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CONSIDERATION OF THE ASPECTS OF THE TRANSPORTATION SYSTEMS MICROSCOPIC MODEL APPLICATION AS PART OF A DECISION SUPPORT SYSTEM

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The article presents the experience in using decision support system (DSS) when managing urban transport system (UTS) and a possibility of using microscopic modelling as an integral part of the decision-support system (DSS) when managing the urban TS. To illustrate the problem and a possible DSS-based solution, an example of a specific project has been examined, where microscopic modelling was used for the analysis of possible reconstruction of a transport system (TS) fragment in the city of Riga, – which was performed in 2010 in the laboratory of applied software systems of the Transport and Telecommunication Institute (in Riga). The project goal was the consideration of expediency for implementation of a pedestrian area in the street of city centre with the existing street traffic. The article formulates some problems that occurred in the process of development and application of simulation model for analysing various scenarios; some possible alternatives of their solution are suggested.

An alternative of possible DSS architecture for managing TS in Riga is suggested; some requirements to the data handling and organization in the system are examined. Special attention has been paid to the problem of synchronizing the data handling of macroscopic and microscopic models of urban TS. The article formulates the requirements to organization of data transmission interface between macroscopic and microscopic data. The suggested DSS concept can be used when solving various problems of transportation planning.

Keywords: Decision Support Systems, Urban Transportation System, Microscopic Model, Data Requirements, Macroscopic Model Integration

1. Introduction and State of the Art

The efficiency of TS management implies realization of a broad range of measures (TS control policies) and using the system approach at all managerial levels. Decision-making with regard to all aspects of UTS planning and management is a complex process, which requires consideration of the current state of traffic and transportation network, its configuration, its future condition forecast, the relevance of someone or other route, weather conditions, location of zones of influence, preferences in selecting travel mode, and many other factors.

The useful approach applied when managing such complicated systems is as follows – using simulation modelling as an auxiliary instrument enabling one to assess the current situation in all the system functioning aspects, to make a forecast of the dynamics of system functioning characteristics, and to estimate the efficiency of the suggested solutions of the existing problem based on the experiments with simulation model.

Microscopic modelling of transport systems is extensively used in the tasks of analysis, traffic control, reconstruction or planning of new TS sections. Microscopic modelling, in its turn, is aimed mainly at tactical planning and tactical solution of operational tasks, and enables one to investigate the transport network and the properties of traffic flow (including its participants) with a high degree of particularization. However, a fragmentary and external usage of modelling outside of the general (DSS) can bring about problems at all stages of development of simulation model and its usage.

The problems encountered by analysts can imply, first of all, some troubles connected with the availability of actual data for model development and data for model calibration and validation. These problems don't allow carrying out the correct experimentation with the model. The currently existing distributed pattern of data storage and lack of systems approach to the data handling organization are connected, first of all, with total lack of integrated database embracing all TS items (from the infrastructure to the intensity and organization of traffic) – that would be accessible to schedulers and analysts.

The one of particularities of UTS management and controlling tasks is a continuous character of their implementation. The UTS cycle is presented on Figure 1 and includes the following stages: functioning, UTS monitoring and measures of efficiency (MOE) estimation; operation control based; tactical planning and control; strategic planning and UTS reconstruction or expansion. And the decision-making process should have a cycling type. The possible scheme is presented on Figure 2. All stages of UTS evolution life cycle are based on the continuous monitoring and MOE estimation. The decision-making is a complex process in such conditions and should be based on the analysis of its implementation results at all levels of the UTS functioning. The DSS should help to support such type of system management and controlling and it is applied in order to find the best solution, taking into account all constraints and interconnections.

