MESOSCOPIC SIMULATION CONCEPT FOR TRANSPORT CORRIDORS

Mihails Savrasovs, Transport and Telecommunication Institute, 1st Lomonosov street, Riga, LV-1019 Latvia Tel.: +371 29654003. E-mail: mms@tsi.lv

ABSTRACT

A transport corridor is a (generally linear) tract of land in which at least one main line is provided for transport, whether it is a road, rail or canal facility. In this article under transport corridor we will understand a road which connects two geographical points. The need of research and analysis of the transport corridors is mainly connected with wish to locate bottlenecks of the corridor and to estimate different characteristics, for example, the average speed along the corridor, the average travel time etc. The main tasks of this article is to show advantages and disadvantages of microscopic simulation and macroscopic simulation, to make an overview of the existing mesoscopic models and to present a concept of new mesoscopic traffic model which is developed for transport corridor simulation with the acceptable level of output results exactness on the base of the earlier used mesoscopic model.

Keywords: transport corridor, mesoscopic model, simulation

INTRODUCTION

According to (European Road Statistics 2008) the registration number of vehicles in EU10 is growing almost linearly. Of course, because of crisis, the growth will be decreased, but the main tendency is steady growing. The vehicles registrations dynamics is presented below.

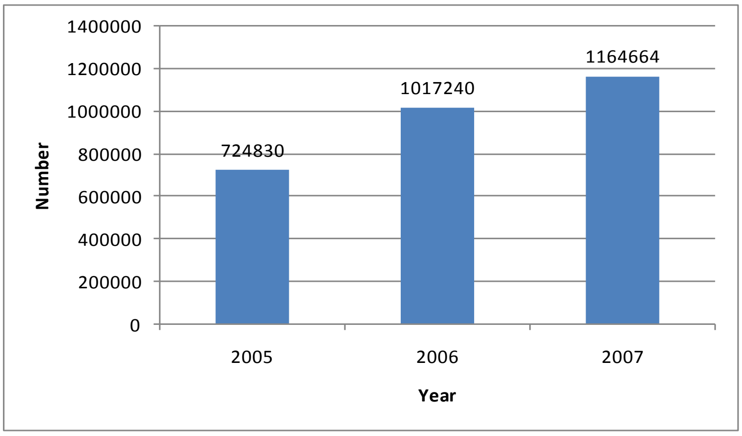

Figure 1 – Vehicle registration dynamics in EU10

This tendency emphasizes that more and more cities across of EU will meet the problem of transport infrastructure overloading and traffic jam. Of course, to solve these problems different methods could be used. One of such method is to develop and to increase the capacity of transport infrastructure. But it is a question of huge financial investments. Another possible variant is to optimize current infrastructure. This approach should not be so demanding to investments. But to do such optimization a big research work must be done. The tasks of data collection, data validation, traffic infrastructure bottleneck debugging, optimization variants development, optimization variants research and selection are necessary. Some of the tasks mentioned above require the mathematical methods to be applied. In general, under mathematical methods should be understood the mathematical modelling. The mathematical modelling gives powerful possibilities of modelled system investigation and analysis. The mathematical model could be presented in two different forms: in the analytical form and in the simulation form. The need of using modelling could be explained by means of figure 2.

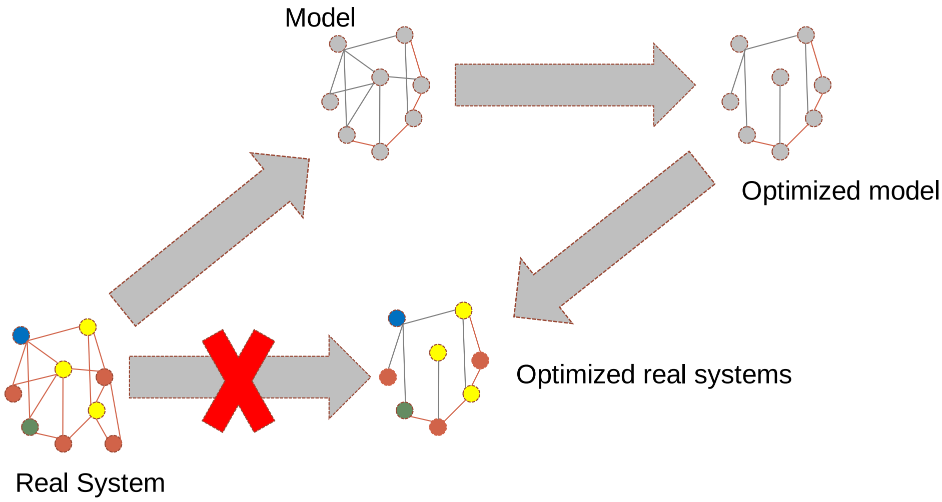

Figure 2 – Modelling as a tool of system analysis

Usually because of the system complexity it is not possible to optimize or to investigate system through real object. That is why modelling could be applied. The real system is transferred to the model and experiments happen with the model. The results of modelling could be applied to the real system.

Because of the investigated systems complexity the analytical modelling is not usually used. The simulation approach is mainly used to model transport systems. The simulation gives big possibilities for modelling different types of systems. The simulation is treated as the universal tools for system investigation, but transport system could be modelled on the different levels, because of different goals. The classical scientific literature dedicated to the transport modelling emphasizes three levels of detalization on which the traffic model could be created (Kutz 2004, Hall 1999). These levels are: microlevel, mesolevel, macroscopic level. The microscopic and macroscopic modelling is well known, widely used and have exact definition. The example of using simulation on the microscopic level and on the macroscopic level could be observed in the following references (Yatskiv et al. 2007a, Yatskiv et al. 2007b, Savrasovs 2007)

The main tasks of this article is to show advantages and disadvantages of microscopic simulation and macroscopic simulation, to make an overview of the existing mesoscopic model and to present a concept of new mesoscopic traffic model which is developed for transport corridor simulation with the acceptable level of output results exactness on the base of the earlier used mesoscopic model.

MICROSCOPIC AND MACROSCOPIC TRAFFIC FLOW SIMULATION

The microscopic and macroscopic levels could be treated as classical, because these two ones are well described and differences among them could be enumerated without problems.

Microscopic models

Accordingly (Hall 1999) the micromodels are characterized by traffic flow detailed description and also by infrastructure detailed description. The objects of the modelling for this level are crossroads, groups of crossroads, bridges, flyovers, traffic circles etc. The main application is the decision making on the tactical level. The tasks which could be solved using such models could be enumerated:

- choice and search for optimal traffic light cycle;
- optimal traffic organizations;
- architectural plan checking up according to requirements;
- different characteristics estimation (queue length, level of service, delay times etc).

Certainly, to solve the mentioned above problems the simulation model should use the data. The input and output data for microscopic simulation could be seen in table 1.

