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THE APPLICATION OF COMPUTER SIMULATION IN SOLVING TRAFFIC PROBLEMS IN THE URBAN TRAFFIC MANAGEMENT IN SLOVAKIA

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Abstract
This paper deals with the description of the simulation transport hub model in the urban concentration of Vranov nad Topľou, Slovak Republic. The simulation model was developed to analyze the transport hub of Heroes of Dukla (Duklianskych hrdinov) in the City of Vranov nad Topľou. The issue of this transport hub is quite a hot topic in the City. The main problems involve long-time queues of vehicles formed in the peak hours and a continual distortion of the carriageway of the intersection. The simulation model will be used to verify the individual variants.
Keywords: Transport problem, simulation, traffic flow intensity

1. INTRODUCTION

The realization of innovative transport services, requires increasingly greater flexibility and inexpensiveness of the service (Carotenuto, Monacelli, Raponi, & Turco, 2012). Because of that reason mentioned issues about public transportation are subject of research for more than only one author. Review of city logistics modeling efforts is reported in the literature for urban freight analysis (Anand, Quak, van Duin, & Tavasszy, 2012). Novel approach is presented to examining the transportation/land use relationship from a logistics land use perspective (Woudsma, Jensen, Kanaroglou, & Maoh, 2008). Framework for city logistics is proposed for planning (Kuse, Endo, & Iwao, 2010). Firstly, article describes the relationship between logistics and city formation through a historical review. Secondly we can mention discussion focused on logistic concepts that clarifies the role of logistics infrastructure planning. Thirdly, three stages of logistics are described considering the balanced role of the public and private sectors.

One of the effective tools that is suitable for city logistics problem solving is computer simulation. The simulation is able to point out the relations existing among city logistics measures, decision-maker choice dimensions by using a multi-stage demand model and a discrete choice approach for each decision level (Comi & Rosati, 2013). Monte Carlo Simulation of Ultrafast Carrier Transport is discussed by more authors (Karaivanova, Atanassov, & Gurov, 2013). Discrete simulation analysis of a logistics supply system is analysed in details by authors (Iannoni & Morabito, 2006). Modeling approach for locating logistics platforms for fast parcels delivery in urban areas (Guyon, Absi, Feillet, & Garaix, 2012). Integration of logistic regression, Markov chain and cellular automata models is used to simulate urban expansion (Jokar Arsanjani, Helbich, Kainz, & Darvishi Boloorani, 2013).

Multi-agent freight transport model presents logistics decisions and can be separated into two different roles: Transport service providers, which create transport chains, and carriers, which plan tours and schedule vehicles (Schroeder, Zilske, Liedtke, & Nagel, 2012).

Slovakia is a landlocked country, situated almost in the heart of Europe. Slovakia had been passed for long by important transportation and trade routes between the Baltic and the Adriatic Seas and between the Black and the North Seas. Slovakia borders the Czech Republic, Poland, Ukraine, Hungary and Austria.

2. CHARACTERISTICS OF SETTLEMENTS IN SLOVAKIA

The development of most cities in Slovakia is more or less similar. The basic concept of the structure of cities is given by a long-term development respecting the following:

- The historical center is located near the river or ridge;
- Offices and self-governing departments are located in the city centers;
- Settlements are located on the outskirts of cities;
- Production facilities built in the last 50 years are located outward from the city centers;
- New production enterprises are outside the built-up areas of the cities;
- New technological zones are located on the outskirts of cities near the major transport routes.

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Transport, including also the roads and streets, linked to the original main roads that, after some time, became insufficient in terms of their capacities and had to expand. Noise and exhalation of air emissions were becoming intolerable and burdened the surroundings. It was necessary to gradually reorganize routing of traffic across the built-up areas and move beyond the most densely built-up areas (Vozenilek & Strakos, 2009), (Danek, 2006).

3. SELECTION OF A TYPICAL CITY WITH TRAFFIC PROBLEMS

The City of Vranov nad Topľou (Fig. 1) is located in the Eastern Slovakia. The closest district towns that surround it are Prešov, Trebišov, Michalovce, Strážske, Humenné, Stropkov. The county seat is Prešov. Košice, as the second metropolis of Slovakia, is almost 70 km far from Vranov nad Topľou. Neighboring countries, such as Poland, Hungary and Ukraine, are about equally far, up to 80 km.