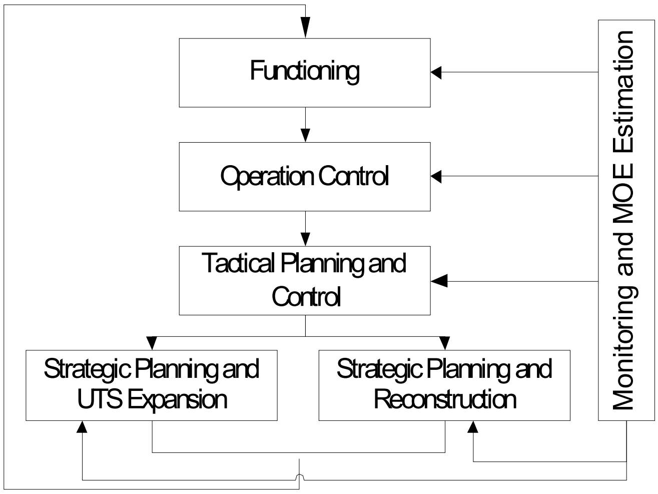

Figure 1. UTS Evolution Life Cycle

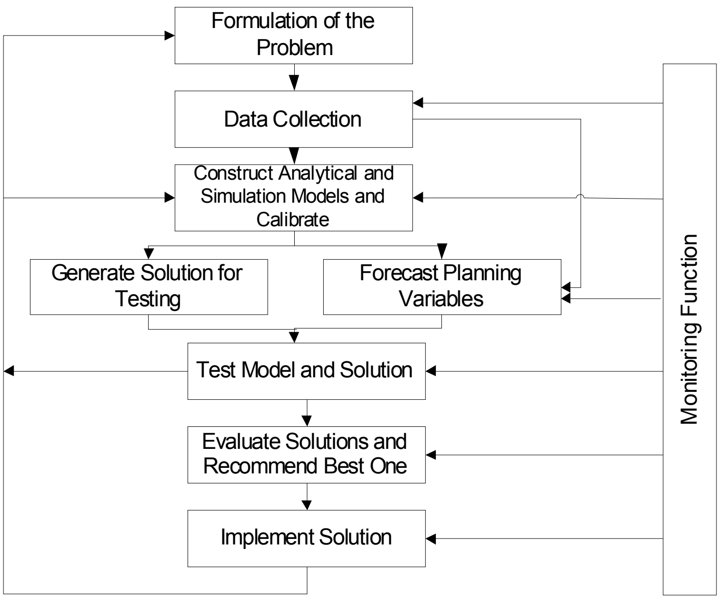

Figure 2. Decision Making of UTS Planning and Monitoring Using Models [2]

The idea of DSS application for UTS was considered by different scientists [2, 4, 9, 10, etc.] in many works. Authors consider application of DSS for UTS control using a modelling approach as a part of DSS. J.Barcelo considered the DSS for Madrid UTS management using the models implemented in AIMSUN and GERTRAM. Authors A.Uliead & A.Esquius considered the framework of DSS for the European transport system management and controlling. Some works consider the application telematics for intelligence traffic control within the bounds of DSS. For example, Houng Y. Soo, Dusan Teodorovic, J. Collura [6] presented the DSS framework provided a holistic framework to perform analytical assessments of integrated emergency vehicle pre-emption and transit priority systems. Juan de Dios Ortuzar in his monograph [2] describes the role of DSS in transportation system management and planning, and he paid special attention to the modelling application as a part of decision-making.

The analysis of the information sources has proved the current existence of a wide variety of DSS that are used in UTS management problems. The systems meant for strategic or tactical planning, operational planning, and the mixed-type ones are singled out. There are systems featuring both de-centralized and centralized data storage organization, as well as decision support systems in online or offline modes. According to the level of decisions taken, the systems are subdivided into strategic, operational, tactical, or mixed-type ones. In terms of the DSS target, one can discriminate between single-purpose ones (which are meant for solving individual problems), – the multi-discipline ones (uniting a few problems) and universal systems. A wide practice of using macro- and microscopic modelling exists, implying their usage as an assistant helping one to develop solutions on evaluation of the current situation and to assess short-term, medium-term, and long-term forecasts of the system state development with a view of evaluating the suggested measures aimed at improving the situation. The following can be attributed to those DSS, which have a common interface with simulation packages: SCOOT operating jointly with the simulation package of microscopic modelling PARAMICS [3]; SCATS operating jointly with the simulation package of microscopic modelling VISSIM [4]. Some systems supporting a few approaches in systems modelling can also be encountered. For instance, ICM AMS system is meant for managing traffic of major travel corridors and uses macro-, meso-, and microscopic modelling; the system TRIM [7] supports both micro- and macroscopic modelling and is meant for developing TS sections control strategies at the tactical decision level.