Table 1 – Input and output data for microscopic models

Input data	Output data
• Number of lanes • Lanes width • Road location high level • Allowed speed • Transport flow structure • Flow intensity or OD (origin-destination) matrix • Priority rules • Traffic lights parameters • Acceleration function • Deceleration function	• Queue length (m) • Delay times (s) • Level of service (LOS) • Travel times (s) • Average speed (m/s) • Maximal speed (m/s) • Minimal speed (m/s) • Animation

As could be seen from the table 1 there are a lot of data required to develop the microscopic model. Normally these data could be obtained from the transport surveys, which are oriented to collect the information on the traffic flow intensity. The animation could be treated as an important result of such type of the simulation. In general, the animation could help during model validation and result analysis. The example of the animation from the microscopic model could be seen in figure 3.

Figure 3 – Example of microscopic traffic model

But because of such detailed modelling, the microscopic simulation meets a lot of disadvantages. They could be drawn as follows:

- big resource requirements (time, money, staff) during model development;
- a batch of runs should be completed to get reliable results;
- a big number of input data;
- the need to disaggregate input data;
- model parameters calibration;
- model high sensitiveness to errors in input data.

These disadvantages usually make the microscopic simulation unusable in real projects.

Macroscopic models

The traffic flow on the macroscopic level is presented in general, and is associated with the fluid flow (hydrodynamic model) or with the gases (gasodynamic model) (Kutz 2004). The transport infrastructure is presented with the low level detalization: crossroads as nodes, streets as links which connect nodes. The objects of modelling are districts of the city, city, regions of the country, country etc. The output data are presented with the average values and could be used for decision making on the strategic level. The tasks which could be solved on the macroscopic level could be enumerated:

- roads loading level over whole modelling objects;
- intensity of traffic over all the modelling objects;

- public transport route and schedule optimization;
- traffic forecast;
- system bottleneck research;
- public transport route effectiveness estimation.

The data required to build macroscopic models have mainly the aggregated characteristics. Of course, because of the aggregated characteristics of the input data we should not expect high precision of the output results. But low precession of the output data is compensated by the size of modelling objects. The input and output data are presented in table 2.

Table 2 – Input/output data for macroscopic models

Input data	Output data
• Transport infrastructure • Capacity of the links • Free flow speed for each link • Allowed turns for each node • Transport systems • Transport zones • OD matrix • Volume delay function for each type of link	• Free flow travel time from one transport zone to another • Travel time from one transport zone to another in loaded network • Average speed of travel for each pair of zones • Loading level for each link • Intensity for each link • Public transport effectives indices • Graphical representation of the results

The mentioned below data are mainly obtained from different types of transport surveys. These surveys are oriented to collect information about people mobility, attraction points, travel goals, travel transport system and statistical information for each transport zone. This information is necessary for developing the origin destination matrix, which describes travels between transport zones. In general, the results are aggregated for modelling horizon and are static. It means that we could not observe system dynamics. The results are presented in the graphical and tabular view. Figure 4 demonstrates one of the possible outputs from the macroscopic model. The figure shows the loading level of different roads of the city in colour. Red means that the loading level is higher than 120%, yellow shows that the loading level is between 80% and 120%, and green represents information that the loading level is less than 80%.

The results of output could be used effectively by the transport engineer as the decision support information. But usually the simulation on the macrolevel could not be applied because of its disadvantages:

- output results have general characteristics;
- the results are static;
- additional research should be done to determine input data;

Because of the disadvantages of the micro and macro models, a new type of models called the mesoscopic models could be implemented. The term “mesoscopic modelling” itself shows us that models, developed on the mesoscopic level, are something between micromodels and macromodels. And we can expect that mesoscopic models do not have the disadvantages mentioned for micro and macro models, but have the advantages of both of them.

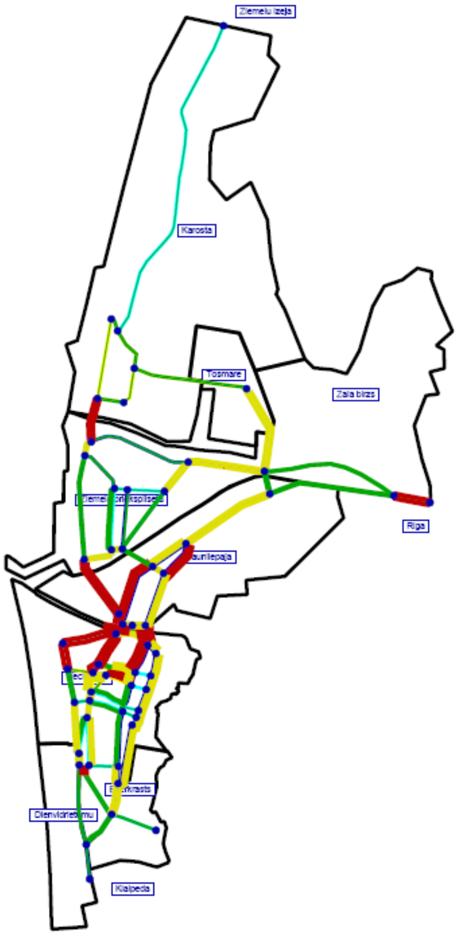

Figure 4 – Macroscopic model results example

OVERVIEW OF EXISTING MESOSCOPIC MODELS

The mesoscopic models are not so widely used. It is connected with the problem that different scientists interpretate the term “mesoscopic modelling” in different ways. Some researchers suggest that the mesoscopic modelling should integrate characteristics of both microscopic and macroscopic levels (Burghout 2004). Moving deeper, the following definition could be formulated: “Mesoscopic models combine the properties of both microscopic and macroscopic simulation models. These models simulate individual vehicles, but describe their activities and interactions based on the aggregate (macroscopic) relationships”. Another definition sounds like “Mesoscopic models of traffic flows imply the estimation of the macroscopic indicators on the mesoscopic level”. Further the first definition will be used to understand the concepts of different mesoscopic models. The concepts of the first traffic mesoscopic model were developed in the late 1970s by the UK Transport Research Laboratory. The main goal was to model urban traffic schemes. In 1989 the model was described by Leonard (Leonard et al. 1989). On the base of this concept software called CONTRAM was developed in 1990. In 1996 Ben-Akiva presented concepts of the mesoscopic model called DynaMIT (Ben-Akiva 1996). This model was integrated into traffic estimation and prediction system for the Center for ITS Implementation Research. Earlier in

1994 Jayakrishnan developed the mesoscopic model called DYNASMART. This model afterwards was extended by such scientists as Gawron (Gawron 1998) by model called FASTLANE and by Mahut (Mahut 2001) by the model called DTASQ. And the last model called MEZZO was developed by Burghout in 2004 (Burghout 2004).

CONTRAM

CONTRAM was the first model ever developed which presents the aspects of mesoscopic modelling. The name of the model itself stands for the **CON**tinuous **TR**affic **A**ssignment **M**odel. The structure of the model is based on the link-node network, where the link behavior of packets of vehicles is determined by the free-flow speed on that link, or a speed/flow relation. At the moment the speed/flow relation is also known as the volume delay function. Additionally the links have saturation flow limits. The nodes represent crossroads in model that is why the additional delay value is calculated. This value is connected with the signal timing plans, average give-way delays, etc. Mostly this information is estimated from real observations. Also throughput of node is known, a queue could exceed the available link space. The link space is determined by the link length and number of lanes for this link. If the link is fulfilled then it cannot accept new vehicles packets. A characteristic feature of CONTRAM is that the model is designed iteratively and progressively within iteration assign proportions of OD flows until one or more of a set of “equilibrium conditions” are met (Taylor 2003, Leonard et al. 1989). All the aspects of model could be represented graphically in figure 5.

