PRACTICAL ASPECTS OF MODELLING IN THE TRANSPORT NODE RECONSTRUCTION IN RIGA

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KEYWORDS

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ABSTRACT

The paper describes the questions of decision support system in transport planning. One of the methods used for studying the relationships and underlying the transportation decision-making is transport modelling, which includes traffic modelling on micro and macro levels. The research considers the example of the micro-simulation model of Riga complex transport node. 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 two sets of experiments with the model were undertaken: 1 - with fulfilled reconstruction and 2 – with offered improving of this node. The data prognosis of this traffic for 8 years was used in both experiments.

INTRODUCTION

Cities have developed over many years and both their transport and their social systems are complex. It is clear that these problems cannot be solved by simply increasing transport supply; demand management is both desirable and necessary. Complexities of city structure, an integrated systems approach to travel, demand management on the base of modelling and simulation provide the best opportunity for the development of equitable, efficient and sustainable urban transport systems (Kabashkin et al. 2003).

Decision-makers have to take into account a large number of factors influencing their decisions and a large number of factors influenced by the decisions. This is especially true in the field of traffic and transport, as transport is dependent on economical developments (growth and spatial organisation of economic activities). As Ginzberg and Stohr's (Ginzberg and Stohr 1982) define Decision support system (DSS) as "...a computer-based information system used by decision-makers to support their decision-making activities in the situations where it is not possible or not desirable to have an automated system perform the entire decision process".

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The DSS for transport planning helps the user (decision-maker) to modify the information as needed to define alternatives before he starts the decision process. For implementing the decision support system in transportation the two tasks are important. Firstly, it is necessary to have access to a high-end information system with qualified and full statistical database about the urban movements and the other transport information. The quality of the data models is very important for DSS tasks. The process of these data collection may be organised on the base interview with passengers; the outer observation or traffic statistics obtained with the help of objective control systems on the basis of modern transport telematics aids.

The second task for implementing the decision support system in transportation is the set of realized transport models on macro- and micro-levels. The macroscopic model simulates current and future transport flows, the city road network, analysis of the intensity of movement, scenario 'what if' scheduling. The microscopic model simulates transport jams forecast, chooses the optimal organisation of transport movement on junction, and analyses the "bottlenecks" in the transport network.

The DSS is intended for transportation planners and engineers, transportation researchers, and policy-makers. User's input should include transport system operational parameters (roadway characteristics, traffic characteristics, and system operational strategies), transit signal priority alternatives, and stakeholder concerns and preferences. The desired DSS output includes graphic and numeric results relating to economic analysis (payback period, capital recovery period, NPV etc.), operational performance (transit run-time reduction), transit signal priority strategy alternatives etc.

The Riga transport system does not satisfy today's needs of the population for travelling. Considering global character of problems, in plans for development of the city the Riga Council stipulates some ambitious projects: to move an administrative centre from the city centre to the left bank of the Daugava River, in Pardaugava area: to construct the new bridge and to reconstruct wholly the node around this bridge etc. It is expected that the given re-planning will lead to the reduction of congestion of the city centre and will lower the acuteness of the problem of the bridge's capacity. However, such cardinal changes demand the careful analysis of current situation, transport flow forecast and modelling and answering questions "what if". These are the real tasks for decision support system in the city logistics and transportation. In the paper (Kolmakova et al. 2006a) the tasks of decision support system in transportation and city logistics are considered.

The paper includes the example in which the simulation models were used later than it was necessary and the problems that should be really solved were not settled in time.

OBJECT OF INVESTIGATION

The transport interchange "Slavu Street – Krasta Street – Maskavas Street" ("SKM" interchange) with constantly appearing traffic jams was considered to be the object of investigation. The role of this interchange is almost huge because of its disposition: it connects the important ways for freight transportation and provides the way from the bedroom communities to the center of Riga. The scheme of its disposition is presented in Figure 1.

Figure 1: Scheme of the "SKM" Interchange

It earlier attracted the attention (2004) because of its permanent congestion condition. The Transport and Telecommunication Institute (TTI) experts proposed the new design of "SKM" interchange and set up the hypothesis that this decision will improve the current situation. The simulation model with the aim to test this hypothesis was implemented. The given results demonstrated that proposed hypothesis was true and the proposed design doubled the throughput capacity [4]. But the obtained decision remained on paper and was not considered by the government because of starting the new project implementation at that time – the building of the new bridge (South bridge). It will be the biggest bridge in Riga and Latvia which will connect the right and the left Riga banks of Daugava. The considered interchange falls under the reconstruction within the borders of this project. According to this project the "SKM" interchange will be the connecting link between the South Bridge and the railway Slavu Bridge and it was planned to be reconstructed as a three-level flyover. However, this project was developed on the base of the experts' estimation and engineering solutions only. The simulation approach was not used at the stage of this interchanges and new bridge designing. The TTI researchers decided to try to estimate the future situation when the bridge will be put into commission.

