

# COMPUTER SIMULATION AS MEANS OF URBAN TRAFFIC ELEMENTS DESIGN

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## Abstract

This article is devoting to using of computer simulation for needs of solution and designing of urban elements of traffic. Road, crossroad, tram, rail and trolley road but also metro and different kinds of underground and overground roads belong to basic elements of traffic in urban nodes and for every this elements their common element - stop. Within the article we will closely devote to the road and different kinds of roads (tram, trail and trolley road and road of city) as servicing equipment. Usage of the simulation will be closely shown on concrete example from experience.

**Keywords:** Simulation, Urban traffic, Elements, Design, Projection.

## 1. INTRODUCTION

Actual high intensity of the traffic in the cities requires detailed analysis of issues and utilization of simulation systems for their complex solution. Advantage of utilization of simulation systems for needs of streamlining of traffic flows within the cities are the high-precision, large-scale, real-time interaction (Zheng, Zhang & Chen 2014), opportunities of observation of huge amount of variants, research and design of solution without intervention into the real system, minimization of risks caused by improper process, observation of variants which aren't built in reality yet. From the point of complex solution of

urban intensity of traffic is necessary to take into account also the methods and principles of logistics and traffic (Comi & Rosati 2013), which are accurately used and incorporated in simulation models therethrough effectivity of achieved solutions for concrete environment and practise is increasing. Among criteria ,which clearly impact fluency and intensity of traffic, is possible to class amount of vehicles in time on the same road, resp. within the certain localization, current speed of vehicles (Huang et al. 2013), current state of restrictions and unforeseeable events, which may occur in time and given localization. Defined parameters influence not only freight transport but also passenger transport, whereby the individual streams amalgamate with each other, supplement each other, divide and combine independently on each other (Bohari, Bachok & Osman 2014).

Many of urban transport systems are dependent on road infrastructure in towns and traffic nodes, whereby historically are not designed and laid out for the current load and traffic intensity. In the past it was typical to design crossroads which allow vehicles to go in any direction, which in a large extent causes cruising, braking and slowing of traffic flows sites (Van den Berg et al. 2003). Simulation systems allow to test and verify options (Kliment & Trebuňa 2014), which do not allow traffic to turn in any direction but allow to manage traffic flows through the flow direction, thus the entire transport operation within the cities is streamlined (Pepucha et al. 2014). This is related to the acceptance of basic and necessary restrictions and limitations during the designing of urban transport systems.

For the needs of simulation can be used a significant amount of simulation systems (witness, extendsim, gpss, simul 8, tecnomatix, ...), For the needs simulation is possible to use a significant amount of simulation systems (witness extends, GPSS, simul 8, Tecnomatix, ...) which allow any arbitrary and universal creation of simulation models, resp. which are specialized for a particular type of simulation of areas ,that they have to solve and at which they are more closely programmed just like Simulation of Urban Mobility - SUMO (Behrisch et al. 2011), resp. VISSIM (Lin, Yang & Gao 2013). If the models are well prepared, the differences in the results should be minimal. The main difference is in conformity, flexibility, creation and processing of generated simulation models. In many cases, resp. for specific situations of solved problems is necessary and appropriate to create a custom programming means, which is solving defined parameters much faster than universal software systems and equipment (Štangová 2014).

## 2. TRANSACTIONS, REQUIREMENTS – BASIC DYNAMIC ITEMS OF SIMULATION

The advantage of simulation before experimentation with real system is mainly that is much cheaper, more flexible, safety, does not affect the on-going production, traffic, economical and other processes (Pekarčíková, Trebuňa & Markovič 2015). For solve of urban traffic problems is simulation main topic

branch. Life of cities is dependent on distribution of good. Different types of goods are distributed or collected daily on the main streets of the urban centres (Oliveira, Oliveira & Assis Correia 2014). This activity which keeps life of cities very comfortable and practice is one of main factor of urban traffic high intensity. Simulation model in generally is able to satisfactorily simulate the real time traffic conditions. Detailed analyse of urban traffic is depended on roadway traffic characteristics, distribution of vehicles along roadway width and speed distribution of vehicles (Metkari, Budhkar & Maurya 2013).

In terms of the simulation model it is important to define the unit(s), the basic dynamic item, which can be a piece of some goods, a box, a pallet, a truck (all goods transported), m<sup>3</sup>, kg, tons, etc., it is generally referred to as transactions, respectively requirements for solution of item dimensioning of distribution systems. If transactions within the distribution system represent only one type of goods (one type of transaction) there are sufficient input parameters to a node and output parameters from a node or processing parameters (time of storage) of transactions in a node for design of a distribution system nodes.