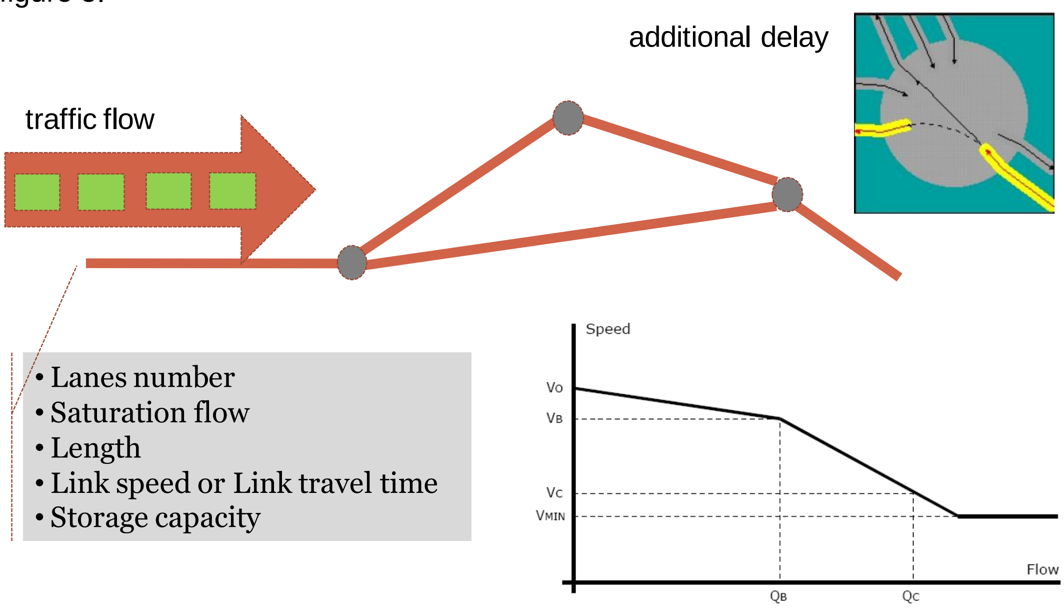

Figure 5 – CONTRAM model concepts

The basic input data for the model could be mentioned:

- saturation Flow (pcu/hr);
- link Length (m);
- green Time (%);
- free Flow Time (sec);

- free Flow Speed (km/hr);
- speed/Flow Curve Number;
- number of Lanes;
- storage Capacity (pcus);
- link Number;
- OD matrix.

The output data of the CONTRAM model could be drawn:

- total flow (veh);
- average flow (veh/hr);
- speed (km/h);
- queue (veh);
- delay (sec);
- capacity (pcu/hr);
- PCU ratio;
- generalized cost;
- congestion index;
- vehicles stopping (%);
- capacity reduction (%);
- etc.

DynaMIT

DynaMIT (**Dy**namic **N**etwork **A**ssignment for the **M**anagement of **I**nformation to **T**ravelers) is a real time dynamic traffic assignment system that provides traffic predictions and travel guidance (Ben-Akiva et al. 1998). DynaMIT has been developed since the beginning of the 1990's at the Intelligent Transportation Systems lab at MIT, with the explicit aim of being able to simulate and to predict the effects of real-time traffic information provided to the drivers. It consists of two main engines:

- The supply simulator, which simulates the movements of the vehicles over the network;
- The demand simulator, which simulates the time-varying Origin-Destination (OD) demand flows, disaggregates route choices etc.

These two modules interact continuously with each other, and with the traveller information that is provided. The supply simulator is a mesoscopic traffic model that models the individual drivers/vehicles. The modelling of the road network is per link, per segment and per lane. As in the previous model the model represents network as set of links and nodes. Links and nodes are treated as static elements of the network. The dynamic components are designed to capture aspects of traffic dynamics. The dynamic components of the network are continuously updated. Each link is divided into segments that capture variation of traffic conditions along the link. While the most segments are defined in advance, the additional segments of the network can be dynamically created to capture the presence of incidents. Each segment has a capacity constrain at its downstream and depending on the nature of the segment; this capacity constraint can appear due to the static physical characteristics of the road or to the dynamic occurrence of an incident. Each segment has a moving part and a queuing part. The moving part represents the portion of the segment where vehicles can move with some speed. The queuing part represents vehicles that are queued up (Burghout 2004). The mentioned above logic could be demonstrated using figure 6. Traffic dynamics is captured by two major models: a deterministic queuing model and a speed model. The speed model is based on the following assumptions.

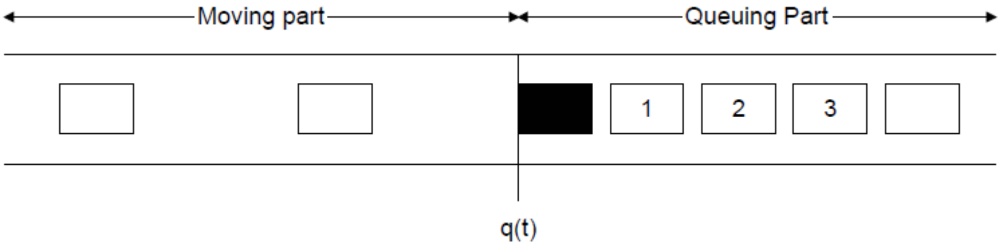

Figure 6 – Queuing model

For a given moving part of a segment, two speeds are computed. The speed at the upstream end of a segment is a function of the average density on the moving part of the segment. The speed at the downstream end is the speed at the upstream end of the next segment. An acceleration/deceleration zone of length is the speed at the upstream end of the next segment. An acceleration and deceleration zone of some length is defined at the end of the moving part. Before that zone, each vehicle is moving at a constant speed (Ben-Akiva et al. 1998). Within the zone, the speed of vehicles varies linearly as a function of the position, as illustrated in figure 7.

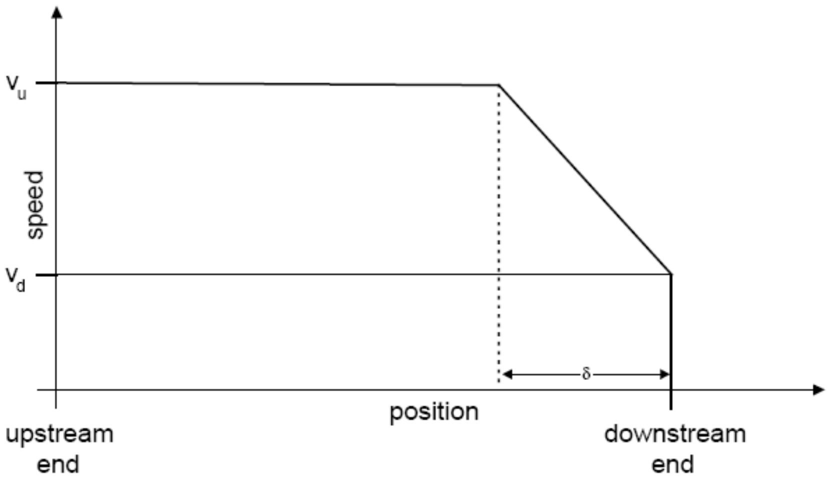

Figure 7 – Speed model

Based on the model description we can conclude that input data for DynaMIT model is in general the same as for CONTRAM model. The possible output data could be splitted into two parts. The first could be the called primary data:

- flow;
- speed;
- density;
- queue length;
- spillbacks.