DSS including microscopic modelling allows one to test various scenarios of traffic condition development given the current data and by using short-term forecast data, – and to obtain estimations of the efficiency of suggested measures aimed at TS re-organization. However, applying various levels of modelling at a time seems to be the most prospective, since applying only macro- or micro approaches in UTS development and control planning tasks does not allow one to obtain a comprehensive and proper picture of the network situation development. The macroscopic approach can enable one to obtain a generalized estimation of the load applied on urban TS; however, the macroscopic approach is not sufficient to reveal any reasons for problems arising at the local level and seeking solution. Neglecting those problems can aggravate the situation at the global level. Microscopic modelling allows one to estimate the situation scrupulously with respect to individual sections of the network, – but it doesn't give one a chance of estimating the impact of the suggested decisions upon the general condition of UTS at the micro-level. That's why their interaction in DSS seems the most prospective.

This article states the problems arising in process of modelling and the ways of eliminating them with a view of enhancing the reliability of decisions taken. To illustrate the problem and a possible DSS-based solution, an example of a realized project has been examined, where microscopic modelling was used for the analysis of possible reconstruction of a transport system (TS) fragment in the city of Riga, – which was performed in 2010 in the laboratory of applied software systems of the Transport and Telecommunication Institute (in Riga). The problems (especially in availability of data) that occurred in the process of development and application of simulation model for analysing various scenarios are considered; some possible alternatives of their solution are suggested. Also, the requirements to organization of data transmission interface between macroscopic and microscopic data are formulated in the article.

2. Example of Riga Node' Microscopic Model Application as Means of Decision-Making

The laboratory of applied systems (LAS) TTI has experience of applying microscopic modelling of Riga TS fragments with a view of their investigation at various stages of life-cycle: from design and operation stage to reconstruction. The illustration of using microscopic modelling as a decision support tool will be presented on the basis of the project "Pedestrian and Transport Flows Analysis for Pedestrian Street Creation in Riga City" (2010–2011 years).

The Riga City Council has put forward a proposal of establishing a pedestrian area in the centre of Riga – in Terbatas Street. Several scenarios have been discussed:

- From Elizabeth Street to Lachplesha Street,
- From Elizabeth Street to Matisa Street,
- From Elizabeth Street to Tallinas Street.

Submitting this proposal required the analysis of the impact expected to be rendered by shutting off the public and private traffic across Terbatas str. upon the adjacent parallel streets: Brivibas, Kr. Barona and Chaka str., which are important traffic arteries in the downtown, – and upon 10 cross streets (Fig. 3). The investigated territory is both a traffic source and the attraction site since it covers residential buildings, office premises, shops, trade centres, the market, cinemas, and restaurants. Furthermore, most of the streets have car parking zones, a few large car-parking lots and the parking places within the yards of large houses and office buildings. The total characteristics of the modelling object: the total extension is approximately 1.5 km from the south-west to the north-east; the territory covers more than 50 road intersections, 51 routes of public transport (bus, trolleybus, tram), – and 59 stops.

The main project implementation phases are the following:

- planning;
- organization and collection of data on traffic and pedestrian flows, investigating passenger traffic;
- statistical processing and summarizing of the obtained flow-describing data;
- implementation of the transport network simulation model with the static routing of the flows inside it;
- analysis of the loading level of the network investigated without making any alterations, and estimation of the correspondence matrix;
- development of TS simulation models taking into account the suggested scenarios based on dynamic routing;
- implementation of experiments and analysis of the results.

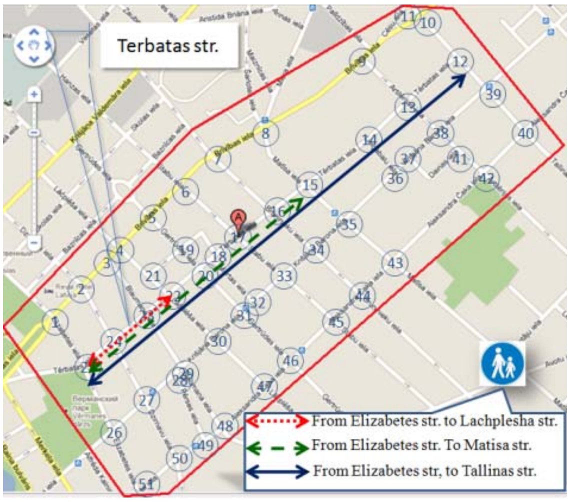

Figure 3. Modelling Object in the Frame of Project "Pedestrian and Transport Flows Analysis for Pedestrian Street Creation in Riga City"