If nodes represent warehouses, distribution centres involving processing a large amounts of different types of goods, in this case each type of goods represent a separate transaction with its parameters about the input, output and processing times. In terms of simulation it is possible to continue with the generalization of the system parameters and to modify requirements to transactions performance in a way to work with their averages during a certain time, which facilitating the creation of simulation models.

### 3. CHARACTERISTICS OF URBAN TRAFFIC ELEMENTS

In terms of distribution of products and the creation of simulation models it is important repetition of road, railway track, tramway track or trolley-bus track to obtain the information necessary for improving quality and effectiveness of activities of the distribution system. It is possible to consider a road, railway or tramway track as a queuing theory system. A car, which overcomes certain distance, is moved along this path a certain time, i.e. it is delayed for a certain time that is required to provide, i.e. to overcome the distance. It means that it is possible to model the road (railway track, tramway track, trolley-bus track) by two ways:

- road as a simple service equipment,
- road as multichannel service equipment.

Road as simple service equipment is possible to imagine as a tunnel at which end it is recorded outbound cars (trucks) and their interval leaving of the tunnel, i.e. the cadence of cars exiting the tunnel with its dispersion, which represents the delay in a simple servicing equipment (Figure 1).

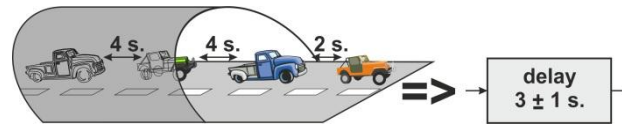


FIGURE 1 – ROAD AS SIMPLE SERVICE EQUIPMENT

Road as a multichannel service equipment is possible to imagine as many lane road along which in the same direction, at the same time there are a large number of cars, but in each lane can be only one car at the same time, i.e. delay in a multichannel service equipment is the time required to overcome the entire length of road with a proper dispersion of delay. The capacity of multichannel equipment is determined by the number of service equipment, which it consists of. That is why, the road as multichannel service equipment is necessary to be defined with a sufficiently large capacity by (Figure 2):

- a sufficiently large number, where it is not forming a queue of un-serviced transactions, cars in front of a multichannel equipment,
- or a distance of a road, the average speed of a car and under the rule 2 s of space between two cars to calculate the number of cars, i.e. the capacity of multichannel equipment, which at the same time can be on a road.

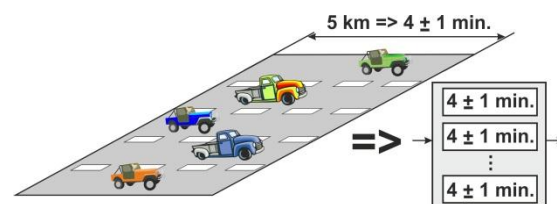


FIGURE 2 – ROAD AS MULTICHANNEL SERVICE EQUIPMENT

Similarly, it is possible to model the rail, respectively tramways, cross-road, subway and other parts of the transport system.

#### 4. DESIGN OF CONCRETE URBAN TRAFFIC IN COMPUTER SIMULATION ENVIRONMENT

Transport company, which carries traffic especially by pick-up type cars, received a contract to transport food from the nearby train station (food is in wagons) to the warehouse, which serves as a reserve supply of food for the population in a given district. The company has the task within one shift to transport as many boxes as possible. Into one pick-up fits exactly 50 pieces of boxes. Since the

company also has other contracts which are bound by agreements and realisation deadlines at the same time it is necessary to find out how many cars is needed to transport the greatest number of boxes within one working shift of 8 hours. Other parameters of the system and the activity of transport can be defined as follows:

- cars will start at 7:00 am from the parking lot at the company premises with time interval from 6 to 10 seconds,
- railway station is located 5 km from the parking lot of the company, cars need 4-5 minutes to overcome the distance,
- space for unloading the wagon and loading into cars, at the railway station, is limited and there is possible to load only one car at the moment, loading of one car lasts 4-6 minutes,
- cars with laden goods are directed into the warehouse, which is 20 km form railway station, cars need for overcoming the distance from 15 to 23 minutes,
- unloading of one car in the warehouse lasts from 8 to 10 minutes,
- in the warehouse is possible to unload up to 3 cars at the moment,
- unloaded cars are returning for loading back to railway station.

Using computer simulation is necessary to find out how many cars are needed for effective activity of the system, resp. to set the traffic system so that:

1. loading in the railway station would by stepless and without downtime,
2. unloading in the warehouse would by stepless and without downtime.

Whereas it was described that the road is also the operating device, that regarding the transaction, i.e. vehicle, goods, resp. driver makes the delay, it is possible to modify the analysed system, transformed into the formalized scheme (Figure 3), into the form, from which is possible to create functional simulation model.