These data are calculated for each segment of the road. The second part of the data is calculated basing on the primary data and could include the following information:

- total savings in travel delays;
- costs;
- revenues;
- air pollution;
- safety;
- fuel consumption;
- etc. (Ben-Akiva et al. 2001)

DYNASMART, FASTLANE, DTASQ

Alternatively, a queue-server approach is used in some models (DYNASMART (Jayakrishnan, Mahmassani et al. 1994), FASTLANE (Gawron 1998), DTASQ (Mahut 2001), where the roadway is modelled as a queuing and a running part. The lanes can be modelled individually, but usually they are not. Although the vehicles are represented individually and maintain their individual speeds, their behaviour is not modelled in detail. The vehicles traverse the running part of the roadway with a speed that is determined using a macroscopic speed-density function, and at the downstream end a queue-server is transferring the vehicles to the connecting roads. This approach combines the advantages of the dynamic disaggregated traffic stream modelling (since the vehicles are modelled individually), with the ease of calibration and the use of macroscopic speed/density relationships. The capacities at the node servers follow from the saturation flows and their variance (measured or calculated). Signal controlled intersections can be modelled by replacing the queue servers with the gates that open and close according to the states of the signal control (green / yellow / red). The adaptive signal control is harder for the model since the positions of the vehicles on the link are not known, and therefore it is difficult to know when they pass the detectors connected to the signal control (Burghout 2004). The concepts of the models are presented in figure 8.

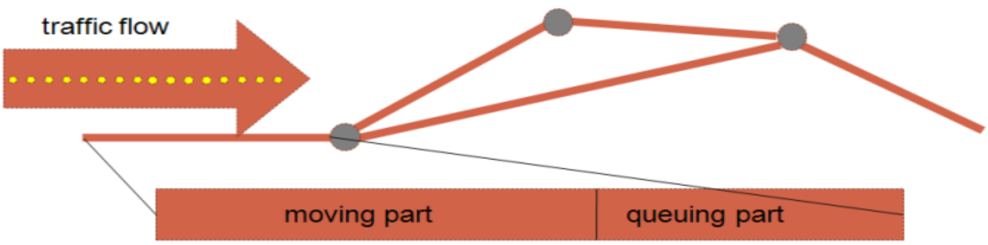

Figure 8 – Moving and queuing part

The output data could be drawn as follows:

- intensities per link;
- average speed per link;
- average travel time for each origin-destination point;
- average delays per directions;
- routes.

Here should be noted that the big advantage of these models is that vehicles are modelled individually, this gives us information about the routes of travel. It is not available in the previously described models, because in these models vehicles were grouped somehow.

MEZZO

The traffic network in Mezzo is represented by a graph that consists of nodes and links. The nodes are the points where the multiple traffic streams join or diverge, such as intersections, on / off ramps, as well as origins or destinations of traffic. The links represent the roadway between such nodes, and are unidirectional. This means that a regular street is usually represented by two links, one for each direction. The lanes on a road are not represented separately. The nodes have usually multiple incoming and outgoing links, and are considered to be the main sources of friction in the traffic streams.

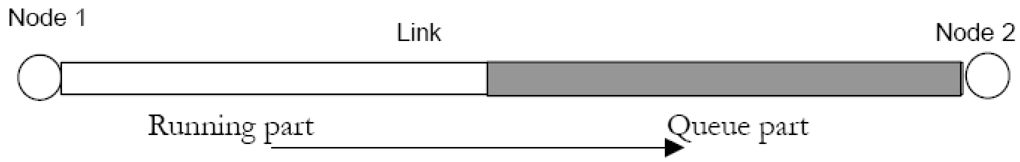

Figure 9 – Moving and queuing part in Mezzo

As can be seen in figure 9 the link is divided into two parts: the running part and the queue part. The queue part starts at the downstream node and grows towards the upstream node, when the incoming flow exceeds the outgoing flow on the link. For instance, when a traffic light at the downstream node goes to red, the queue part will grow. The running part is the part of the link that contains vehicles that are on their way to the downstream node, but they are not (yet) delayed by the downstream capacity limit (for instance the traffic light). This means that the boundary between the running part and queue part is dynamic, and usually varies over time, depending on the variations in the inflow and outflow. The queue part is defined to contain at time t, those vehicles that have the earliest exit time smaller than t. In other words, all the vehicles should have left the link, if it were not for some delay caused at the downstream node.
At the downstream end of the link, the node connects it to other links. Each connection between the incoming and the outgoing link is called the turning movement (even the straight going movements) (Burghout 2004). See figure 10, for an example.

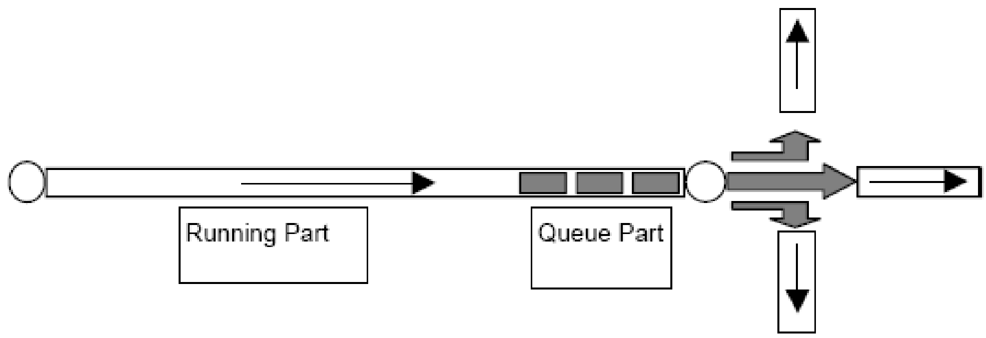

Figure 10 – Turning movements in Mezzo

The possible output data could be described here:

- average speed;
- average density;
- average income flow;
- average outcome flow;
- average queue length;
- travel time;
- travel routes.

MESOSCOPIC APPROACH

Comparing mesoscopic approach with the other approaches is something in the middle of the microscopic and macroscopic approach. This approach should use advantages from both of them. The philosophy behind this approach can be described with the phrase "discrete time/ continuous quantity". The representation of individual flow objects that reproduce persons, job orders, goods etc is dispensed with. The only employed members that are used in the model represent the respective quantities of objects or materials and can be modified with mathematical formula in every step of the discrete simulation time. This type of mesoscopic modelling and simulation is the method helping to complete planning tasks in production. Also results of simulation on mesoscopic level can be introduced as graphs of the processes, which are very useful on practice. The concept of simulation on mesoscopic level specifies the development of the principally new class of models.
Mesoscopic modeling shows only discrete changes of the corresponding continuous flows. It means, that flow intensity λ(t) stays unchangeable in each interval of time between flow changes Function λ(t) could be called slice constant function. Figure 11 presents functions of income and outcome flow for simple store. Last graph presents contents of the store for the given input and output flow. Because λ(t) is slice constant function the graph of contents of store could be only the piecewise-linear function. The main advantages of such process representation in mesoscopic modeling are probably forecasting (to planning, calculating) moments of time, then contents of store and cumulative value of flow reach the given values.