FIGURE 1 - LOCATION OF THE CITY OF VRANOV NAD TOPĽOU, SLOVAKIA
(“http://www.eplato.eu/sk/infocenter/0002/0002/,” n.d.)

By its location, Vranov nad Topľou is an easily accessible place for the surrounding district towns.

Transportation is provided by the following roads:

- Vranov nad Topľou – Prešov, Michalovce: the I/18 First Class road;
- Vranov nad Topľou – Trebišov, Sečovce: the I/79 First Class road;
- Vranov nad Topľou – Humenné: the II/558 Second Class road;
- Vranov nad Topľou – Stropkov, Svidník: the I/15 First Class road;

The City is directly connected in the direction of Prešov - Vranov - Humenné and backwards by railway. In the past, there was also a railway line to Trebišov in operation; it is currently not in use due to economic reasons.

The transport network of the district of Vranov nad Topľou consists of the road and rail transports. Major traffic arteries passing the district are the state I/18 and I/79 First Class roads. The state I/18 road is a vital link with the west-southeast transport artery of the Prešov – Vranov n/T – Michalovce line and the I/79 road forms an important north-southern axis of the Vranov n/T – Trebišov line.

Administration and maintenance of the road network is provided by the Road Administration and Maintenance of the Prešov Region, the territory of Vranov nad Topľou. The state roads at the district territory contain 129 bridges, 3 rail crossings, and 9 underpasses. There are no highways and international routes passing through the territory of the district.

The rail network of the district consists of the railway line No. 193 in the direction of Prešov – Vranov n/T – Humenné and the railway line No. 192 in the direction of Vranov n/T – Trebišov (with the operation canceled).

The biggest transport problem in the City of Vranov nad Topl'ou is associated with the intersection of Heroes of Dukla. The issue of this transport hub is quite a hot topic in the city; the main problems are in long queues of vehicles formed in the peak hours and in the continual distortion of the carriageway at the intersection.

4. TRANSPORT PROBLEMS OF THE CITY

A recurring problem of the City, which has been going on from the past, is the high volume of traffic in the City Center that currently undergoes a large-scale reconstruction of buildings and traffic infrastructures. The City initiated the creation of a pedestrian zone in the City but, in light of the potential for the transport network in the City Center, it is a matter far into the future. The traffic in the City Center was significantly eased by a construction of a sally road in 1986. Until 1986, the traffic in the direction of Košice, Prešov - Michalovce, Stropkov, Humenné and backwards was directly passing the City Center. Today, this traffic flow is redirected to theI/18 First Class road beyond the city borders. Another factor increasing the intensity of traffic in the City includes the vehicles of civilians who commute to the City. Only few of these people are using public transport services. There is a lack of Park&Ride facilities linked by public transport. It is also caused by a poor awareness of the public regarding the public transport, whereby the capacity of this kind of transport is not used in full, making the bus lines very precious there. The citizens of the City would like to see the cycling routes here, which are currently being under construction.

Another problem is parking spaces. A paid parking service was initiated in 2011, but only with small, insignificant increase in parking spaces (it was more about charging the free parking spaces), which

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ultimately forced the drivers of vehicles, for whom the price is too high, to park among apartment buildings of housing developments. Again, there is a lack of parking garages and their connection to the public transport.

The transport problem has its Achilles tendon in the transport hub of Heroes of Dukla, which is located on the outskirts of the City, on the I/18 First Class road, in the direction from Košice and Prešov to Michalove, Humenné and Stropkov.

FIGURE 2 - SATELLITE VIEW OF THE TRANSPORT HUB OF HEROES OF DUKLA
(“http://maps.google.sk/maps/ms?ie=UTF8&t=h&source=embed&oe=UTF8&msa=0&msid=215283659815693859137.0004a956842c7e1fee87e,” n.d.)

The traffic course on this transport hub was satisfactory until the moment when the Tesco Store and other stores were later constructed nearby. Dense queues of vehicles formed every day are increasing every year.

