRODUCTION

For the past 30 years in the EU states the number of cars has been increasing for three times and is increasing to 3 million cars annually (European Commission work, 2001). Many current transport problems (traffic jams, accidents, etc.) appeared as the results of poorly designed transportation system. The approach to improve the design of city transportation system includes many decisions: addition of new streets, introduction of the transit system, new arterials meant for relieving congestion, moving the centres of the population attraction, etc. Choosing this or that approach it is necessary to analyse a set of consequences, among which can be both positive and negative indirect consequences. The approach to analyse such kind problems in complex is to use microsimulation in decision process making.

Riga, the capital of Latvia, also has faced the problem of overloading of the transport system. Special problems are created with the star-shaped type of traffic leading to huge problems in the so-called rush hours or peak hours and also the troubles of the insufficient capacity of bridges over the Daugava River. The out-of-date layout of the city, its transport system does not satisfy today's needs of the population for travelling.

Considering the global character of problems, the strategic plan for development of the city the Riga Council stipulates to move the administrative centre from the city centre to the left coast of the Daugava River (Pardaugava area). This re-planning is expected to reduce the congestion of the city centre and to lower the acuteness of the problem of bridges capacity. However, such cardinal change of the administrative attraction demands the careful analysis of a today's transport infrastructure in Pardaugava area, and, undoubtedly, will result in developing and re-planning of an existing transport network.

The simulation model has been designed for the analysis of the current state of the transport node, which is located between two bridges connecting the right and left coasts of the river. The given bridges will take up the basic loading at transport travelling to a new administrative centre. It is necessary to estimate the capacity of the existing transport node from the point of view of a today's situation and possible increase of the intensity of vehicles travelling in the future.

As instrument for simulation model realization the package VISSIM 4.2 family PTV Vision has been selected.

THE TASK DEFINITION

The considered transport node (fragment of the transport network at crossing of streets: Uzvaras avenue – Ranka dambis street – A.Grina avenue – Slokas street) is presented in Fig.1.

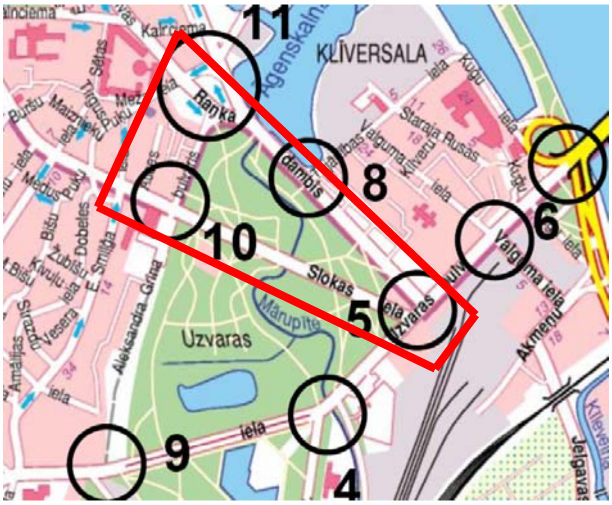

Figure 1: Subject for Modelling

Proceedings 21st European Conference on Modelling and Simulation
Ivan Zelinka, Zuzana Oplatková, Alessandra Orsoni ©ECMS 2007
ISBN 978-0-9553018-2-7 / ISBN 978-0-9553018-3-4 (CD)

This fragment of Riga transport network includes the following crossroads:

1. Uzvaras avenue – Slokas street
2. Uzvaras avenue – Ranka dambis street
3. Ranka dambis street – Trijadibas street
4. Slokas street – A.Grina avenue
5. Balasta dambis street – Daugavgrivas street (1 part)
6. Daugavgrivas street – Ranka dambis street
7. A.Grina avenue – Ranka dambis street (1 part)
8. A.Grina avenue – Ranka dambis street (2 part)
9. Balasta dambis street – Daugavgrivas street (2 part)