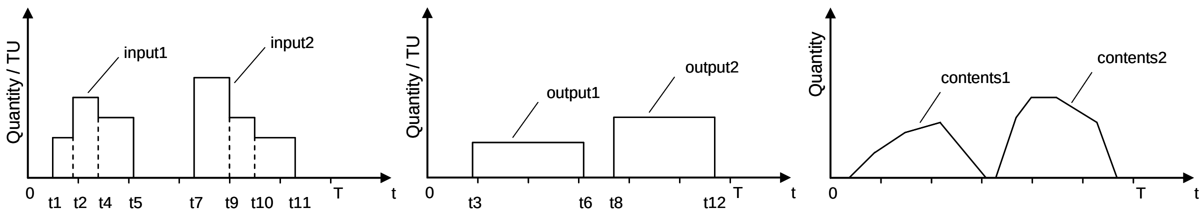

Figure 11 – Process presentations in mesoscopic level

So dual properties are characteristic of the mesoscopic model:
Its flow processes characterized by intensity λ(t) (as in case of model of continuous type). For processes in store and for cumulative values of flows the future events (as in case of models of discrete events) could be planned.
The single continuous fragments of flow, that will be called the batches of product, could be treated as objects. The mesoscopic model feature is the possibility to control the path of any

batch of product during it movement through the model structure. In figure 12 an example of mesoscopic model is presented. Instead of stores in the presents the so called multichannel funnels. Because of the parallel channels, batches of products in the same funnel at the same time could be divided. Funnel channels (see funnels stock1 and stock2 on figure 12) have numbers, which are numbers of parallel flows of products (see products Pr1 and Pr2 in figure 12). Conformity between products batches, which are created and processed in the model, and the numbers of parallel flows, are given in frame of conceptual model.

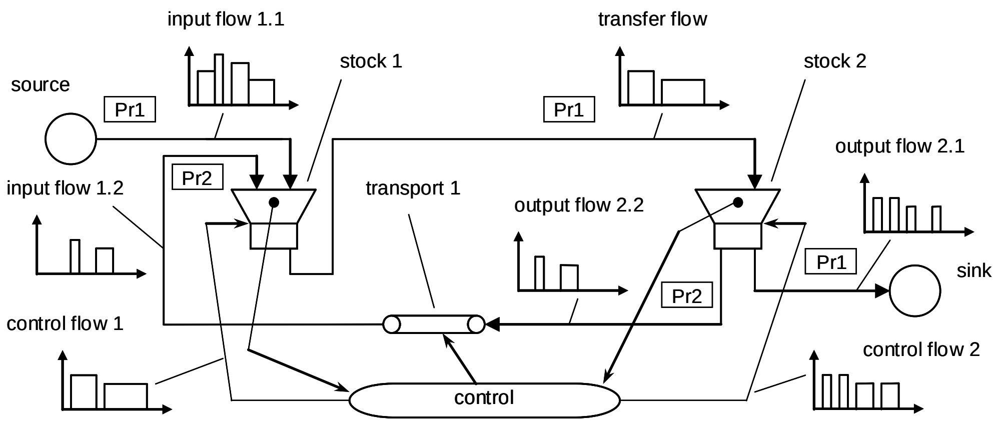

Figure 12 – Example of mesoscopic model structure

MODELLING AND SOURCE DATA DESCRIPTION

A transport corridor is a (generally linear) tract of land in which at least one main line is provided for transport, whether it is a road, rail or canal facility. In this paper under transport corridor we will understand a road which connects two geographical points. The need of research and analysis of the transport corridors is mainly connected with wish to locate bottlenecks of the corridor and to estimate different characteristics, for example, the average speed along the corridor, the average travel time etc. The main idea of the transport corridor could be presented using figure 13.

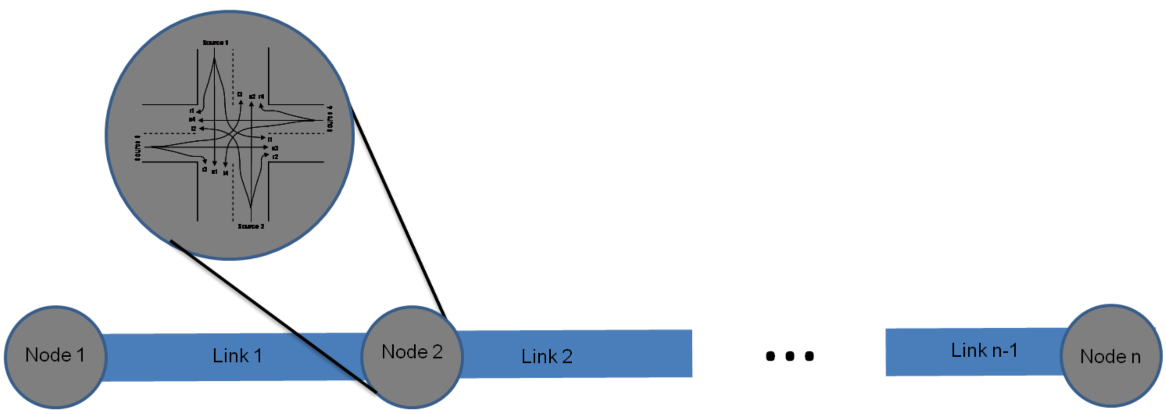

Figure 13 – Schema of transport corridor

As could be seen the transport corridor is a sequence of nodes and links. The structure of each node could be defined. To simplify the process of demonstration we will use two nodes and one link between them. So the conceptual model of the analysed transport corridor fragment is presented on figure 14.

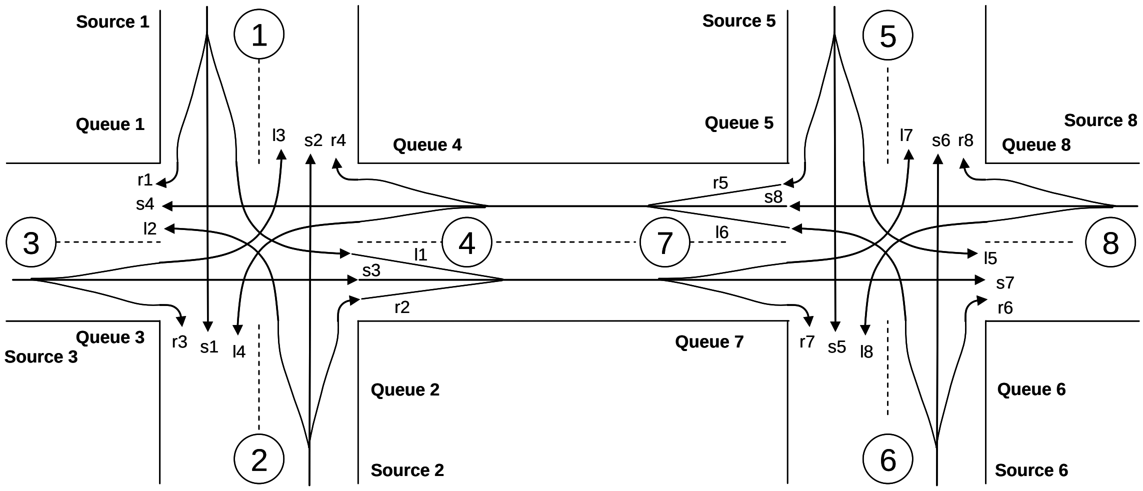

Figure 14 – Transport corridor fragment.

