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APPLICATION OF MICROSCOPIC MODELS AS A PART OF THE DECISION SUPPORT SYSTEM AT ALL STAGES OF TRANSPORTATION SYSTEM EVOLUTION

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Abstract

The development of economics is accompanied by the rapid growth of the demand for mobility of population, causing, in its turn, the demand for the necessary level of service rendering. The main task of the urban transportation system (UTS) planning and management is achieving the best adjustment between demand and supply. There exist several approaches to decision making related to UTS: decisions based on master plans, the normative decision theory, the behavioural decision theory, group decision making, adaptive decision making, and the mixed-mode decision-making strategies. The last one is one of the most usable approaches, combining all the other approaches. The modelling often plays an important role in this case. The Decision Support System (DSS) can be considered as a complex system, which may consist of the parts as follows: the data management system, the users' interface system, the knowledge-based management system, and the model management system. The last one represents the repository of the models, which are used for considering the different scenarios of TS planning and functioning, and play an important role in the decision making process. This repository may include different types of transportation system (TS) models based on: macroscopic and microscopic approaches.
The paper will consider the role of microscopic models in DSS, - highlighting the specific tasks that may be solved by the models, the data needed for developing them, the requirements to the data, the kind of results they can yield, and their impact on different levels of decision making. As an example, an experience of application of microscopic models will be demonstrated for the solution of the Riga TS problems.

Keywords: urban transport system, decision support system, modelling, microscopic simulation, optimisation

1 Introduction

The contemporary tendencies of the world economic globalization derived the distributed production that in one's turn derived the increasing of transportation of resources and goods. As result the humanity has been faced with problems of congestion, pollution, accidents, financial deficits and so on. That's why the planning and management of TS render a significant effect upon the entire processes running in states, regions, towns or cities. However, it is necessary to point out that this is a very complex task because the TS can be classified as a complex, large, integrated open system (CLIOS) [1]. Normally, systems of such type are counterintuitive in their behaviour, defying description and analysis. Moreover, TS optimization is a multi-criterion problem because the transportation planning problem implies different stakeholders getting involved (inhabitants, shippers, government, transport system operators etc.), - each of them having its own interests and vision of optimal planning. That is why the TS planners solve very complex task in the field of TS quality improvement, and the contemporary information and computing technologies play important role in this problem. Moreover, contemporary electronics and computing have advanced so much as to make possible some new conceptions of transport infrastructure and movement systems [2]. The role of DSS and simulation modelling, applied in the field of TS management, are considered in this paper. Special attention was paid to application of the microscopic simulation at all stages of TS evolution. In general, the role of transport planning is to ensure satisfaction of certain demand for person and goods movements with different travel purposes, at different times of the day and the year, using various modes, providing TS with a certain operating capacity [2]. The TS investigation and optimisation should be carried out continuously during the time, taking into account all changes which may happen within the respective period. The life cycle scheme of TS development is presented in figure 1.

Figure 1 TS planning life cycle

Deciding on how to improve the current state of TS depends on the data collected during the current state of monitoring. Taking into account the results of processed data, one can define the goal and the tasks to be solved with the aim to improve the transportation quality. Depending on the goals, different strategies of yielding the best results are developed. Further, all these scenarios should be analyzed in order to predict the possible consequences of their implementation. The predicted results should be assessed and, on the basis of comparative analysis, the best strategy will be selected for implementation. The implemented decision should be monitored with the aim to prevent possible negative consequences of its implementation and as a result it is possible to define the new goal and tasks. That's why this process is presented like a cycle.

TS planning and management in Riga has neither systematic nor continuous character. Most of decisions are of fragmentary nature and are not considered in a complex. Quite often, the proposed local solutions are not considered in the context of their influence on the whole transportation system. That's why the implementation of DSS for Riga TS planning and management plays an extremely important role.

2 DSS and modelling

Taking into account the complexity of TS the planner has to take into account a large number of different factors making the decision on what kind of strategy should be selected. According to definition from Ginzberg and Stohr (Ginzberg and Stohr, 1982), - DSS is "...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 performing the entire decision process".

The main functionalities of DSS the transportation system monitoring and the future states prediction; data collecting, storing and pre-processing; knowledge storing; different decision scenarios generating and storing; scenarios implementation modelling; assessment of the scenarios modelling results; interactive user interface supporting. Taking into account the requirements to the DSS functionalities, it is possible to single out the four main DSS subsystems: subsystems of data management, models management, knowledge management and user interface. All these four subsystems play important role in the process of decision making and are tightly interrelated.

Two tasks are important to implement DSS in transportation. First, it is necessary to have access to a high-end information system with a qualified and complete statistical database on urban movements – as well as other transport information. The quality of the data is very important for DSS tasks. This data collection process may be organised based on interviews with passengers; the external observation or traffic statistics obtained with the help of objective control systems based on modern transport telematics will be helpful. The DSS must support the tools for data processing and different data problems solving. For example, they have to support the data fusion and imputation procedure; weighting procedures for tackling the problems related to sampling errors; procedures for post-processing of the data collected etc.