The main goal of the investigation was to make the comparative analysis of the considered interchange throughput capacity as it was in 2004 and as it will be in 2012, when the project will be done. As the base for the analysis the results of the implemented project in 2004 were considered (Kolmakova et al. 2006b.). Also, the simulation model of the new trestle design was implemented taking into account the future traffic properties.

As an instrument for simulation model implementation the package VISSIM 5.1 family PTV Vision has been selected. 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 and the forecast data of traffic volume in 2012. The traffic characteristics of the renovated transport node are investigated and compared to the traffic characteristics of this node in 2004. It is necessary to estimate the capacity of the existing transport node from the point of view of today's situation and possible increase of the intensity of vehicles travelling in the future (in 2012).

CONSTRUCTION OF THE MODELS

One of the starting conditions of an adequate model creation in VISSIM is the presence, at least, of one scaled map displaying a true network. Due to such opportunity in the package, the model approximates reality as much as possible. On the basis of the map proposed by the architectural agency of LTD "TiltProjects" in the format of AutoCAD and the information on the forecast of the transport flows intensity, their description and distribution along the network supplied by the LTD "***imink***" (Niedole et al. 2005) the simulation model of the analysed area has been constructed.

The data on intensity and traffic volumes were forecast for the summer period of 2012 (8:00 – 9:00). The screenshot of simulated transport node with 5 areas, being sources of traffic, is presented in Figure 2.

Standard VISSIM types of transport (Car, HGV, Bus, Tram, Bike, Pedestrian) are used as objects of the model. The set of options was defined for each type (length, acceleration and deceleration functions etc). The traffic composition (proportion of Cars, Buses and HGVs) is presented in Table 1.

Transport units' routing has been set in the form of static O/D ways where it has been necessary to set the simulation time and the relative flow of vehicles for the chosen network area. The volumes of traffic flow from 5 sources divided by 3 main modes are presented in the Table 2. OD matrixes for 2004 and 2012 years are presented in Tables 3 and 4 respectively.

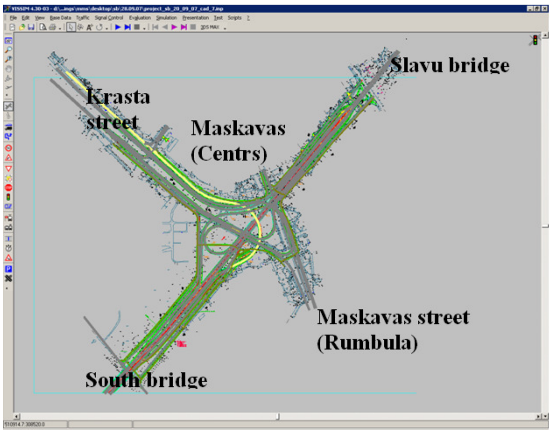

Figure 2: Screenshot of Simulated Transport Node with the Areas Being the Sources of Traffic

Table 1: Traffic Composition for 2004 and 2012

Traffic Source	Type of vehicle		
	Car	Bus	HGV
Krasta	87%	2%	11%
Maskavas (Centre)	92%	0%	8%
Maskavas (Rumbula)	90%	3%	7%
Slavu bridge	90%	1%	9%
South bridge (2012.g.)	90%	1%	9%

Table 2: Amount of Vehicles per Hour for Every Area Generating an Input Stream

Traffic Source	Year	Car	Bus	HGV	Total
South Bridge	2004	0	0	0	0
	2012	3406	55	320	3780
Maskavas (Rumbula)	2004	1922	68	140	2130
	2012	2774	98	202	3074
Maskavas (Centre)	2004	53	0	4	57
	2012	77	0	6	83
Slavu Bridge	2004	1174	19	110	1303
	2012	3153	51	296	3500
Krasta	2004	1928	35	250	2213
	2012	1759	32	228	2020

Numerical characteristics of implemented model complexity:

- simulation model was constructed from 465 fragments (type of object in VISSIM - «Link&Connector») on the basis of the map given by the architectural agency of SIA "TiltProjects" [5];
- 20 points of traffic sources were introduced to the model, 13 of them being the sources of vehicle flow and 7 of them – the sources of pedestrians and bike flow;
- 68 decision points were described in the model;
- 7 priority rules were introduced and 49 conflicted zones were defined;
- 3 groups of traffic lights were described;
- main speed at intersection – 50 km/h and few zones with the speed of 70 km/h were introduced. 32 Desired Speed Decisions objects were introduced;
- Data Collection Points - 36, Queue Counters -17.