Crossroads are connected with the road, which is a part of model. The flow of the vehicles enters the network from 6 zones, which are enumerated by numbers 1, 2, 3, 5, 6 and 8. Each income flow is divided on three moving direction: right (r), straight (s) and left (l). The geometry of the crossroads is constructed in such way, that vehicles which enter the network from one zone and belong to one direction r, s and l, can reach and pass the crossroad independently from others directions. Only vehicles which turn left (flow l), depends of flow s duration, which pass crossroad straight in counter lane, during green phase of traffic light. Because of the modelled object's topology the total entering flow of the left crossroad (figure 14), which enter from zone 4, is equal to sum of flows r5, s8, and l6. In the same way, entering flow for right crossroad is calculated as sums of flows r2, s3, and l1. The mesoscopic approach uses the queue length of vehicles waiting at a crossroad for determining the quantity of vehicles (q). This concept is also used for describing the number of created vehicles and vehicles passing a crossroad. If the number of vehicles in the incoming flow is known, at example 10, the queue length of vehicles can be easily estimated using empirical data. The flows in the model will be described in meter/minutes (m/min).

Table 3 shows the numerical parameters of stationary incoming flows, which are used in the example presented here. The parameters for all 6 stationary flows are the same. The number of vehicles for each traffic light cycle is generated with given distribution laws taking into account cycle duration. In this example the cycle duration for first (left) crossroad is 60 seconds (25s+5s+25s+5s). For the second (right) crossroad is 70 seconds (30s+5s+30s+5s). During flows generating the distribution on direction (r, s, l) is done according proportion r/s/l=0,25/0,6/0,15.

Table 3 – Parameters of incoming vehicle flow

Incoming flow	Distribution law	Flow intensity mean value (m/min)	Crossroad passing
r	uniform	20	0,6
s	uniform	65	0,8
l	uniform	10	0,6

In model is taken into account the real length of the road, which connects zones 4 and 7. So the maximal total amount of the vehicles for directions 7→4 (Queue 4) or 4→7 (Queue 7) should be defined. In this example for both directions, as the highest level limit is used value 130m. The queue length for internal flows is not limited.

For high plausibility maintenance of the crossroads passing is used empirical function (see figure 15), which could be estimated during direct observing of the passing process, for each direction of crossroad passing. It is supposed that function is preserved for all directions and it numerical values could be obtained based on Exemplary chart, by the way of multiplying the value if function to the coefficient presented in table 3 in column "Crossroad passing". The function is used in the model as direct and as inverse function. Figure 15 shows that during the first t1=25,5s of a traffic light cycle a vehicle flow with the length q1=122m can pass the crossroad and the flow of length q2=185m will need a t2=32,5s to pass the crossroad.

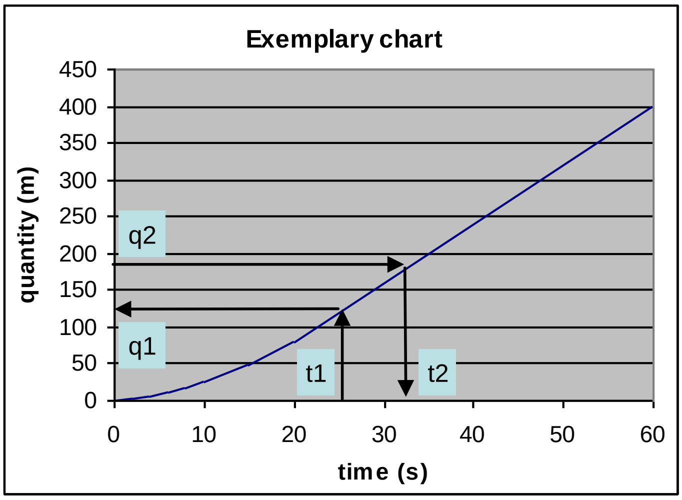

Figure 15 – Dynamic of vehicle flow during crossroad passing

Described above problem was successfully solved and results of modelling, experiments and validation could be observed in (Savrasovs, Toluyew 2008). But the validation of the results shows that additional detalisation of model is required if the length of the link between nodes is growing. The more is length of the link between nodes more difference is observed between simulation results and real data. This situation could be commented in the following way, that proposed mesoscopic model do not take into account a moving time between two nodes. That is why the update of the model should be done to use it for transport corridor analysis.

The existing mesoscopic model overviewed earlier use running-queuing part approach to simulate the movement of vehicles between nodes. This approach could be easy applied for described model.

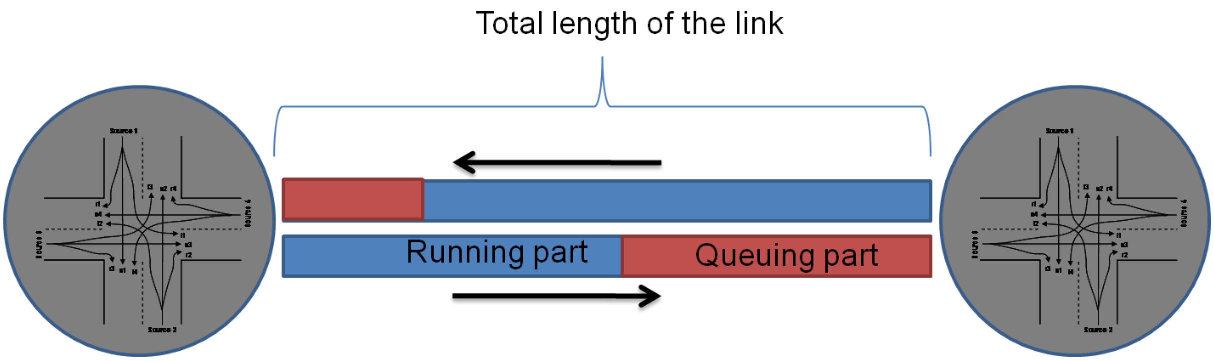

Figure 16 – Running-queuing approach application

The total length of the link is a sum of lengths of running part and queuing part. The length of the queuing part could be changed dynamically during simulation if the queue is growing. Described above model take into account queue length, but do not take into account the movement time on running part. To include this new possibility the following alternative decisions could be used:

1. Movement time could be calculated as division of running part length to the earlier defined speed allowed on this link.