The second task for implementing the DSS in transportation is the set of implemented transport models developed on macro- and micro-levels. The macroscopic model simulates the current and the future transport flows, the city road network, the analysis of the intensity of movement, and schedules the scenario “what if”. This approach may be used at the stage of strategic and tactical planning.

The microscopic model may be used at operational and tactical level. It simulates the fragments of TS with a high level of specification. The microscopic model consists of transportation network model (oriented graph of transport network links and nodes); transportation demand model (original-destination matrix, models of demand for transportation); model of transport mode selection (discrete choice models of transport mode selection); route assignment model (discrete choice models of the route selection); driver behaviour model (driver following models, gap acceptance models, lane changing models etc.). The main objects of investigation are some fragments of UTS (crossroads, road interchanges and fragments of roads). This approach solves such problems as current state of UTS fragments monitoring and analysis and prediction of the future conditions of traffic; the traffic parameters (speed, density), capacity and interchanges of roads controlling; organization of signal control, traffic flow routing and reverse traffic; organization of UTS fragments infrastructure etc.

The complex approach to decision-making implies that the DSS repository of models should store the microscopic models of the UTS interchanges and crossroads; this repository should be replenished permanently. This allows to make analysis of current situation any time, finding the answer to the question “what happens on the local level if a decision-maker decides to make some changes on macro-level?”, - and finding the specific solution of the current problem.

The proposed solution implying UTS fragments optimization will impact the transport traffic quality, which, in its turn, may exercise influence on the UTS and some neighbouring fragments of the latter. The DSS should support the interface for microscopic models simulation results transfer to the macro level (the opposite data transfer is necessary as well). The microscopic simulation may give the following data for macroscopic models: traffic intensity, speed distribution, density, volume, directions, distribution of flows; new UTS network and infrastructure configuration. The macroscopic model may use this information for OD-matrix, transport mode and traffic assignment models calibration, estimation of new state of UTS at whole. It is necessary to mention that this process is be-direction.

3 Case study

The presented case studies demonstrate the application of the microscopic modelling for decision making at different stages of TS life cycle. All models were implemented using simulation modelling tool PTV Vision VISSIM.

3.1 Case study 1: Investigation of TS fragment “Sloka-Uzvaras-Ranka dambis” current capacity, - implying a possibility of occurrence of some new attractive zones

The Riga TS fragment which is located across three main streets: Sloka, Ranka dambis and Uzvaras in the Pardaugava district of Riga – was selected as the subject of research. This TS fragment was chosen because of the Riga Council stipulates to move the administrative centre from the downtown to the Pardaugava district. This re-planning is expected to reduce the congested traffic of the city centre and to alleviate the bridge capacity problem [3]; however, it might increase the traffic flow within the TS fragment examined. That’s why it was necessary to carefully analyze the current and the future condition of this TS fragment, which includes 9 crossroads and operates public and private transport.
According to the ICU standard, the level of congestion of the majority of crossroads to-date comply with the respective standard. The investigation goals were as follows: analyzing the capacity of the transport node under the existing conditions; revealing its bottlenecks and carrying out a number of experiments with the view of forecasting the intensity of traffic until the year 2010. An example of constructed model is presented in figure 2.

Figure 2 Example of implemented model fragments

The first analysis was based on the data of 2005. During simulation, a few most problematic intersections were distinguished. The information on queues length is presented in figure 3.

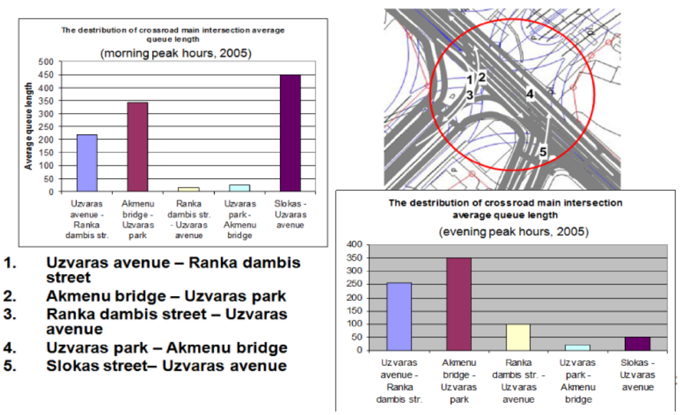

Figure 3 Distribution of Average Queue Length on Crossroad Main Intersection (morning peak and evening peak hours, 2005)

Furthermore, a forecast of future situation with this fragment was made, taking into account the traffic intensity which had been forecasted for 2006, 2007, 2008, 2009, and 2010. The simulation results are presented in figure 4.
The result shows that the future increase of motorization of the Riga population will lead to junctions increase and the transport node capacity will not be sufficient in the future. The

analysis of the other transport node crossroads demonstrates they will be overloaded too. This fact should be taken into account when accepting plans of developing a new business centre in this district. Evidently, it is necessary to carry out the entire transport node reconstruction.