In times of high intensity of vehicles in the City, the transport hub is insufficient to lead vehicles out of the City; therefore, some kilometer-long queues of vehicles are formed there. This situation is also supported by a railway crossing, which, when closed, blocks vehicles coming out of the City. The accumulation of these vehicles then hangs near the roundabout and blocks also other sections of the road. When the railway crossing opens, the mass of vehicles moves towards the transport hub, which is not capable, in terms of time, of releasing them due to the main traffic flow on the No. 18 First Class road and on other lanes of the intersection; vehicles gather in queues and impatient drivers enter the railway crossing without being sure that they pass it safely, until it closes again due to an approaching train on the track. This queue of vehicles also prevents the passage of the preferred vehicles, e.g. the emergency medical vehicles, vehicles of fire brigade, police and the like. Several solutions have been proposed to solve this problem; a selection of an optimal solution has been designed using a computer simulation model.

5. CREATING A SIMULATION MODEL

There are dozens of simulation models currently used to simulate the transport processes. In this case, the EXTEND simulation program was used, which simulates a number of processes and contains dozens of blocks to perform the simulation process.

The task of the model is to simulate the operation of the intersection from 07:00 a.m. to 08:00 p.m. during the day. This model is based on the traffic data survey, which was conducted on September 17, 2011. This traffic survey included data on the number of vehicles, namely freight vehicles, cars and motorcycles, and the way they pass the intersection lanes from 07:00 a.m. to 08:00 p.m. Freight vehicles were considered lorries of the groups of over 3.5 tons. Freight vehicles below 3.5 tons and passenger vehicles were classified as passenger cars; the last category was formed by motorcycles of all kinds, i.e. mopeds, racing motorcycles and the like. Data on the number of vehicles in the simulation model was recorded per each traffic direction, namely in the Program simulation block, which simulates the way vehicles approach the intersection in various hours, with their numbers per hour, while the vehicles in the traffic flow were not distinguished as the trucks, passenger and motorcycles.

Vehicles standing in front of the railway crossing or a signaling device of the intersection were simulated by the Queue and FIFO blocks; these blocks record a number of stationary vehicles and their subsequent departure. Simulation of the railway crossing is quite complicated. We know that the railway crossing is closed at the time of passing trains. The time of the arrival of the train also depends on the traffic conditions on the track. The model is based on the given constant times in view of the timetable of the railway station in Vranov nad Topľou.

Simulation of the intelligent signaling device at the intersection (traffic lights) is not any easier (Surovec, 1998). This signaling device is controlled intelligently by video processors. The model works with the fixed times for each signaling device of the intersection. It does not consider data from the video processors. Simulation of the light signaling device is performed by the Activity Service block in cooperation with the Program, Queue, FIFO, Activity, Delay and Exit blocks. When crossing the intersection, vehicles are heading to the Exit block, which simulates the travel direction of the vehicle

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after crossing the intersection. A simple presentation of the simulation model created in the Extend program blocks is shown on the Fig. 3.

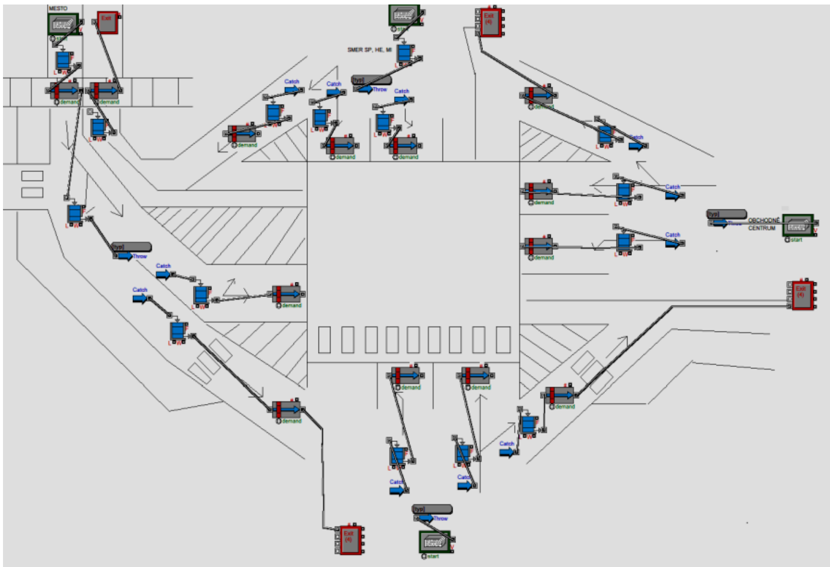

FIGURE 3 - STRUCTURE OF THE SIMULATION MODEL

Simulation of the arrival of vehicles consists of the Program, Queue, FIFO, Activity, Multiple and Input Random Number blocks (Fig. 4).