Table 3: OD Matrix (in %) in 2004

	Maskavas (Rumbula)	Maskavas (centre)	Slavu bridge	Krasta
Maskavas (Rumbula)	-	31%	42%	26%
Maskavas (centre)	-	-	-	100%
Slavu bridge	-	3%	-	97%
Krasta	23%	30%	46%	-

Table 4: OD Matrix (in %) in 2012

	Maskavas (Rumbula)	South bridge	Slavu bridge	Krasta
Maskavas (Rumbula)	-	31%	7%	63%
South bridge	4%	-	85%	11%
Slavu bridge	0.1%	31.2%	-	68.8%
Krasta	73%	3%	24%	-

During the experimentation the model parameters have been varied to make the intensity and structure of transport flows correspond to the observable ones – thus the validation and calibration of the model has been made. To validate the model the distribution of the total volume to the single lines was examined. The method of "Significant Intervals" was used for validation. The results demonstrated that the models are trustworthy.

EXPERIMENTATION WITH THE MODEL AND COMPARATIVE ANALYSIS OF SIMULATION RESULTS

Three experimentation plans were performed during the investigation:

1. experimentation with the SKM crossroad as it took place in 2004;
2. new "SKM" interchange throughput capacity investigation taking into account the traffic flow forecast for 2012;
3. investigation of the efficiency of the proposed decision which was aimed at decreasing the negative influence of the non-optimal organization of one of the crossroads.

The key differences between the first two experiments are architectural decisions on the organization of the transport node, distinctions in the volumes of traffic and distribution of stream to directions. Every experiment included 50 runs of simulation model, every run was imitated by the hour of work of the real system.

The following measures were considered:

- Average time of some section crossing per vehicle, s.
- Average delay time per vehicle, s. Delay time – subtracting the theoretical travel time from real travel time; it doesn't include passengers' and transit stops.
- Average stop delay per vehicle, s. – it does not include passengers' stop times at transit stops or in the parking lots.
- Average stops number per vehicle, not including stops at transit stops or in parking lots.
- Total time the vehicle spent in congestion, s.
- Average, maximum queue length (m), number of vehicle stops within the queue.

Some of these measures are presented in Table 5.

The results demonstrate that the proposed new design on transport node SKM will increase its throughput capacity. The average speed will be increased by 19%, the average vehicle stop delay will be decreased by 46%. But the particular analysis of the several fragments of the interchange demonstrates that the throughput capacity improving has the fragmentary nature.

Several crossroads of this interchange were studied. As the criteria of the consideration was used the index of the level of service (LOS). It is the description of the level of the transport node' workload that was realized in the package of VISSIM, and settles accounts on the basis of delay time on the intersection. The delay time was evaluated as a difference between the time, which was spent by the vehicle in crossing of the intersection and the time, which would be spent by the vehicle at a free stream. A delay does not take into account the delay time because of the signal of the traffic light.

The results demonstrated that the majority of crossroads had normal LOS, except the crossroads Maskavas 1 (N1), Maskavas 2 (N2), Krasta-Maskvas (N3) (Figure 3). The LOS indices of interchanges N1 and N3 were in 2004 really high, equal to F (last legitimate value LOS equal to D) and for N1 equal to D.

Table 5: Measured Results of the Experimentation with the Model

Measures	Year	Average	Standard deviation	95% signif.level	Min	Max
Average delay time per vehicle, s	*2004*	103.9	2.0	104.7	100.6	107.9
	2012	85.5	1.5	86.0	82.7	89.2
Average num. of stops per vehicle	*2004*	11.6	0.4	11.7	10.7	40176
	2012	10.5	0.5	10.6	10	11
Average speed, km/hour	*2004*	13.6	0.2	13.70	13.3	13.9
	2012	29.9	0.3	30.0	29.6	30.5
Average stop delay per vehicle, s	*2004*	56.3	1.8	20821	53.8	59.2
	2012	30.4	0.4	30.6	29.6	31.4

It is possible to notice that in spite of the fact that intensity of traffic to 2012 grew on the whole, the reconstruction of this transport node allowed improving the LOS on the areas of segments N3 and N1; however, the level of service on segment N2 remained unsatisfactory (F).

