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DEVELOPMENT OF RIGA-MINSK TRANSPORT CORRIDOR SIMULATION MODEL

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This paper deals with the developed cargo traffic macroscopic simulation model. The goal of model development is to analyse and study Riga-Mink transport corridor. This transport corridor is an important transport arterial between Latvia and Republic of Byelorussia. The growth of goods movement between these countries also could be explained by transit characteristics of both countries. The duration of transport corridor on Latvian territory is approximately 300 km. The corridor crosses a lot of small and large cities and that is why the question of its functioning performance exists. The simulation model was developed using specialised simulation software called PTV VISION VISUM. VISUM uses the transport model that defines requirement for input data. The developed model consists of transport network model and demand model. The demand model is presented by two origin destination matrices, which have been calibrated using TFlowFuzzy algorithm. Further calibrated model has been used to estimate two development scenarios using different output data of VISUM.

Keywords: transport corridor, macroscopic model, simulation, bottlenecks, development scenarios, TFlowFuzzy

1. Introduction

For the last years relationship between Latvia and the Republic of Byelorussia has become very close. The goods turnover is increasing between these two countries [1]. The similar feature for Latvia and the Republic of Byelorussia is the fact that both are transit countries. Mainly two transport types: railroad transport and cargo auto transport are used during transportation. This paper describes the results of work on analysis of transport corridor between Riga (capital of Latvia) and Minsk (capital of the Republic of Byelorussia).This work considers only a part of this corridor from Riga to Latvia's border, it is connected with lack of data about the second part of transport corridor. The main goal of described research is to locate bottlenecks of this corridor and estimate different indexes of its functioning. Also different development scenarios should be implemented and compared using simulation models.

The simulation models are selected because of their flexibility on possibility to play different scenarios and analysis features. The traffic could be simulated on different levels [2]: microscopic, mesoscopic and macroscopic. Because of simulation object complexity and its physical distribution the microscopic models could be applied only for simulation some parts of transport corridor [3], transport nodes or control check point, but not for whole transport corridor. The mesoscopic models could simulate such distributed objects [4], but the traffic mesoscopic models are not widely used and the software for them is not available. Macroscopic transport models are specially designed for such object simulation [5] and it is possibly to use it. The disadvantage of applying macroscopic simulation is connected with aggregated state of output data.

The first section describes the simulation model in details, paying attention to the transport infrastructure, which organizes transport corridor. The second section presents the methodology of macroscopic models development and summarizes the list of data required for model construction and calibration. The third part describes the developed model and presents calibration results. The last part describes development scenarios of the transport corridor and simulation results.

2. Riga-Minsk Transport Corridor Description

Riga-Mink transport corridor connects the capital of Latvia and the capital of the Republic of Byelorussia. All the mentioned above characteristics are related to the Latvian part of corridor from Riga to the Latvia's border with the Republic of Byelorussia. The Riga-Minsk transport corridor crosses Latvia from north-west to south-east. The Figure 1 shows the transport corridor in context of Latvian transport infrastructure.

Figure 1. Transport corridor Riga-Minsk

The duration of transport corridor from Riga to Latvia's border is approximately 300 km. The main part of corridor is presented by national level road A6, which connects the biggest two cities in Latvia – Riga and Daugavpils. From Daugavpils to the border the road A6 is used. There are a lot of small and large cities, which are crossed by this transport corridor. Mostly there are no bypass roads. The bypass roads are available only for the following cities: Jekabpils, Plavinas, Daugavpils. The road from Riga to Ogre has two lanes per direction; the same is for transport corridor part from Nicgale to Daugavpils. All the rest parts of transport corridor are presented by road with one lane per direction (see Figure 2).

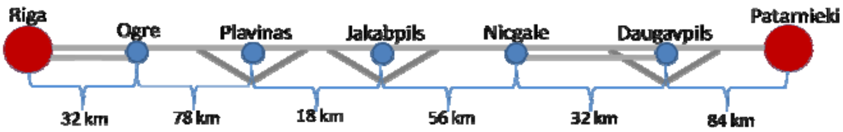

Figure 2. Transport corridor schema

The speed limits are defined by national road rules. The speed limit in city zone is 50 km/h, outside of the city zone – 90 km/h. The current traffic flow intensity is high and keeps growing. According [6] the map of intensities for different parts of transport corridor is presented in Table 1.