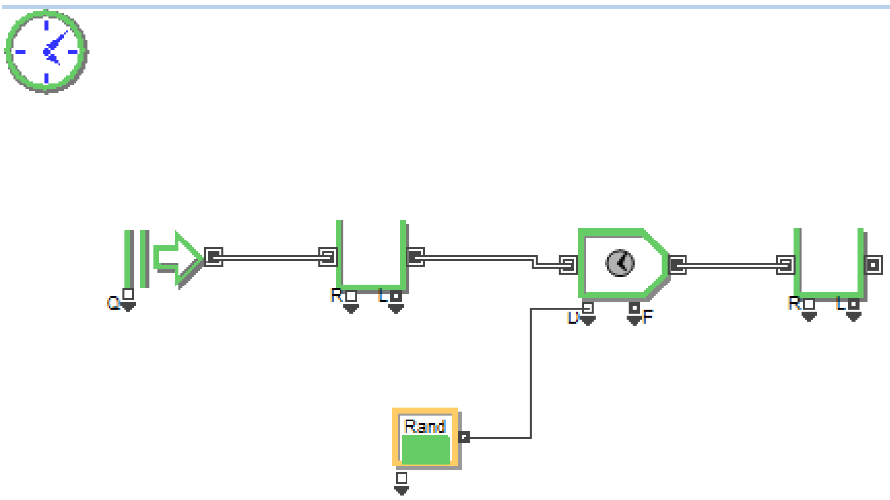

FIGURE 4 - SIMULATION OF THE ARRIVAL OF VEHICLES

The Program simulation block presents a most important task; it contains a specific number of vehicles per hour; then, it generates them in the simulation model according to the current simulation time. View of the settings of the Program block is shown on the Fig. 5.

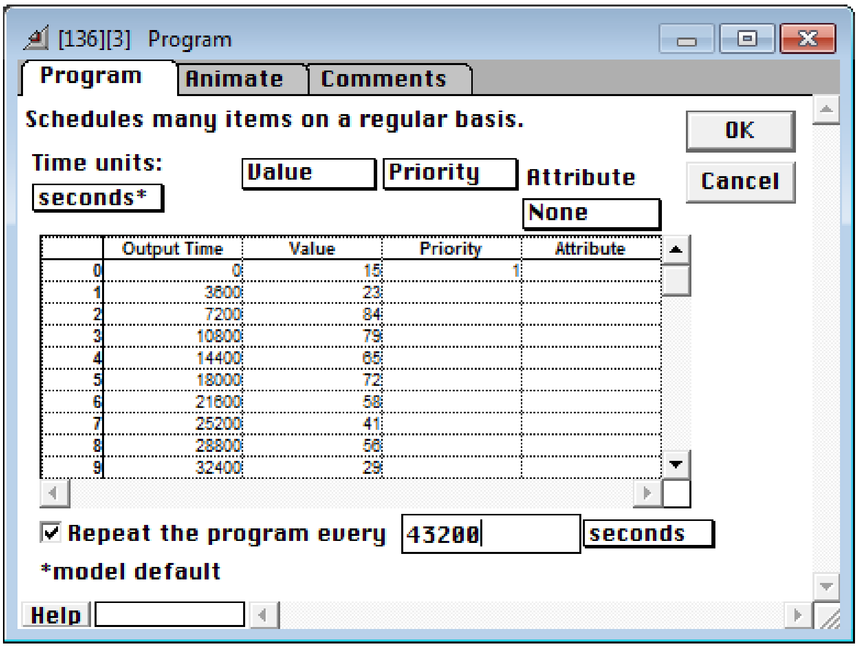

FIGURE 5 - SETTINGS OF THE PROGRAM SIMULATION BLOCK

The Queue, FIFO, Activity, Multiple and Input Random Number simulation blocks represent a line of vehicles standing in front of the signaling device (Weiszer, 2011). The Figure shows a connection of the Input Random Number simulation block with the Activity and Multiple blocks. This is a simulated reallocation of the drives of vehicles within an hour, which is set in the Input Random Number block.