Input data for simulation were taken from the interprise "Solver" Ltd. report, which had been fulfilled according to the order of the Riga Council in 2005. The report consists of the traffic flow data about 19 junctions. The survey was conducted on 14th, 15th and 16th of July 2005 (Thursday, Friday, Saturday) from 16:30 till 19:00 and on 9th, 10th, 11th of August (Tuesday, Wednesday, Thursday) from 7:30 till 9:30. There are the data about pedestrians' traffic analysis as well. The survey was conducted on 29th and 30th of July from 7:30 till 9:30 and from 16:30 till 19:00 (Friday, Saturday).
The level of congestion of the investigated crossroads has been measured and results are presented in Fig 2. Standard ICU establishes A as the lowest level of congestion (55%) and H – the highest (109%). According to the ICU standard, the level of congestion of the majority of crossroads is in norm (A, B, C) and crossroads 3 and 6 concern to the group, which is the last satisfactory (D).

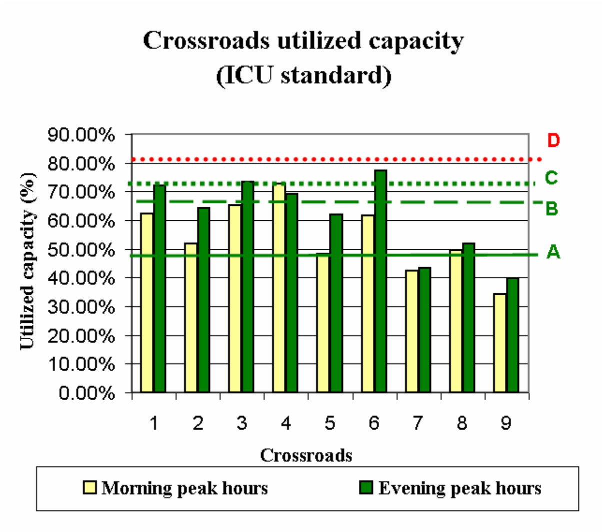

Figure 2: Distribution of the Congestion Level of Crossroads according to the ICU Standard

Intensity of transport and pedestrians' traffic on crossroads in the morning and evening peak hours are presented in Table 1. There is the information on the distribution of the transport traffic on the crossroads. The arrangement of traffic signs has been given as well. A number of crossroads, such as Uzvaras avenue – Slokas street and Uzvaras avenue – Ranka dambis street are regulated. During realization of the project the information on the schedule of functioning of traffic lights on crossroads has been collected by the authors of this paper. The schedule of their work is presented in Fig. 3.

Table 1: Intensity of Transport and Pedestrians' Traffic

Crossroads	Morning peak hours (8:15 - 9:15)		Evening peak hours (17:00 - 18:00)	
	veh.	ped.	veh.	ped.
Uzvaras - Slokas	1423	379	1534	456
Uzvaras - Ranka d.	2549	59	3102	64
Ranka d. - Triadibas	2131	32	2656	56
Slokas - A.Grina	783	25	772	314
Balasta d.–Daugavgr.	1365	122	1765	113
Daugavgr. –Ranka d.	1395	64	1675	43
A.Grina - Ranka d.(1)	1427	0	1425	0
A.Grina - Ranka d.(2)	2292	0	2686	0

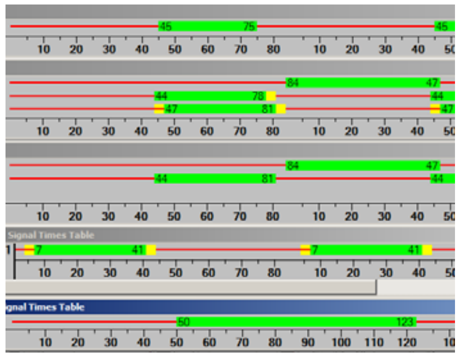

Figure 3: Schedule of Traffic Lights Operation on the Crossroads

The package gives the possibilities to take into account the structure of transport flow, which is presented in Table 2.

Table 2: Structure of Transport Flow

Vehicle Type	Flow share
Car	0.8
Lorry	0.05
Bus	0.15

Also within territory of the considered transport node 6 routes of trams move: 1,2,4,5, 8 and 10.
The tasks of investigation are the following:

- to analyse the capacity of the investigated transport node under the existing conditions, to reveal its bottlenecks;
- to carry on a number of experiments with the purpose of forecasting the intensity of traffic until the year 2010.