Table 1. Day traffic intensities for different parts of transport corridor

Road Nr.	*Road Part*	*from km*	*to km*	*2008 intensity*	*2008 CT%*
A6	Riga border - Salaspils	17.370	19.130	31416	16
A6	Salaspils - A4	19.130	22.950	20514	19
A6	A4 - Ikšķile	22.950	29.350	23204	13
A6	Ikšķile - Ogre	29.350	39.050	20154	13
A6	Ogre - Ķegums	39.050	46.980	13538	17
A6	Ķegums - Lielvārde	46.980	51.780	11734	19
A6	Lielvārde - Skrīveri	51.780	77.850	7769	22
A6	P32 - P87	77.850	87.060	9171	25
A6	P87 - Pļaviņas	87.067	117.717	7298	23
A6	Pļaviņu beltway	117.720	131.660	3198	43
A6	V996 - Jēkabpils	131.657	143.956	6871	18
A6	Jēkabpils - Līvāni	149.545	172.050	4776	18
A6	Līvāni - P64	176.170	201.736	3291	21
A6	P64 - P67	201.736	224.550	3629	21
A6	P67- P65	224.550	238.646	1893	53
A6	P65 - Krāslava	238.646	268.714	2820	17
A6	Krāslava - Boundary of Latvia	274.078	307.000	1148	31

The Table 1 defines average day traffic intensities for different part of transport corridor for 2008. The first column defines road number, the second one defines road part, the next two columns describe road kilometres, the fifth column presents average day intensity for each corridor part and the last column presents the percents from intensity of cargo (CT%).

Figure 3. The main sources of cargo traffic

The main sources of cargo traffic, which fill the transport corridor is transit traffic from Estonia and Latvian ports: Ventspils, Liepaja, and Riga. The sources are presented on Figure 3.

3. Methodology of Building Traffic Models on Macroscopic Level

For the model constructions there has been used PTV VISION VISUM software, which is one of leaders in macro modelling of transport flows. For models development system there has been used a special metamodel, which is presented on Figure 4.

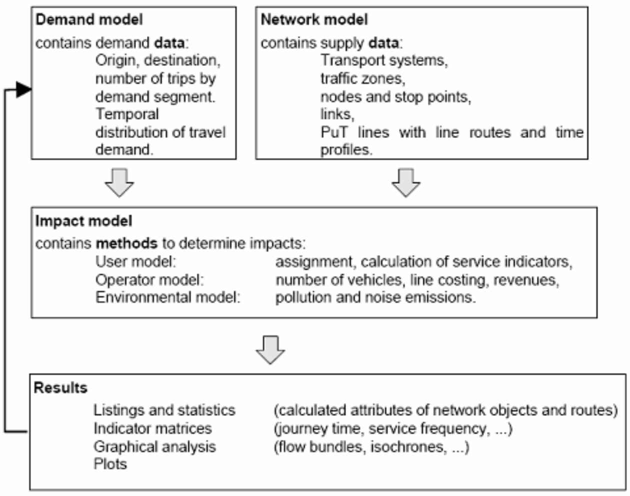

Figure 4. VISUM transport model [7]

The transport model normally consists of a demand model and a network model. The demand model contains the travel demand data. The network model describes the relevant supply data of the transport system. It consists of traffic zones, nodes, public transport stops, links and public transport lines with their timetable. The impact model takes its input data from the demand model and the network model. VISUM provides different impact models to analyse and evaluate the comprehensive transport system. VISUM displays the calculated results in graphic and tabular form and allows analysing the results graphically. In this way, for example, routes and connections per OD pair, flow bundles, isochrones and node flows can be displayed and analysed. The transport model like all models represents the abstraction of the real world. The model creation can be divided into few steps, which are described in details below.

Transport infrastructure development

This stage includes the development of the transport infrastructure using the system of special objects Nodes and Links, those objects representing roads intersections and roads accordingly. The nodes are connected with the links and in such way the transport network is implemented. Of course before constructing network the scale should be defined, allowing the program to calculate the link length automatically. Also for all links a set of the following parameters should be defined:

- Speed restriction
- Link capacity
- Allowed transport systems

Also for each node the allowed direction of moving should determined.