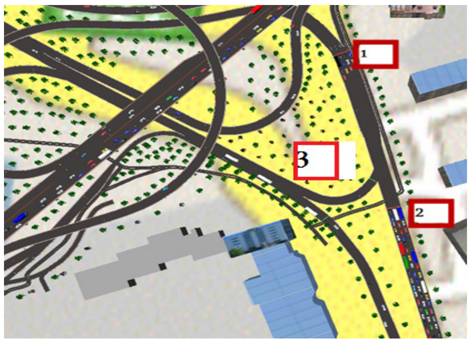

Figure 3: Layout of Transport Node with the Problem Zones

Comparison of the state of three problem zones for the purpose of vehicles delay makes it is possible to mark the change in architecture of this transport node, intensity of traffic and redistribution of streams resulted in diminishing of temporal delay on the segment N1 and N3, but did not have a positive influence on the segment N2. The mean delay time in this area for 2012 will even grow by 10% (Figure 4).

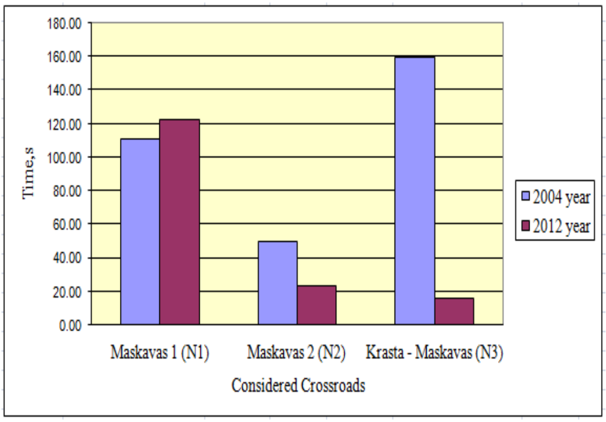

Figure 4: Average Delay Time in the Problem Zones for 2004 and 2012

The reason for this situation is the pedestrians' light signal disposition in this area. The hypothesis was proposed that the excluding of this light signal (it is possible because of building the pedestrians' subway) will reduce the level of saturation in this transport system segment. This hypothesis was tested by the simulation of the new model without the pedestrians' light signal was implemented and 50 experiments with it were carried out. The experimental results demonstrated that the proposed reconstruction will be helpful and resolve the existing problem. The comparative characteristics are presented in Table 6.

The average speed increased by 34%; the average delay time decreased by 53%. The LOS of the interchange segment N2 changed from the level F to the level A (the best level of service).

Also the level of air pollution in this segment was considered; that is why the traffic jam involves the increasing of emission and as a result the pollution of the air. The level of CO, NO_X and VOC was measured. The comparative analysis demonstrated that the level of the pollution decreased by 18%; that undoubtedly will have a good influence on the ecological situation.

The 3D film which may be used for the presentation of new project as well as the tool for making decision of existing problem solution finding was made. The example of the 3D model is presented in Figure 5.

Table 6: Measured Results of the Experimentation with the Reconstructed Model

Measures	Experiment	Average	Std.Dev.	95% Signif. level	Minimum	Maximum
Average speed, (km/h)	2-nd	29.96	0.25	29.98	29.55	30.47
	3-rd	40.08	0.33	40.13	39.37	40.76
Average delay, (s)	2-nd	85.49	1.48	86.02	82.74	89.2
	3-rd	40.24	1.13	40.59	37.79	43
Average number of stops	2-nd	10.52	0.50	10.63	10	11
	3-rd	1.96	0.20	2.02	1	2
Average stop delay, (s)	2-nd	30.38	0.35	30.59	29.63	31.36
	3-rd	8.51	0.22	8.93	8.04	9.1

Figure 5: View on the Three-level Flyover in 3D Animation

CONCLUSIONS

During the investigation there were implemented several simulation models of Riga interchange: the model of the old design of crossroad, two models of its new designs, and the model which was aimed to resolve the existing problem of the new design made by the planner. The obtained simulation results quantitatively demonstrated the level of the proposed service by the old crossroad, new crossroad design and allowed proving the expediency of the proposed way of solving the existing problem.

The results of carried on investigation rigorously prove the necessity of the application of the simulation at all stages of the transport system evolution. The obtained results demonstrated that the timely applied simulation may resolve the current crossroad problem on the stage of its designing and may reduce the expenditure for removing it now.

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