In the course of modelling, a few microscopic models of the investigated TS fragment were constructed: the current-state model plus several TS models with the dynamic routing, taking into account three alternatives of the pedestrian area development. In total, 11 variants of model have been implemented, which took into account possible scenarios in traffic organization, transfer of public transport route, the traffic forecast for 2014 and 2018, – and the scheduled alterations to be made to traffic organization in the city – which, in their turn, will also impact the traffic flow redistribution within the TS fragment investigated.

The modelling made it possible to estimate the following: the loading level of crossroads under each of the scenarios suggested (Fig.4); the time spent for moving along the main itineraries; moreover, it is possible to detect some bottlenecks and reasons for the congestion of some individual sections. The analysis has enabled one to estimate the aggravation degree of the situation to be expected at the TS on the territory adjacent to Terbatas Street after the scheduled establishment of the pedestrian area, – and to single out the scenario, which is expected to being about the least worsening of the current situation. In particular, such a scenario implied the alternative of introduction of the pedestrian area across the section between Elizabeth Street and Lachplesha Street and some modification of trolleybus route No 1.

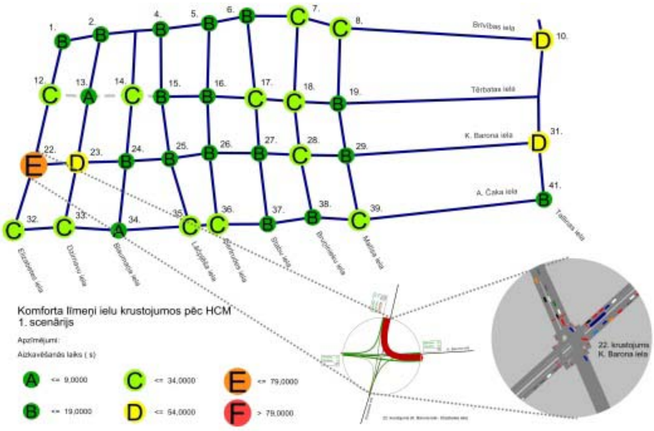

Figure 4. Simulation Results in Graphical Form: a Map of Crossroads Loading Level (LOS) According to HCM Standard

This project is an example of the system approach that should be exercised at decision-making on the expediency of taking alterations to TS, since the decisions were made based on simulation experiments accompanied by a thorough in-depth analysis of situation development in future, – trying a number of possible alternatives. Despite of that, however, a number of difficulties related to investigation process arose in the course of realization.

The main problems in the course of project implementation were connected with lack of access to the data necessary and the problem of getting that data both for planning of data collection and the model implementation. The modelling was based on the real time traffic data collection, which had been scheduled and implemented within the framework of the investigation carried out. The truth is that no centralized TS-describing data storage exists in Riga: the data is stored in various municipal structures and subcontracting companies having concluded agreement with the municipality. There is no explicit data register that would precisely state the whereabouts of the specific information. Moreover, the data is frequently duplicated; there is no system approach to its updating, and there is no information available on any updating policy with respect to the data. For example, „Rīgas ģeometrs, Ltd" and the Traffic Department of the Riga City Council possess two macroscopic models of the TS of Riga: one never can tell, which of the two is more updated and, which reproduces the structure of the Riga TS more precisely; neither can one tell how the updating of that model is organized. Another example is data storage organization in traffic signal: the information on street-traffic control lights and their operating cycles is held by the Traffic Department of the Riga City Council; however, the information on how „the green wave" is organized possessed by „Rīgas luksofors, Ltd". Lack of information on data sources and lack of access to them has lead to violation of the project implementation schedule.