Zones

On this stage, the investigated object must be divided into zones. The zones of the model are represented as geometric shapes. But it should be taken into account that transport flow movement starts and ends in the zone geometric centre. It is not obligatory to define zone as the geometric shape; it could be presented as the point. Using system object called connector the zones centre must be connected with the transport network via nodes. In such way incoming and outgoing points of flow can be determined. A lot of such connections for one zone can be defined. If zone has more than one incoming/outgoing point, then the weight for each point should be defined. This weight defines the percentage of the transport flow, which uses this node for getting into the zone and getting out of the zone.

Demand model development

The demand model defines the quantity of trips between different zones, with different goals using different transport systems. But in this work there has been used only one type of transport system – private transport system and no goals are defined. So the demand model is presented only with one OD matrix (origin destination matrix), which describes the volumes of traffic flow moving from one zone to another.

4. Model Development and Calibration

According to the described above strategy the macroscopic model of transport corridor has been developed in PTV VISION VISUM 11.0 software [8]. The developed model includes not only transport infrastructure of the transport corridor, but also main national roads of the Latvia. The network infrastructure has been created using VISUM special objects called links and nodes. The network in developed models is presented by more than 60 nodes and more than 130 links of different types. The types of the links are defined by allowed moving speed. Finally only two types of links are defined:

- Links with travel speed 50 km/h – links, which represents intercity roads;
- Links with travel speed 90 km/h – links, which represents out of city roads.

Here it should be underlined that transit cargo vehicles must use bypass roads in Daugavpils and Plavinas city. The developed network model is presented on Figure 5.

Figure 5. The transport network model

The yellow links indicate the first class of link (allowed speed 90 km/h), the red one presents the second class of links (speed restriction is 50 km/h). Another important option for link, which must be defined, is the capacity of the link and transport systems. In the model only two transport systems has been used: cargo transport system and car transport system. The capacity of link should be defined taking into account that the simulation of twenty-four hours is taken. In general the capacity is also defining a number of lanes per direction. The Table 2 defines the twenty-four hours capacities for two types of link.

Table 2. The capacity of different link types

Link type	Description	One lane capacity	Two lanes capacity
R50	Speed restriction - 50 km/h	1488	2678
R90	Speed restriction - 90 km/h	26400	47520

Also the volume-delay function (VDF) should be defined for links. VISUM offer a huge set of different VDF, which differs by forms and parameters. For both types of link the following VDF called BPR [7] has been implemented:

$$t_{cur} = t_0 \cdot (1 + a \cdot sat^b)$$

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

$$sat_{crit} = 1$$

where t_0 – free flow travel time [s],

q – traffic volume [vehicle units/time interval],

$qMax$ – capacity [car units/time interval],

t_{cur} – travel time in loaded network [s].

The values of parameters are taken by default: $a = 1$; $b = 2$; $c = 1$.

The next step of model creation is connected with transport zone definition. Transport zone is origin and destination of transport flow. The movement of traffic from and into zone happens from geometrical zone centre. But in this model the geometrical shape of the zone were not defined, because it does not influence the model. Finally 14 transport zones were defined in the model. Transport zones were connected with transport network using special VISUM objects called connectors. Necessary to underline, that movement time on connector is set to zero. The zones and connectors are presented on Figure 6.

Figure 6. Zones and connectors

As could be seen on Figure 6, totally there are 14 zones which are externally located relatively of Latvia. These zones represent main origin and destination point of transit cargo flow. As zones are defined the origin – destination (OD) matrix could be filled. The model uses two OD matrixes: one matrix for cargo transport systems, the second one for car transport system. Both of them are estimated according information from [6]. They describe traffic average twenty-four hour's traffic movement in 2008. The developed matrix could not be treated as a real one. The estimation of matrix has been done because of lack of surveys in this area. But further, estimated matrix will be replaced with calibrated one and it could be treated as a real one.

Macroscopic models in general give aggregated output data, which are mainly presented graphically or in tables. In this research we are interested in searching a bottleneck of systems and estimating different performance characteristics like average speed across transport corridor, average movement time across transport corridor. The motioned data will be presented only for cargo traffic as it is an object of research.

To assign both cargo and car flows Equilibrium assignment algorithm is used. The result of this method is assignment of traffic flows on network. The result for cargo flow could be seen on Figure 7. This Figure demonstrates twenty-four hours intensity across all links of the model. The size of diagram defines traffic volume. Of course numerical values also could be obtained. For the moment it seems strange that traffic volume from Liepaja and Ventspils to Riga is very high.