THE MODEL CONSTRUCTION AND ANALYSIS

During the project implementation two models of transport node were created: the models of morning and evening peak hours crossroad loading. There was created the network model of road interchanges that takes into account the physical geometry of roads and intersections as well as the footpaths. As a base for model creating the map of real transport system has been taken into consideration. The link model is presented in Fig.4.

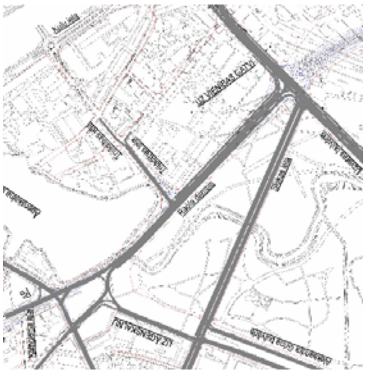

Figure 4: Implemented Link Model of the Explored Riga Transport System Node

The model contains 18 descriptions of the transport routes. There were outlined described the real data of traffic structure, its intensity and distribution through the routes. There were implemented the tram routes and their stops also. The real schedule was specified. Over 200 priority rules for non-signalised intersection traffic regulation (see Fig.5) were described. The transport node consists of signalised and non-signalised intersection. Also 5 signal controllers and signal groups were fulfilled for signalised intersection. Vehicles', trams' and pedestrians' signal controllers were described separately. The example of the implemented signalised intersection is presented in Fig.6.

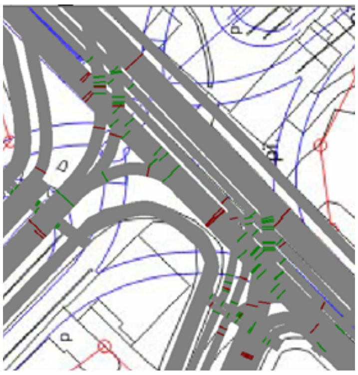

Figure 5: Example of Priority Rules Description for Non-Signalised Intersection

Taking into account the necessity of analysis of intersection loading and capacity the special tools for data collection were implemented: the Data Collection Points, Travel Time Section and Queue Counters. Under consideration follow up such measures like:

- Vehicle average time of some section crossing up (sec.).

Figure 6: Example of the Implemented Signalised Intersection in the Model

- Average total delay time per vehicle (sec.). Delay time – subtracting the theoretical travel time from real travel time; it doesn't include passengers' and transit stops.
- Average standstill time per vehicle (sec.) – it does not include passengers' stop times at transit stops or in parking lots.
- Average number of stops per vehicle, not including stops at transit stops or in parking lots.
- Vehicle capacity.
- Total time the vehicle spent in congestion (sec.).
- Average, maximum queue length (m), number of vehicle stops within the queue.
- Link evaluation: volume (veh/h), vehicle density (veh/mi) and average speed (mph).

The first analysis was based on the data of 2005. The most problematic are 5 micro intersections (see Fig.7):

1. Uzvaras avenue – Ranka dambis street
2. Akmenu bridge – Uzvaras park
3. Ranka dambis street – Uzvaras avenue
4. Uzvaras park – Akmenu bridge
5. Slokas street– Uzvaras avenue

Figure 7: The Most Problematic Part of the Transport Node for Model Experimentations (Uzvaras avenue – Ranka dambis street– Slokas street)

Let's take into consideration these five most problematic intersections. The crossroad average queue length at these parts was explored. The results are presented in Figures 8 and 9. The data were collected during the 1 simulation hour.