Microscopic modelling aimed at a high enough reproduction of TS properties is extremely demanding to accuracy and completeness of information describing both the geometry of transportation network and the tenants' mobility. Lack of sufficient information on population mobility and location of major centres of gravity has lead to some delinquencies when planning data collection, and brought about the subsequent troubles when developing the correspondence matrix. For instance, due to lack of any preliminary data on organizing mass events in the vicinity of Terbatas Street and due to lack of any real-time information on the working time of road signs, – the system observation time and duration was ill choice; that led to obtaining inaccurate information and some extra loss of time at the simulation model validation phase.

Lack of any urgent and detailed map of the urban TS and the working time of road signs would also lead both to errors in data collection planning and troubles when implementing simulation model. When developing the traffic network model, the model developers used as a basis the city map where TS is represented schematically enough. The dimensions of the object simulated have made the implementation of the traffic network model still more complicated.

This problem could have been avoided if a system of centralized access and storage of TS-describing information and a unique policy of monitoring and updating information had existed in Riga. As a rule, centralized storage and updating of data is organized within DSS when planning the urban traffic systems. This would allow one to reduce the data retrieval and obtaining costs, ensuring reception of real time data and simplifying the process of planning the extra data collection; moreover, it would reduce costs directly related to the model implementation and planning of experiments.

3. Requirements to DSS with Microscopic Models as a Constituent Part and Features of Implementation

The main tasks of DSS are: organizing storage and access to data required in TS planning and control tasks; data storage and ensuring access to knowledge base; storage of models; ensuring the work with models, and the user interface providing for data input by user; manipulating with models and data, and presentation of output results in graphic and textual forms or in the form of generalized reports. The GIS-systems usage simplifies the data acquisition and its visualization, as well as development of TS simulation models. A possible scheme of DSS based on modelling approach application is presented on Figure 5. Generally, DSS should partially to automate some procedures, like data collection, pre-processing and processing; models running and Measurement of Efficiency (MEO) estimation, comparative analysis implementation; data processing, models simulation results presentation; user graphical interface supporting, etc.

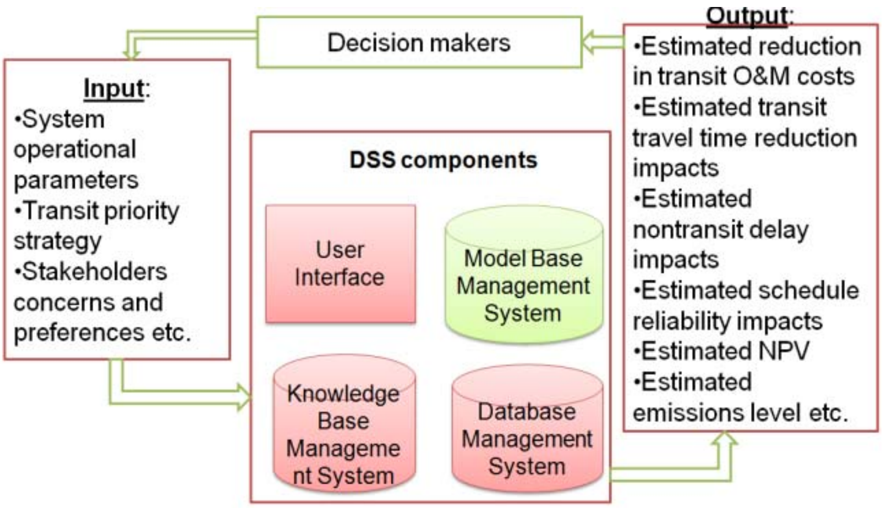

Figure 5. Scheme of DSS for UTS Planning and Controlling [8]

If microscopic TS models are used as a constituent part of DSS it is necessary to take into account that DSS should to be a data source, storage and updating place for: preliminary project planning (TS section modelling); organizing additional data collection; TS section model developing; microscopic model aggregated and disaggregated sensitivity analysis, its calibration and validation implementation; Measures of Performance (MOP) and Goodness of Fit (GOF) estimation; number of experiments planning and execution. The DSS should include the following data:

- about the demand on transportation and the factors which have the influence on the population movements:
  - data on city zonal subdivision and economic activities run in the respective city zones;
  - data on land utilization and location of parking places, parking lots, and terms of their usage;
  - data on the gravity centres location and traffic flows adjacent to these centres;
  - data on movement demand;
  - preferred alternatives of routes and transport mode selection;
  - OD-matrix;
- about the TS network and its infrastructure properties and traffic characteristics:
  - detailed and real-time map of transportation network with a detailed presentation of the transportation network geometry;
  - information on organizing traffic within transportation network showing the road signs arrangement, traffic lines, etc.;
  - information on traffic lights control;
  - map and the information on organizing the public transport operation;
  - data on flow intensity and its composition, the flow distribution on the network map, etc.