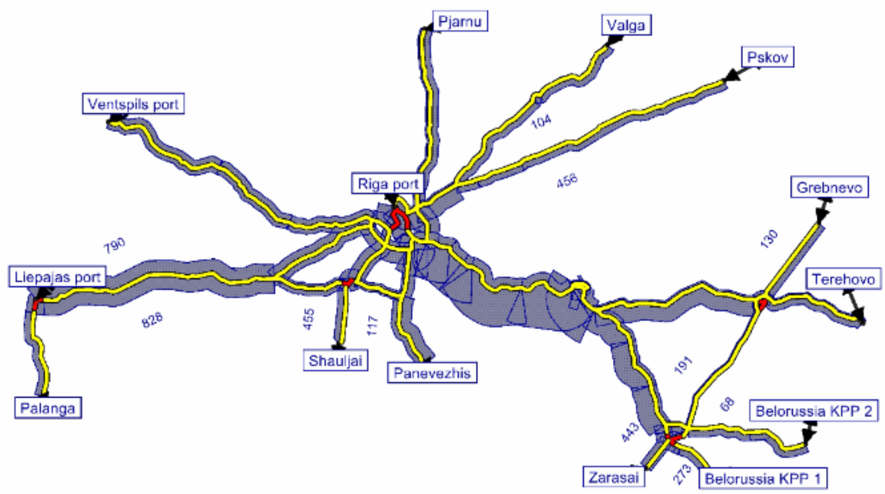

Figure 7. Cargo traffic volumes (un-calibrated matrix)

This fact assures us that estimated OD matrixes do not describe real flows from one transport zone to another. That is why the calibration of OD matrix should be used to get more realistic flow distribution. The calibration itself defines unknown or estimated parameters by comparing model output data (in our case traffic volume) with known real traffic counts in some point of transport network. These counts have been obtained by real traffic observations. Finally 20 points of counts are used to calibrate OD matrixes. TFlowFuzzy procedure has been used for calibration. The main idea of this procedure is presented on Figure 8.

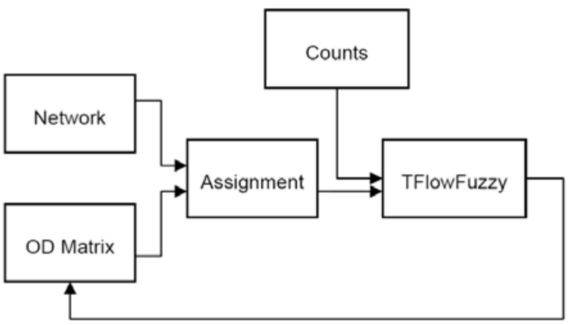

Figure 8. The main concept of TFlowFuzzy method [9]

To estimate calibration quality the R-square characteristic is used. This characteristic defines how well relationship between observed volumes and counted fit to linear relationship and to target value. The better is relationship the higher is R-square (minimum is 0 and maximum is 1)
As could be seen on Figure 9, the R-square is rather low only 0.042; after few iterations of applying TFlowFuzzy could be seen that R-square is growing and reach the level of 0.85.

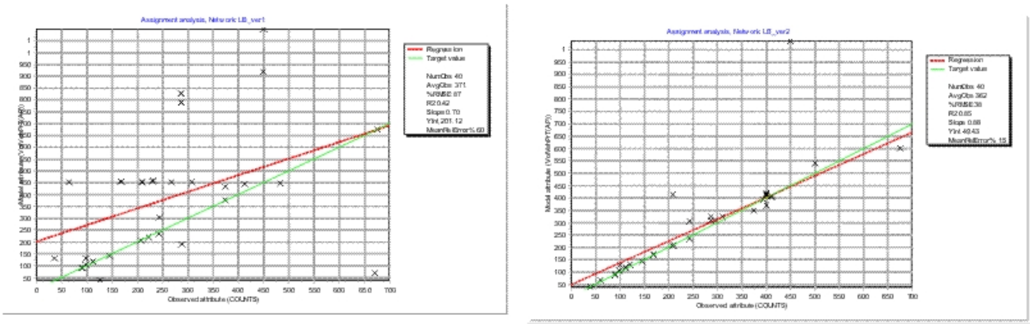

Figure 9. Dependence between simulated and real flow distribution before and after calibration

Finally after calibration procedure the flow redistribution is obtained and can be presented using Figure 10.