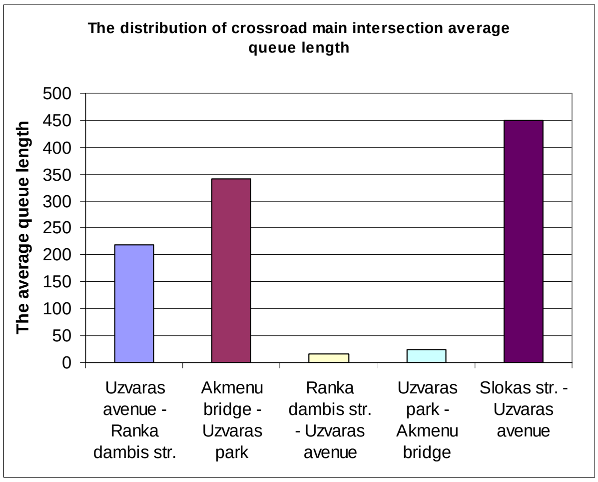

Figure 8: Distribution of Crossroad Main Intersection Average Queue Length (morning peak hours, 2005)

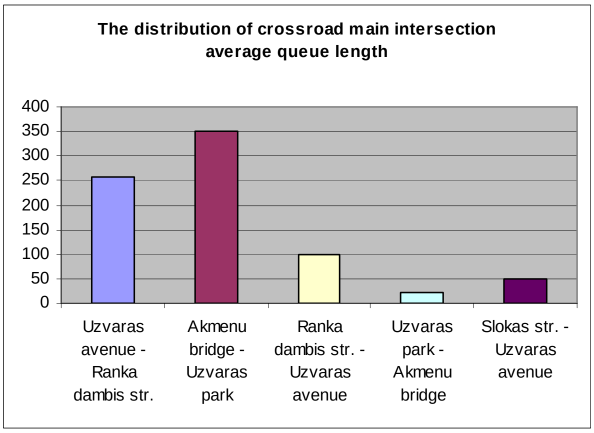

Figure 9: Distribution of Crossroad Main Intersection Average Queue Length (evening peak hours, 2005)

The maximum loading was observed on Slokas street – Uzvaras avenue, Akmenu bridge – Uzvaras park, Uzvaras avenue – Ranka dambis street crossroad intersections. Taking into account the fact that maximum segment length of the Slokas street is 580m and therefore it is possible to point out that Slokas street queue length is the critical one. The same situation was observed in the segment of crossroad Akmenu bridge – Uzvaras park (the maximum segment length – 480m). The average car speed in this area was 15.98 km/h in the morning and 17.8 km/h in the evening.

TRAFFIC FORECASTS

The main goal of the planned experiments is to define and analyse the capacity of the above-mentioned crossroads. The model has been developed and validated using available statistical data for 2005; that is why the forecasts have been made for 2006, 2007, 2008, 2009, 2010.

The forecast value of traffic can be estimated using extrapolation method. To forecast traffic value should multiply current traffic value by the extrapolation coefficient, which can be calculated using following formula described in the article (Pihlak, I. 1996):

$$K = \frac{V}{v}\frac{M}{m}\frac{U}{u},$$

where K – extrapolation coefficient or growth coefficient;
V – forecasted value of population;
v – current population;
M – forecasted motorization level (transport by 1000 people);
m – current motorization level (transport by 1000 people);
U – forecast of the transport use level;
u – current transport use value.

Data for extrapolation procedure about population and the motorization level were taken from the home page of the Latvian Statistical Institute. Using these data two regression models were built: the first – to forecast population value and the second – to forecast motorization value. As the result of the analysis we've got two forecasting models, which describe population and transport dynamics. The model quality metrics for both are the following:

- multiple determination coefficient is higher than 0.9;
- p-value for F-criteria is less than 0.00001.

The results of the forecasts according to obtained models can be seen in Table 3.

Table 3: Basic and Forecasted Levels of Population and Motorization

Year	Population	Motorization
2005	885002	394
2006	875309	416
2007	876051	437
2008	878277	458
2009	881986	479
2010	887178	500

Now applying data from Table 3 we can use the formula to define extrapolation coefficient K. The results of calculations are described in Table 4.

Table 4: Values of Extrapolation Coefficients

Year	2006	2007	2008	2009	2010
K	1.057	1.125	1.197	1.272	1.352

To define traffic values we should multiply the estimated extrapolation coefficients by the traffic value in 2005.