The system should receive data describing scheduled major events, which could entail intensification of transport and pedestrian flows; this data is necessary both when planning the project and analysing the expected impact of the planned events and the selected place of their running.

The separate task is arranging for completion and storage of data necessary at the stage of model implementation: sensitivity analysis (SA), calibration and validation of models. This stage requires both aggregated data (traffic intensity, flow average velocity by time or within a section of the network, length of queues at road intersections, traffic flow density, flow composition distribution and flow distribution at crossroads etc.) and disaggregated data.

The microscopic sub-models of a model (Fig. 6) are needed in the special SA and calibration procedure. They are needed in some specific data like a driver's reaction time, decision time for speed rate changing, speed curve and path of motion, etc.

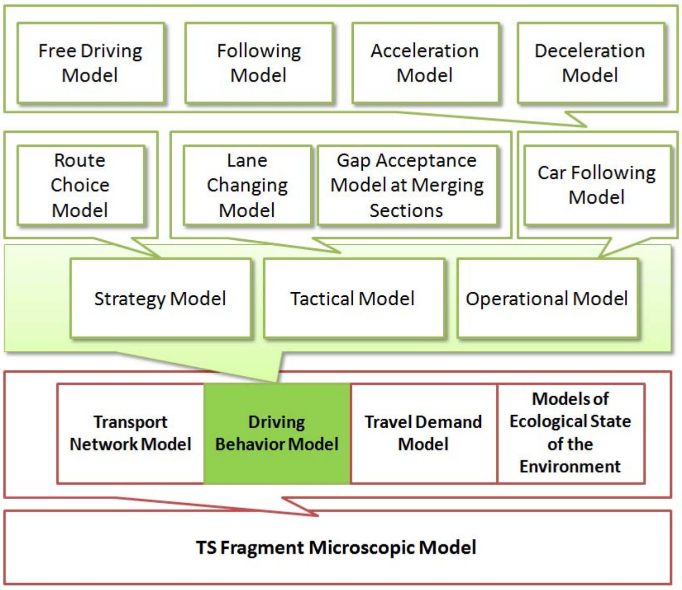

Figure 6. Structure of TS Microscopic Model

DSS should also include knowledge-base that should contain not only normative and reference documents but also methods and methodological instructive regulations for applying someone or other models to be used with regard to someone or other data under definite specific conditions and stemming from the targets and goals posed. Development of such instructive regulations is a separate task, since an analyst facing the problem of selecting one or another way of assessing parameters or analysing situation often spends a lot of time to select an appropriate tool for analysis (a model, a method, an approach).

DSS should provide for an API-interface to external application systems; alternatively, it should include separate modules enabling one to perform the procedures as follows:

- Processing and statistical analysis of data (both obtained to the input from a real system and results of modelling and experiments), – as well as forecast;
- Modelling of TS at macro- or microscopic level, the economic, demographic, and social situation in the city; modelling the condition of ecology, etc.;
- Aggregated and disaggregated sensitivity analysis;
- Calibration of TS models, OD matrixes and preference functions when selecting routes, mode of transport, etc.
- Validation of models and analysis of scenarios.

A separate task of vital importance is the task of creation and supporting a sub-system for organizing storage of those models and working with them. The scheme of such system is presented on Figure 7. In particular, this subsystem should include a repository of models. The DSS models repository might include algorithm-based models, statistic-based models, linear programming models, graphical models, quantitative models, and qualitative models and TS simulation models. The latter includes macroscopic and microscopic models urban TS fragments.