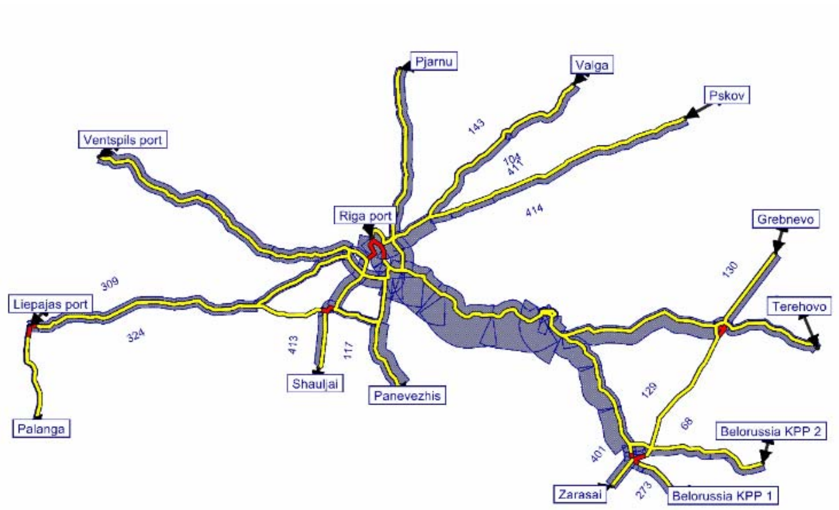

Figure 10. Cargo traffic volumes (calibrated matrix)

5. Scenario Development and Result Analysis

According to project tasks different scenarios development is considered of this corridor. In general scenarios could include the following changing factors:

- Quality of transport infrastructure – this could be simulated by increasing or decreasing capacity of some parts of transport corridors. Also new roads could be added to the model with defined options (like capacity, free flow speed and so on).
- Traffic volumes – this point is mostly oriented on changing existing origin-destination matrix.
- Quality of transport infrastructure and traffic volumes – both changes are allowed in scenarios.

We describe the scenarios, which include only changes of traffic volumes in this paper. The first scenario implies growing of traffic volumes by 50% relating to cargo OD matrix of 2008. The second scenario includes the traffic volumes by 100% relating to cargo OD matrix of 2008. But changes affect only direction to Byelorussia control check point.
To estimate the performance of transport corridor functioning the following indexes are used:

- Volume capacity ration – in general this characteristic describes the loading level of roads. This characteristic is calculated like ratio between capacity of the link and traffic volume on this link.

- Average travel speed – the average speed for transport corridor from Riga to control check point Patarnieki, measured as kilometres per hour.
- Average travel time – the journey time in minutes from Riga to border control check point Patarnieki

1st scenario **2nd scenario**

Figure 11. Loading level of different parts of transport corridor

Figure 11 demonstrates the loading level by cargo transport of transport corridor parts. The red colour presents the loading level higher than 20%, the yellow one loading level between 5% and 20% and the green colour is less than 5%. Analysing this diagram it can be concluded that the part of transport corridor from Riga to Jekabpils in direction from Riga is loaded much by cargo vehicles. The loading level of the opposite direction of this area is smaller and it seems that it does not bring any problems. The remaining part of the corridor is loaded on average or small level. Also the fact of loading level decreasing near the Daugavpils is connected with transport infrastructure two lanes per direction. The average loading level of transport corridor is approximately 13 % in both directions. It seems that there are no considerable changes in loading level of transport corridor. The high level loading of the Riga-Jekabpils part is in direction from Riga. Numerically there are some changes, which lead to average transport corridor loading level decreasing to 10%. This result confirms us that the analysed transport corridor plays a notable role in transit not only in direction from Riga to Minsk, but including another routes as well.. So it should be taken into account that the road renewal and updating is to be done according to modern conditions. Comparing such characteristics as average travel time and average speed for transport corridor across all scenarios and base model it can be concluded that there are no considerable changes in different scenarios. Average speed difference between directions is for base model 6 km\h, for first scenario 11 km/h and for the second one approximately 6 km/h. It is connected with rather small loading level of Patarnieki-Riga direction. The changes across scenarios are small and do not reach 5 km/h. The reason is a very high level of loading of transport corridor part near Riga. Average travel time can reach 5 hours to get from Riga to border control check point. In general travel time for the first scenario is the highest and gives already mentioned maximum 5 hours. In the second scenario an average travel time is decreased approximately up to 20 minutes.