Simulation of the traffic lights at the intersection in the simulation model consists of the Program, Queue, FIFO, Activity Delay, and Activity Service simulation blocks and the Exit simulation block. Subsequent involvement of blocks is given on the Fig. 6.

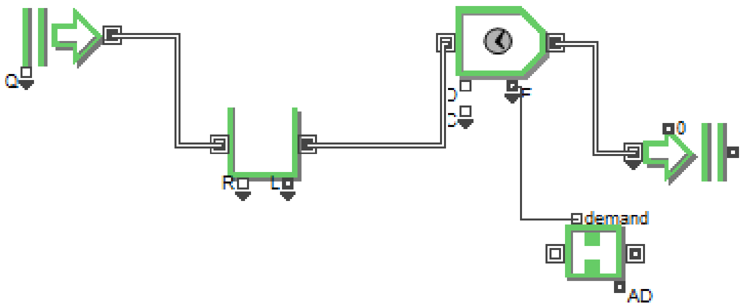

FIGURE 6 - SIMULATION OF A LIGHT SIGNALING DEVICE

The Program simulation block generates the time, in which the signaling device is green, thus facilitating the movement and passing of vehicles in a given direction (Weiszer & Simsaj, 2011). The actual duration of the green light is simulated by the Activity Delay block and the light signaling device alone is represented by the Activity Service block, where the traffic flow of vehicles is heading to. The Queue and FIFO blocks represent in this case the range of information waiting to be processed, which is then processed in the Exit block. The railway crossing is simulated upon the same principle.

The Data Send, Count Items and Plotter and Discrete Event simulation blocks are used to process the data, specifically the data of passage of vehicles and loading of individual traffic directions by the number of vehicles per hour throughout the day.

The Data Send block sends the processed data, in this example to Microsoft Excel.

The Count block works as a counter; it handles the number of vehicles that pass this block and then sends the information to the Discrete Event block, where it is processed to a chart. Individual blocks are shown on the Fig. 7.

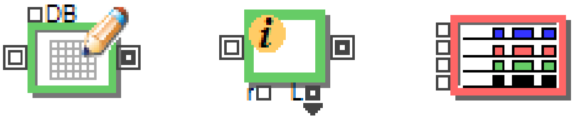

FIGURE 7 - SIMULATION BLOCKS FOR DATA PROCESSING.

After vehicles passed the intersection, they continue in individual traffic directions. The model processes such vehicles in the Exit block.

The Fig. 8 shows the complete set of simulation blocks that simulate the movement of vehicles throughout the day, from 7:00 a.m. to 08:00 p.m. in all traffic directions.