2. Movement time could be calculated using VDF (volume delay function). There are a lot of different VDF so which one to use is a question of model calibration. The example of possible volume delay function could be observed below:

$$\begin{cases} t_{cur} = t_0 \cdot (1 + a \cdot sat^b) & if\ sat < sat_{crit} \\ t_{cur} = t_0 \cdot (1 + a \cdot sat^b) + (q - q_{\max}) \cdot d & if\ sat \geq sat_{crit} \end{cases}$$

$$sat = \frac{q}{q_{\max} \cdot c}$$

$$sat_{crit} = 1$$

where t_0 - free flow travel time [s],
q - traffic volume [car units/time interval],
$qMax$ - capacity [car units/time interval],
t_{cur} - travel time in loaded network [s]

The principal structure of two crossroads model is presented in figure 17. The model consists of eight fragments. Links between them are defined according vehicles flows (see figure 17). Each fragment is includes three parallel channels, which generate, delay and pass throw crossroad flows of vehicles. Last two functionalities are realized using “multichannel funnel”, which is described in (Savrasovs, Toluyew 2007). The content of each channel of the funnel is numerically equal to the length of the queue. The control component of the model (Flow Control) defines the quantity of vehicles which can pass the crossroad in each traffic light cycle for the different directions.

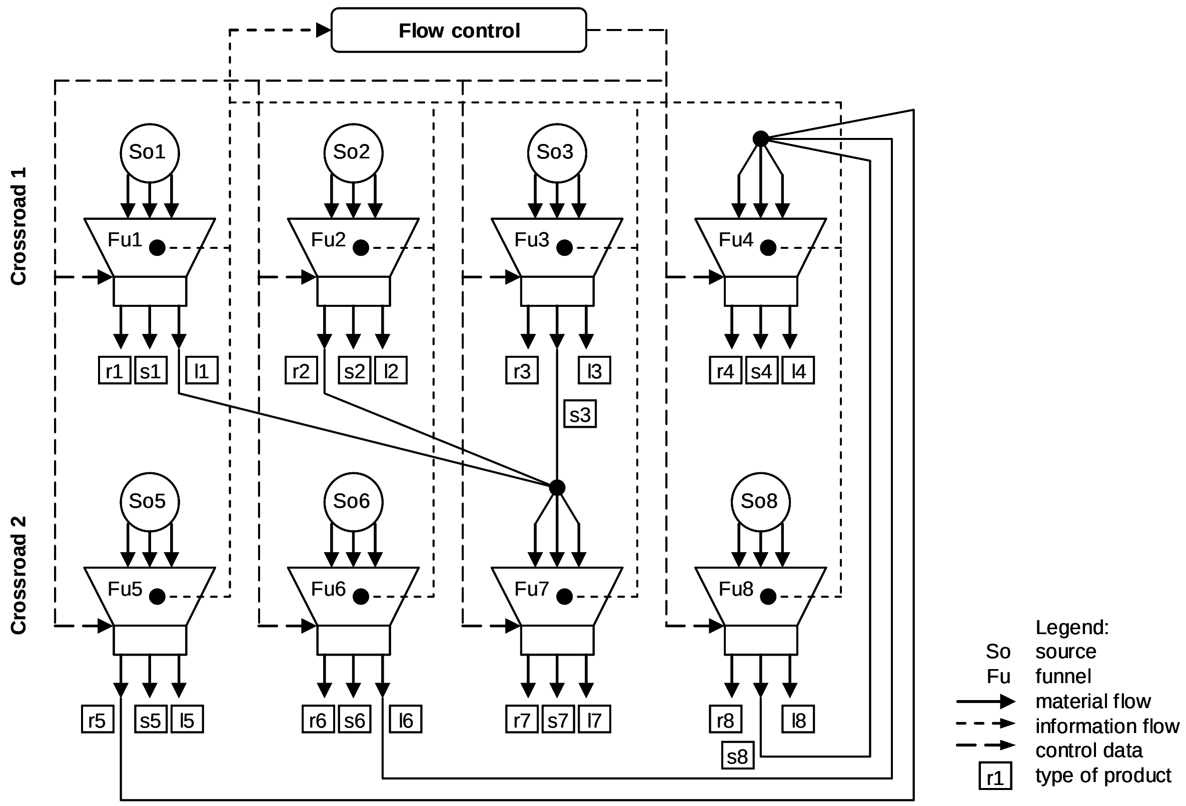

Figure 17 – Principle structure of mesoscopic model of the two crossroads

The kernel of the mesoscopic model of the one crossroad or several crossroads are presented in the table 4. The event planning algorithm determine the next funnels pair, for which green phase is finishing. The model time is "jumping" to the moment then this event will happen. For these funnels new values of variables, listed in table heads are calculated. Calculation happens from left to right. The data calculation for direction l (left turn) is done after the data calculation for straight on flow s. After processing, the event planning algorithm chooses the next pair of funnels, for which green phase is finishing. For event planning and processing algorithm the variable t is defined for each crossroad: variable t1 for the events time of first (left) crossroad and variable t2 for second (right) crossroad events time. As time interval Δt is used, the corresponding duration of half-cycle of the traffic light "yellow + green". At example, for crossroad first value is defined Δt1=30s, but for the second Δt2=35s.
The calculation algorithms of variables presented in the table 4 for flows of type r, s and l are described in detail in (Tolujew, Savrasovs 2008). Here should be mentioned that it is assumed that the defined minimal flow of vehicles can complete the left turn, even if the passer flow exist during all green phase of the traffic light. Before model execution it is possible to give a start condition of the queues. The value of the maximal modelling time is then defined. The model run could be done entirely or step-by-step and it will give possibility to control value of the variables in each step Δt.