The analysed model output data assure us that transit growth across Latvia will lead to increasing of loading level of transport corridor and can lead to increasing a travel time. The bottleneck of the system could be treated at the part of transport corridor from Riga to Jekabpils, also road A5, which connects left and right land near the Salaspils city. But some recommendations on roads renewal activity should be given, for instance:

- to organize additional bypass roads;
- to reconstruct existing roads to increase average travel speed;
- widening of roads to give possibility for cargo transport increase their speed.

6. Development Analysis on the Basis of Merging Macro and Micro Simulation

The results of macro-simulation presented above have aggregated characteristics and could be used only in the strategic level of decision support. To get more detailed results the use of micro-simulation - it is required. The micro-simulation could be used only for simulation some transport nodes. That is why according macroscopic simulation results two nodes have been selected for detailed analysis. The loading level of these nodes is high and could be treated as bottleneck of the systems according the macroscopic analysis. The first node – it is a border control check point and the second one is a road A5, which connects left and right land near the Salaspils city. The main idea of micro and macro simulation could be presented on the Figure 12.

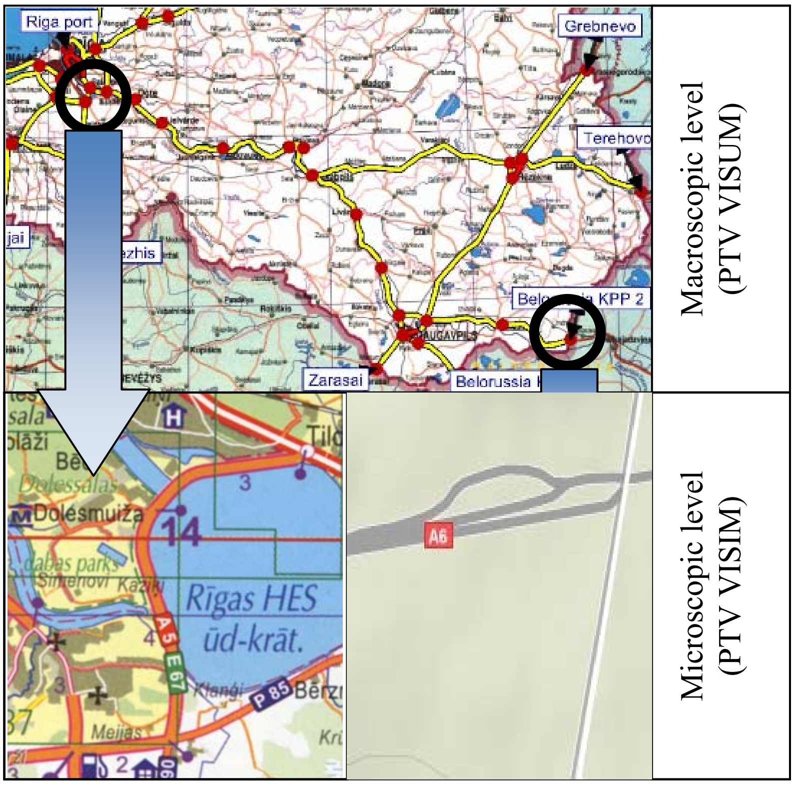

Figure 12. Relationship between macro and micro-simulation

The data required for the transport node simulation on microscopic level could be described as follows:

- 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

The macro simulation results give only flow intensity and transport flow structure. All another input data should be defined using direct observation of transport node infrastructure.

7. Conclusions

This paper demonstrates the approach of transport corridor functioning analysis using macroscopic simulation. The macroscopic model has been developed and calibrated using PTV VSION VISUM software on the basis of the TFlowFuzzy method. According project tasks two scenarios have been implemented and tested using developed simulation model. The loading level diagrams concern as that there are some bottleneck in the transport corridor Riga-Minsk. As the bottleneck of the system could be treated the part of transport corridor from Riga to Jekabpils in direction from Riga. The loading level in this area is more than 20% for cargo traffic flow. Also as the bottleneck the road A5, which connects right and left land near the Salaspils, is considerable.

The capacity border control check point requires additional detailed analysis. This analysis could be performed using microscopic simulation. The next step of this work is a development of microscopic models of transport corridor parts and the border control check point to get more exact results. These models will allow estimating its capacity and will help to define different characteristics like passing time, average queue length, maximal queue length and so on. The microscopic models will be implemented using PTV VISION VISSIM software and as the input data will use output data from developed macroscopic model.

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