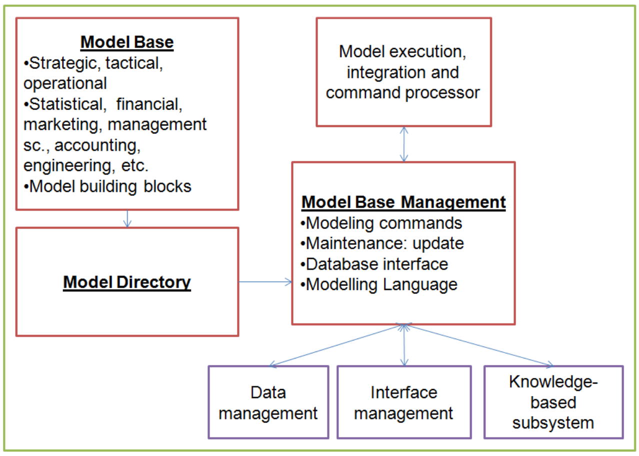

Figure 7. Framework of Model Base Management System

An important task is the data flow arrangement and organizing interaction between separate phases of the work implying the usage of a microscopic model. The scheme of such a data flow is presented on Figure 8. DSS should include a module, which would provide for the data transfer from one phase to another – in the appropriate format fitting into investigation performance. For example, the procedures of sensitivity analysis, model calibration and validation are interconnected. Therefore, DSS should provide for an interface allowing one to select and transfer the input numerical parameter values necessary for execution of those procedures; moreover, transfer of the results obtained and correction of the parameters of the model should be provided. Moreover, all of the obtained results of calibration and sensitivity analysis should be stored in the data repository for future investigations.

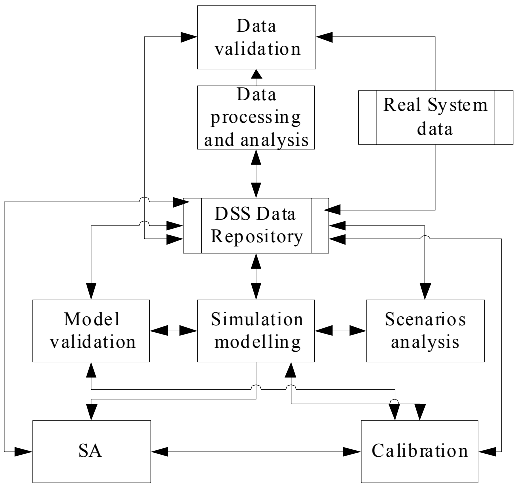

Figure 8. Scheme of Data Flow and Interaction at Various Stages of Data Preparation to Model Simulation and Implementation

It is necessary to organize interaction between models at the system analysis stage. It seems possible to organize a two-direction interaction between various models. In the vertical direction, when the situation within a network section may be changed at microscopic level, – which makes it quite important to estimate the impact of these alterations upon the general traffic flow distribution across the TS of the city at macro-level. In the horizontal level – when interaction between microscopic models of various network sections is required to analyse the changing situation within one of the sections if alterations have been made to another one.

For instance, when examining the vertical interaction between models, one can call to memory the project of arranging a pedestrian area in Terbatas Street. It would be extremely fruitful to organize the transfer of data describing the traffic state at the microscopic model output to the input of macroscopic model; furthermore, it would be expedient to advise the macroscopic model on the load level of the transport network. This data would help one to adjust the functions of deciding on selection of itinerary and mode of transport, – which are used to determine the vehicular flow distribution across the network on macro-level. This would allow one to receive adjusted data of the flow distribution across the network, which could lead to adjusting the input data on microscopic model. This is an iteration procedure (Fig. 9) as a result of which, there arises an opportunity of getting both the adjusted picture on macro level and some more precise information on the load level of TS section at micro level. Unfortunately, it didn't seem possible to implement that within the framework of the project, since we had no access to the complete macroscopic model of TS, and also because DSS was missing.

Examining the problem of interaction between microscopic models at the horizontal level, one has to emphasize the problem of transferring data, which describes the condition of input parameters of the second model when the functioning of the first model changes. The authors believe that the problem can be solved through using a macroscopic model of TS as a connecting link between the two microscopic models.