TRANSPORT NODE CHARACTERISTICS FORECASTS

Taking into account the growth of motorization of population the analysis of the level of crossroad loading has been performed for the nearest 5 years (until 2010). The forecast of crossroad loading has been fulfilled with the help of simulation model taking into consideration the extrapolation coefficient. The complete information about experiments with the models and the roads utilization is presented in Table 5. The results show that the average delay time will be approximately doubled after 5 years.

Table 5: Information about Transport Network Loading

Information about transport network loading	Evening peak hours		Morning peak hours	
	2005	2010	2005	2010
Number of vehicles in the network, all vehicle types	266	621	297	591
Number of vehicles that have left the network, all vehicle types	4435	4585	4265	4534
Average speed [km/h], all vehicle types	17.186	8.609	15.987	9.761
Average delay time per vehicle [sec], all vehicle types	83.786	213.347	91.688	174.263
Average stopped delay per vehicle [sec], all vehicle types	48.116	137.017	48.658	109.544
Average number of stops per vehicles, all vehicle types	1.976	4.004	2.398	3.615

The queue length was analysed too. The average crossroad queues length enlargement is presented in Table 6. It is noticeable that maximum enlargement is going on in Uzvaras avenue – Ranka dambis street and Akmenu bridge – Uzvaras park region, the first mentioned place takes place in the morning, the second one in the evening.

Table 6: Crossroad Queues Growth

Crossroad intersection	Queue length growth (2005 – 2010)	
	Morning	Evening
Uzvaras avenue – Ranka dambis str.	1.35	1.11
Akmenu bridge – Uzvaras park	1.05	1.01
Uzvaras park – Akmenu bridge	1.15	1.21
Slokas str. – Uzvaras avenue	1.46	7.00
Ranka dambis str.– Uzvaras avenue	2.62	2.29

Minor enlargement in other districts can be explained by critical situation that comes right now. Figures 10, 11, 12 show the following 5 years' changes of average queue length, upper bound value of their confidence limits and maximum in the busiest district regions.

The result illustrates that the future increase of Riga population motorization will lead to junctions increase and the explored transport node capacity will not be enough in the future. The analysis of the other transport node crossroads demonstrates they will be overloaded too. This fact should be taken into account according to the plans of creation of a new business centre in this field. Evidently, it is necessary to carry out whole transport node reconstruction.