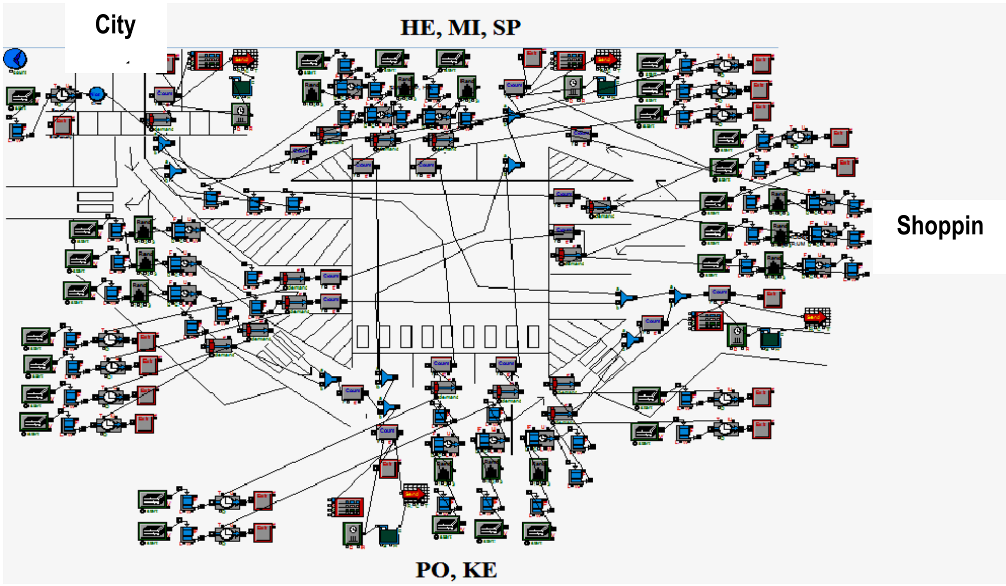

FIGURE 8 - VIEW OF THE SIMULATION MODEL

The Figure shows that the model is complex and less transparent. Because of this, individual model blocks were grouped into different hierarchies and, to achieve a perfect transparency, single connections of connectors of individual blocks were covered. A view of the simplified simulation model is given on the Fig. 9.

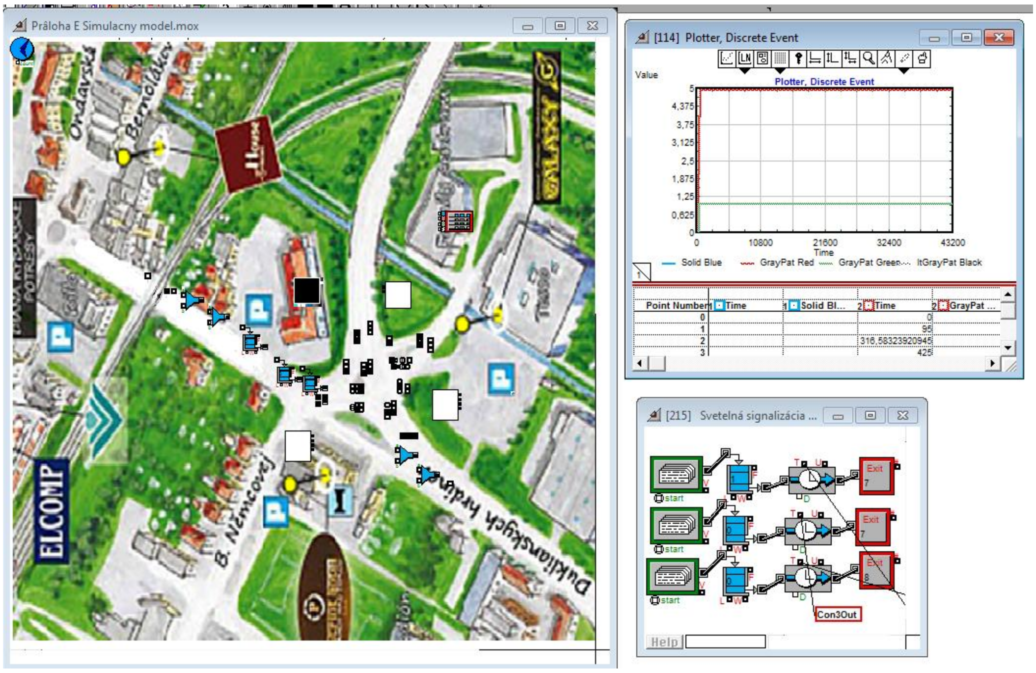

FIGURE 9 - VIEW OF THE SIMPLIFIED SIMULATION MODEL

6. CONCLUSIONS

The simulation model operates with four main traffic flows of vehicles entering the intersection, while each traffic flow divides then to the three traffic directions. Traffic flow division options are as follows:

	City
HE, MI, SP:	Prešov, Košice
	Shopping Center
	Humenné, Michalovce, Stropkov
City:	Shopping Center
	Prešov, Košice
	Humenné, Michalovce, Stropkov

Shopping Center:	City
	Prešov, Košice
	City
PO, KE:	Humenné, Michalovce, Stropkov
	Shopping Center

After passing the intersection, vehicles coming from different directions re-join a single traffic flow to continue in the traffic direction as they have chosen when passing the intersection. Vehicles may proceed in the direction of:

- To the city (city center);
- To Humenné, Michalovce, Stropkov;
- To the Shopping Center;
- To Prešov, Košice

The simulation model monitors this movement of vehicles, which results in a chart of load intensity (congestion) of individual traffic directions in the transport hub. The load intensities of traffic directions in the transport hub are presented in the chart of the simulation model (Fig. 10), which shows the different traffic directions and their intensities in terms of the number of vehicles per an hour.