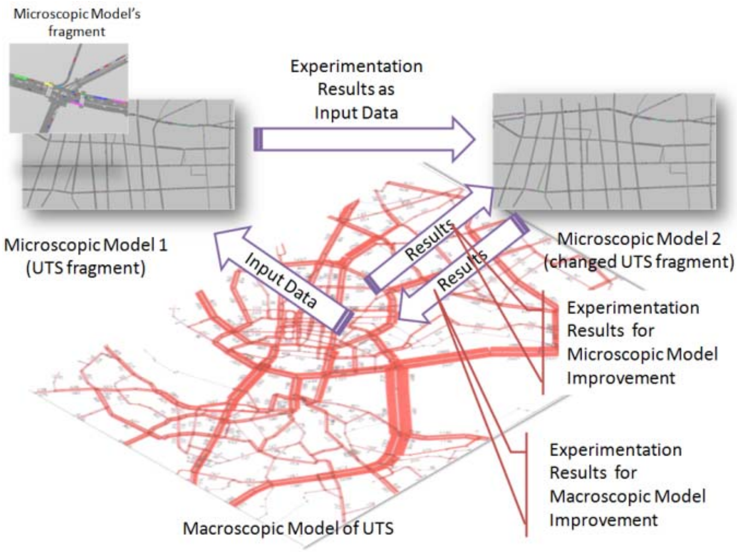

Figure 9. Framework of Different Models Interaction on Vertically Level

The macroscopic model will receive from the first model some information on the new traffic condition within the respective section of the network and at its output points; than the macroscopic model will adapted to the new conditions of functioning (that can be an iteration procedure as in the previous case) and will subsequently transfer that information – as input data describing traffic condition – to the input of the second microscopic model. The schematic interaction between the microscopic models through the macro-level is presented on (Fig. 10).

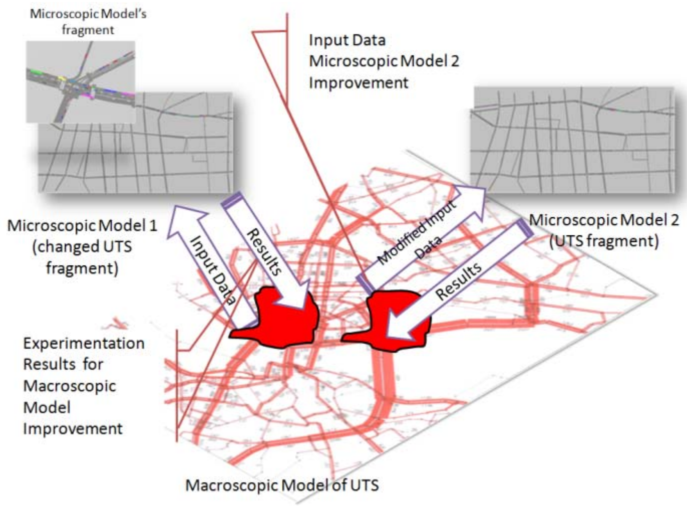

Figure 10. Framework of Different Models Interaction on Horizontally Level Using Macroscopic Model of UTS

4. Conclusions

The permanent UTS monitoring, management and optimisation play an essential role in the contemporary economics. The principal role in this process belongs to DSS, which accompanies all stages of the decision-making at all levels of UTS life-cycle. The models might be used as the tools for testing hypotheses suggested to find the best way of solving the problems related to the existing transportation network. The DSS architecture should provide for a possibility of comprehensive investigation of TS and the checking of formulated hypotheses.

This article formulates requirements to DSS aimed for UTS management (on the base of microscopic models), its architecture and data that should be stored therein. The main components of the system are determined; the problem of interaction between modules is highlighted. Particular attention has been paid to the problem of organizing both vertical and horizontal interaction between models. A new requirement to DSS has been posed – namely, provision for an interface that would allow one to organize data transfer between micro-micro and micro-macro-micro models, and their interaction. It may be data describing traffic properties (intensity, speed, composition), – and the data on the condition and load level of transportation network, playing an important role in models with dynamic routing, which use decision-making functions with regard to itinerary selection. The further investigations in this field are aimed at formulating requirements to the module allowing one to accomplish interaction between models, – as well as experimental implementation of such a possibility by the example of the available microscopic models of TS fragments.

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