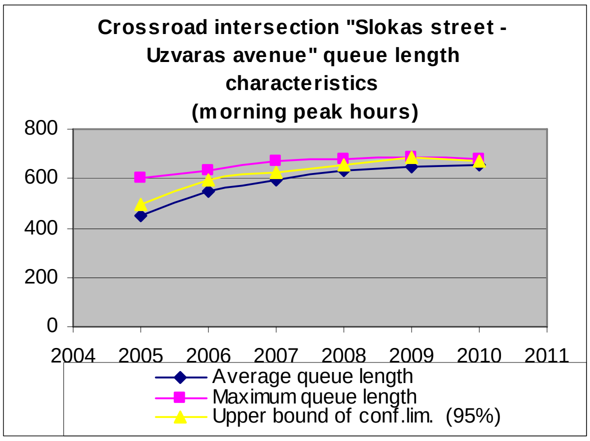

Figure 10: Forecast of Crossroad "Slokas street – Uzvaras avenue" Queue Length

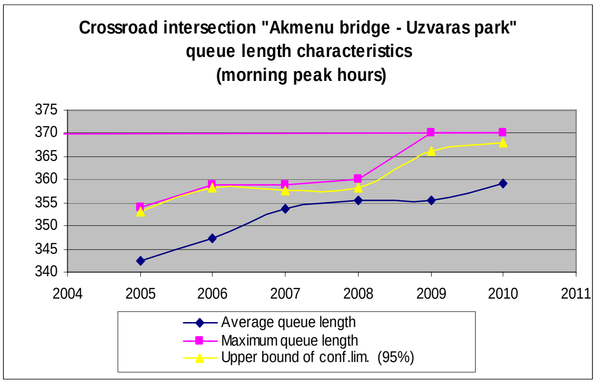

Figure 11: Forecast of Crossroad "Akmenu bridge – Uzvaras park" Queue Length

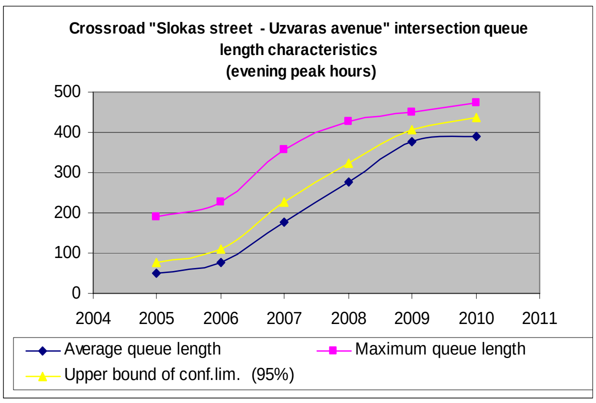

Figure 12: Forecast of Crossroad "Slokas street – Uzvaras avenue" Queue Length

CONCLUSIONS

The performed investigation concerns the one complex transport node in Riga, where its loading can be increased dramatically during the next years. The most problematic directions of transport movements in this node are considered according to the forecasting volume of traffic until 2010. Now these crossroads are at the normal level of congestion according to ICU standard, but the situation will change opposite if the rate of motorization level is held on the same level (as during the last 5 years).

Also, this investigation did not take into account the possible increasing of the traffic volume in case of realizing the construction of a new administrative centre. The authors of this paper have no results of such kind of survey. They just demonstrate the approach of the investigation of development of the future situation in the problematic transport node on the basis of microsimulation model.

The simulation approach allows designing the model of the transport network, reproducing its structures, the organization of crossroads, characteristics of transport traffic with a high degree of the detailed elaboration. The simulation approach makes is possible to analyse the efficiency of the system’s functioning on its model, to collect the data about its functioning and to experiment not destroying the real system.

REFFERENCES

Pihlak, I. 1996. "Norms of street roads designing in Estonia", The Tallinn Technical University.

WHITE PAPER, 2001. *European transport policy for 2010: time to decide.* The report of European commission work.

AUTHORS’ BIOGRAPHIES

IRINA V. YATSKIV was born in Krasnoyarsk, Russia and entered in the Riga Civil Aviation Engineering Institute, where she studied computer science and obtained her Engineer’s diploma in 1982. Candidate of Technical Science Degree (1990), Riga Aviation University, Dr.sc.ing. (1992). Present position: Vice-Rector of Transport and Telecommunication Institute, Professor of Computer Science Department. Member of Classification Society of North America, Member of Latvian Simulation Modelling Society, Director of Latvian Operation Research Society, the leader of the project BSR INTERREG III B Programme InLoC, and the projects connected with the transport system simulation in Latvia. Fields of research: multivariate statistical analysis, modelling and simulation, decision support system.. Publications: more than 70 scientific papers and teaching books.

E-mail address is: ivl@tsi.lv

ELENA YURSHEVICH was born in Riga, Latvia and entered in Riga Aviation University at 1996, which was transformed to Transport and Telecommunication Institute in 1999. She studied computer science and was graduated in 2002. At present she is a lecturer at the Chair of Mathematical Methods and Modelling of the Faculty of Computer Science and Electronics, TTI and continues her education. She is a student of TTI Doctoral Degree Programme “Telematics and Logistics”. The field of scientific interests is as follows: Transport System Optimisation and Modelling. She has an experience participating in several projects connected with transport system simulation and analysis. She is the member of Latvian Simulation Modelling Society, the member of Baltic Operation Research Society, the member of WG3: "Continuous National Travel Surveys", European Committee COST355.

E-mail is: elena_y@tsi.lv.

MIHAILS SAVRASOVS was born in Daugavpils, Latvia and entered Transport and Telecommunication Institute where he studied computer science and obtained Master’s degree of Natural Sciences in Computer Science in 2006. He is a student of TTI Doctoral degree programme “Telematics and Logistics”. Current position: Head of the Laboratory of Applied Systems in Transport and Telecommunication Institute. Fields of research: applied statistical analysis, modelling and simulation. Publications: 2 scientific papers.

E-mail: mms@tsi.lv