Table 4 – Kernel of the mesoscopic model

	Remaining from previous cycle (m)	Arrival per cycle (m)	Wish to drive through (m)	Duration of green phase (s)	Phase capacity (m)	Passed through volume (m)	Duration of pass flow (s)	Remaining on current cycle (m)
Crossroad 1			**Cycle number: 16**			**Time (s): 990**		
Funnel 1								
right (r1)	0,00	17,42	17,42	25	72,00	17,42	10,88	0,00
straight (s1)	0,00	44,09	44,09	25	96,00	44,09	16,11	0,00
left (l1)	31,52	7,76	39,28	25	72,00	17,10	7,05	22,18
total	31,52	69,26	100,78		240,00	78,60		22,18
Funnel 2								
right (r2)	0,00	17,21	17,21	25	72,00	17,21	10,80	0,00
straight (s2)	0,00	53,49	53,49	25	96,00	53,49	17,95	0,00
left (l2)	4,23	7,75	11,98	25	72,00	11,98	8,89	0,00
total	4,23	78,44	82,67		240,00	82,67		0,00
Funnel 3								
right (r3)	0,00	16,22	16,22	25	72,00	16,22	10,44	0,00
straight (s3)	30,85	56,37	87,22	25	96,00	87,18	23,62	0,04
left (l3)	0,00	9,45	9,45	25	72,00	9,45	3,64	0,00
total	30,85	82,04	112,89		240,00	112,85		0,04
Funnel 4								
right (r4)	0,00	30,28	30,28	25	72,00	30,28	15,39	0,00
straight (s4)	0,00	72,68	72,68	25	96,00	72,68	21,36	0,00
left (l4)	8,87	18,17	27,04	25	72,00	9,65	1,38	17,38
total	8,87	121,13	130,00		240,00	112,62		17,38
Crossroad 2			**Cycle number: 14**			**Time (s): 1015**		
Funnel 5								
right (r5)	18,86	26,11	44,97	30	96,00	26,18	14,05	18,79
straight (s5)	0,00	84,75	84,75	30	128,00	84,75	23,24	0,00
left (l5)	2,36	13,91	16,27	30	96,00	16,27	11,37	0,00
total	21,22	124,78	146,00		320,00	127,21		18,79
Funnel 6								
right (r6)	0,00	19,39	19,39	30	96,00	19,39	11,59	0,00
straight (s6)	0,00	56,99	56,99	30	128,00	56,99	18,63	0,00
left (l6)	29,17	9,32	38,50	30	96,00	0,00	6,76	38,50
total	29,17	85,70	114,87		320,00	76,38		38,50
Funnel 7								
right (r7)	0,00	28,97	28,97	30	96,00	28,97	15,04	0,00
straight (s7)	0,00	69,52	69,52	30	128,00	69,52	20,86	0,00
left (l7)	14,14	17,38	31,52	30	96,00	16,09	6,49	15,43
total	14,14	115,86	130,00		320,00	114,57		15,43
Funnel 8								
right (r8)	0,00	27,11	27,11	30	96,00	27,11	14,39	0,00
straight (s8)	0,00	86,43	86,43	30	128,00	86,43	23,51	0,00
left (l8)	0,00	12,44	12,44	30	96,00	12,44	9,14	0,00
total	0,00	125,98	125,98		320,00	125,98		0,00

CONCLUSIONS

- The disadvantages of traffic simulation on the microscopic and macroscopic levels were presented. In general, for microscopic model the disadvantages are connected with the resource requirements necessary to develop, validate, calibrate and experiment with the microscopic models. The output data precision could be mentioned as advantage. The macroscopic model requires less input data for developing, but the output results are presented in the aggregated form and usually do not meet the exactness requirements.

- Mesoscopic models fill the gap between the mesoscopic and macroscopic models, by taking advantages of these models.
- The major part of scientists agrees that mesoscopic models represent the individual vehicles, but describe their activities and interactions based on the aggregate relationships.
- Number of mesoscopic models were overviewed in this paper. They are CONTRAM, DynaMIT, DYNASMART, FASTLANE, DTASQ and MEZZO.
- The main principles of mesoscopic modelling of flow systems were demonstrated. The model does not present individual flow objects, but only defined sets of objects (groups of vehicles coming to the crossroad during one traffic cycle).
- All parameters of the model can be directly estimated. Any empirical data can be used to model the flow dynamics. Incoming flows are modeled as random values of the length of the flow with any distribution law. The duration of a traffic light phase is defined as a parameter.
- The model allows studying a stationary and non-stationary mode of crossroad processes. At example the start values for queues can be given and then time of queues resolving and appearance could be estimated during special conditions.
- First results of modelling can be shown as a detailed trace file of processes for every structural component and type of flow. Any characteristics of the crossroad processes can be calculated on the basis of the trace file. Graphs of process evaluation can also be constructed.
- The developed mesoscopic model could be used for qualitative and quantitative queues dynamic study. It could be easily changed and expanded. Also any algorithms of traffic light phase control algorithms could be integrated.
- The idea of using running-queuing approach in model is presented. The integration of this approach to the existing model helps to increase validity of the model. Especially if simulation object is a transport corridor. In future numerical example is required.

ACKNOWLEDGMENTS

The article is written with the financial assistance of European Social Fund. Project Nr. 2009/0159/1DP/1.1.2.1.2/09/IPIA/VIAA/006 (The support in Realisation of the Doctoral Programme "Telematics and Logistics" of the Transport and Telecommunication Institute).

REFERENCES

Ben-Akiva, M., (1996). Development of a deployable real-time dynamic traffic assignment system, Task D Interim report: analytical developments for DTA system, MIT ITS Program, Cambridge (MA).

Ben-Akiva M., Bierlaire M. Koutsopoulos H., Mishalani R. (1998) "DynaMIT: a simulation-based system for traffic prediction". DACCORD Short Term Forecasting Workshop February, Delft, The Netherlands.

Ben-Akiva M., Koutsopoulos H. Walker J. (2001). "DynaMIT-P: Dynamic Assignment Model System for Transportation Planning". 9th WCTR Conference Seoul, Korea.

Burghout W., (2004). “Hybrid microscopic-mesoscopic traffic simulation” Doctoral Dissertation Royal Institute of Technology Stockholm, Sweden.

European Road Statistics, 2008.

Gawron, C., (1998). Simulation-Based Traffic Assignment; Computing User Equilibria in Large Street Networks, PhD thesis, University of Cologne, Cologne.

Hall R. W., (1999). “Handbook of transportation science”, Springer. – 532 p.

Jayakrishnan, R., H.S. Mahmassani & T.Y. Hu, 1994. An Evaluation Tool for Advanced Traffic Information and Management Systems in Urban Networks. Transportation Research C 2C (3): 129-147.

Kutz M.,(2004). “Handbook of transportation engineering”, McGraw-Hill Professional.-1000 p.

Leonard, D.R., P. Power & N.B. Taylor, 1989. CONTRAM: structure of the model, Transportation Research Laboratory, Crowthorn.

Mahut, M., (2001). A multi-lane extension of the Space-Time Queue Model of Traffic Dynamics. TRISTAN IV, Azores Islands.

Savrasovs M., (2007). “Development of Liepaja city macroscopic model for decision-making”. Transport and Telecommunication, Volume 8, No 2. -38-46 lpp.

Savrasovs M., Toluyew Y., (2008). “Transport system’s mesoscopic model validation using simulation on microlevel”. 8th International Conference, Reliability and Statistics in Transportation and Communication, 2008.-297-304 lpp.

Savrasovs, M., Toluyew, Y., (2007) “Application of Mesoscopic Modelling for Queuing Systems Research”, 7th International Conference, Reliability and Statistics in Transportation and Communication, I. V. Kabashkin, I. V. Yatskiv (Eds.), Transport and Telecommunication Institute, Riga, 2007, pp. 94-99.

Taylor Nicholas B., (2003). “The contram dynamic traffic assignment model”. Netowork and Spatial Economics, 3 (2003) 297-322.

Tolujew Y., Savrasovs M., (2008). “Mesoscopic approach to modelling a traffic system”, International Conference, Modelling of Business, Industrial and Transport Systems, 2008. -147-151 lpp.

Yatskiv I., Yurshevich E., Savrasovs M., (2007). “Investigation of Riga Transport Node Capacity on the Basis of Microscopic Simulation”, 21st European Conference on Modelling and Simulation (ECMS 2007), Prague, Czech Republic, pp.584 – 589.

Yatskiv I., Medvedev A., Savrasovs M.,(2007). “Analysis and Forecast of the Urban Public Transport Flow in Jurmala City”. 7th International Conference, Reliability and Statistics in Transportation and Communication.-79-93 lpp.