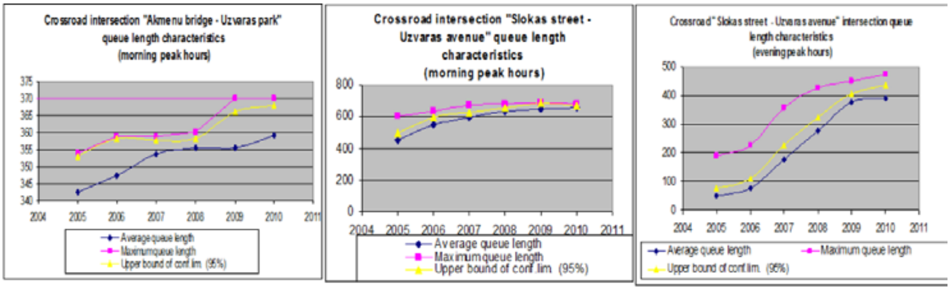

Figure 4 Results of future situation forecast

3.2 Case study 2: Optimization of Riga TS fragment "Slavu-Krasta-Maskavas" organization at the stage of tactical planning

The object of investigation is the transport node (complex junction of crossroads Maskavas – Slavu – Krasta) characterized by permanent traffic jams. The scheme of this TS fragment is presented in figure 5. The main tasks of modelling: the choice of the optimal movement organization and the estimation of capacity for each version of movement; optimization of signal heads operation [4].

It was supposed that a number of offered changes would give a positive effect on the transport traffic organization and will raise the capacity of a considered area. One of the suggestions was: to bring out the roadway directly from Krasta Street to Slavu Bridge (on the bridge) across the currently existing parking place territory (figure 6, on the right). Thus, the system of three signal heads is replaced by two.

Figure 5 The investigated junction Maskavas–Slavu bridge–Krasta (the old scheme on the left, the new design of network – on the right)

The results of experiments with a model before and after reconstruction are presented on the Box&Whisker diagrams in the figure 6, where the mean, the standard error of mean, and the standard deviation of crossing time with respect to the three main routes shaping the crossroad are mapped.

It is possible to see that the average values of crossing times were reduced more than twice. Those visualized results were confirmed by statistical criterion.

This case study illustrates the results of microscopic modelling application at the stage when it was necessary to find the solution of the existing problems. But the obtained result wasn't taken into account by the municipality. One year later, the municipality started the project of new bridge construction and reconstruction of the neighbouring transportation infrastructure (including Slavu-Krasta-Maskavas interchange). The following case study demonstrates the example when the simulation models were used later than necessary, and the problems that should be really solved were not settled in time [5].

Figure 6 Box&Whisker diagrams for the parameters of transport junction crossing time

3.3 Case study 3: Investigation of the efficiency of new project of the Riga TS fragment "Slavu-Krasta-Maskavas" reconstruction

The transport node was the same as in the previous case study and the main goal of the investigation was to perform the comparative year-on-year analysis of the considered interchange throughput capacity - as it was in 2004 and as it will be in 2012, when the project of transport network reconstruction around the Southern Bridge will be completed. The simulation model of the new trestle design Slavu-Krasta-Maskavas (SKM) was implemented and based on the real traffic measurements performed in this area, and on the forecast data describing the 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. The fragments of implemented model are presented in figure 7.

Figure 7 View on the three-level flyover model fragments in 3D Animation (on the left) and the average delay time in the problem zones for 2004 and 2012 (on the right)

Two experimentation plans were performed: new "SKM" interchange throughput capacity investigation with the traffic flow forecast for 2012; the 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 results obtained demonstrated that the proposed new design of the 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 specific analysis of several fragments of the interchange demonstrates that the improvement of the throughput capacity has fragmentary nature. Comparison between the states of the 3 problem zones in terms of vehicles delay makes it possible to note the change in architecture of this transport node; changing the traffic intensity and redistribution of streams resulted in reducing temporal delay on segments N1 and N3, but did not have any positive influence on the segment N2 (figure 7, on te right). The reason for this situation is the pedestrians' light signal disposition in this area. The hypothesis was proposed that omitting this light signal (which is possible due to the pedestrian subway being constructed) would reduce the saturation level in this transport system segment. This hypothesis was tested by the simulation of the new model with the pedestrians' light signal omitted and the experimental results demonstrated that the proposed reconstruction will be helpful and will resolve the existing problem. The average speed increased by 34%; the average delay time decreased by 53%.

4 Conclusion

The permanent UTS monitoring, management and optimisation play an urgent role in contemporary economics. The principal role in this process belongs to DSS which accompanies all stages of decision making at all levels of UTS life cycle. The models may be used as tools for testing hypotheses suggested to find the best way of solving the problems related to the existing transportation network. The three above-mentioned case studies illustrate the achieved advantages of microscopic models application (1) - at the stage of TS current situation analyses/ prediction of future states; (2) – at the stage of tactical planning of transportation network optimisation and (3) - strategical decision making concerning the reconstruction. The performed investigation rigorously proves the necessity of applying simulation at all stages of the transport system life cycle. The obtained results demonstrated that the timely applied simulation may resolve the current crossroad problem at the stage of its design, and may reduce the expenditure for removing it now.

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