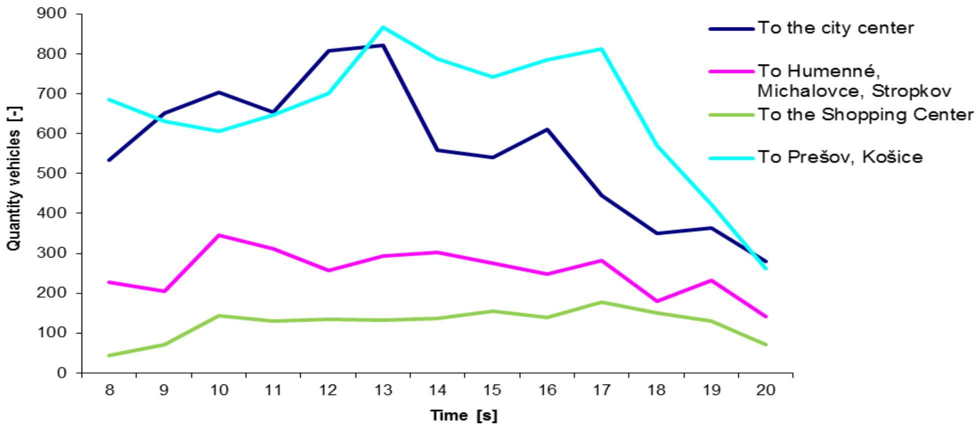

FIGURE 2 - LOADING OF TRAFFIC FLOWS

The simulation model chart indicates the ranking of load intensities per traffic direction. The simulation model also provides another important piece of information, i.e. the data on the formation of queues of motor vehicles on the most busy traffic directions. The results obtained indicate the places, where the queues of vehicles are formed (Fig. 11).

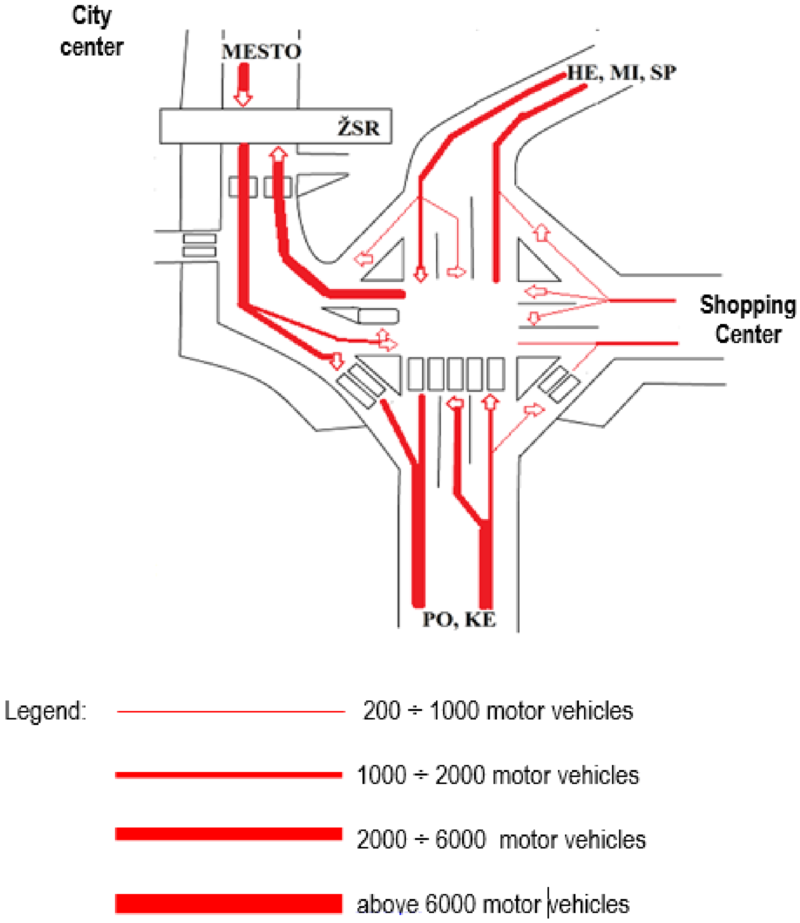

FIGURE 3 - QUEUES OF MOTOR VEHICLES

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