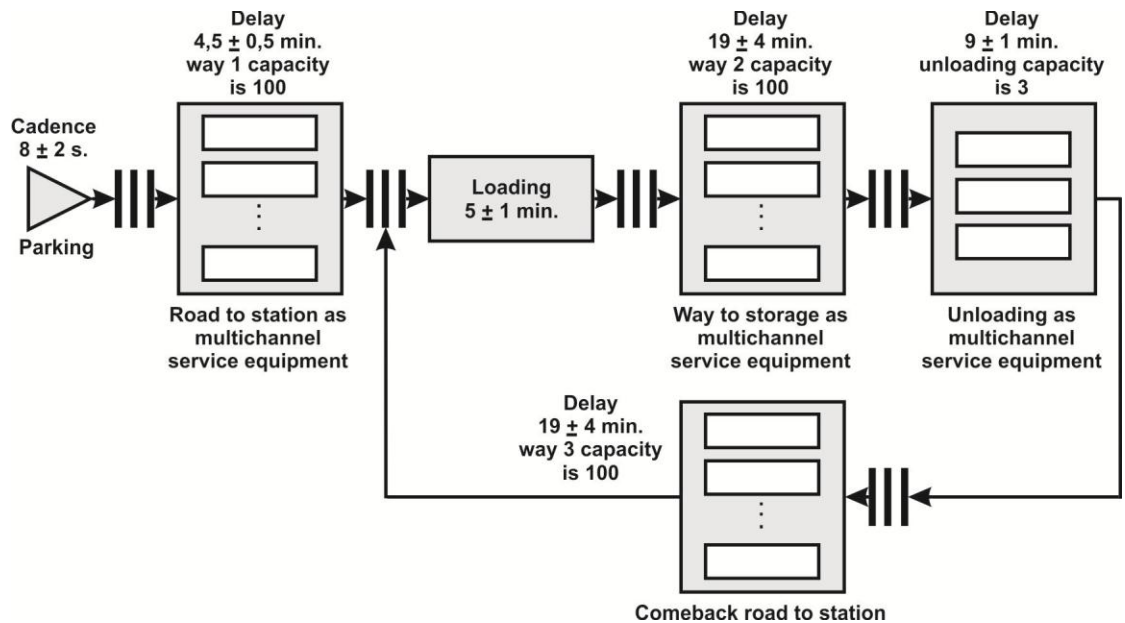


FIGURE 3 – FORMALIZED SCHEME OF THE ANALYSED DISTRIBUTION SYSTEM

The next step is “to format” the formalized scheme into the model of concrete simulation system. From the point of creation of the simulation model and task solution will be used simulation system EXTENDSIM (ver. 8) from American company Imagine That. Simulation system EXTENDSIM allows to realize discrete and continuous simulation, to create 2D and 3D animations of created models. EXTENDSIM belongs to object simulation systems, simulation model created in the simulation system EXTENDSIM consists of several blocks conjoined into the sequence according to logical sequence captured by formalized scheme of the system. Dynamic element in the created model is the requirement, which, in this case, represents vehicle, which realize the good’s transport.

Before the run of simulation and creating of model to modelling desktop it is necessary to adjust the length of time period of the simulation i.e. simulation time. Time parameters in the system EXTENDSIM are defined via main menu, it is necessary to start Simulation setup in the tub RUN. According to Setup tub it is necessary to define basic time unit, in this case minutes, and to define start „START“ and end „END“ of the simulation.

Since the distribution will run eight hours, one shift, after conversion to the minutes, makes 480 minutes. The start of the simulation will be in time zero 0 minutes and the end of the simulation will be in time 480 minutes in single simulation cycle (Figure 4).

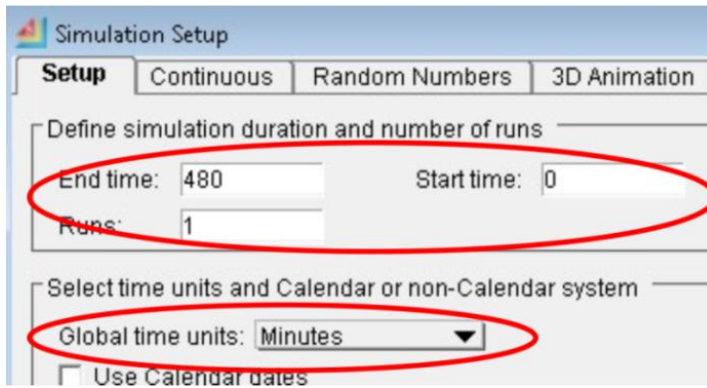


FIGURE 4 – SETTING OF THE LENGTH OF THE SIMULATION AND BASIC TIME UNIT OF THE SYSTEM

After setting of time and period follow the creation of the single model (Figure 5), which represents traffic of goods between the railway station and the warehouse within the city district.

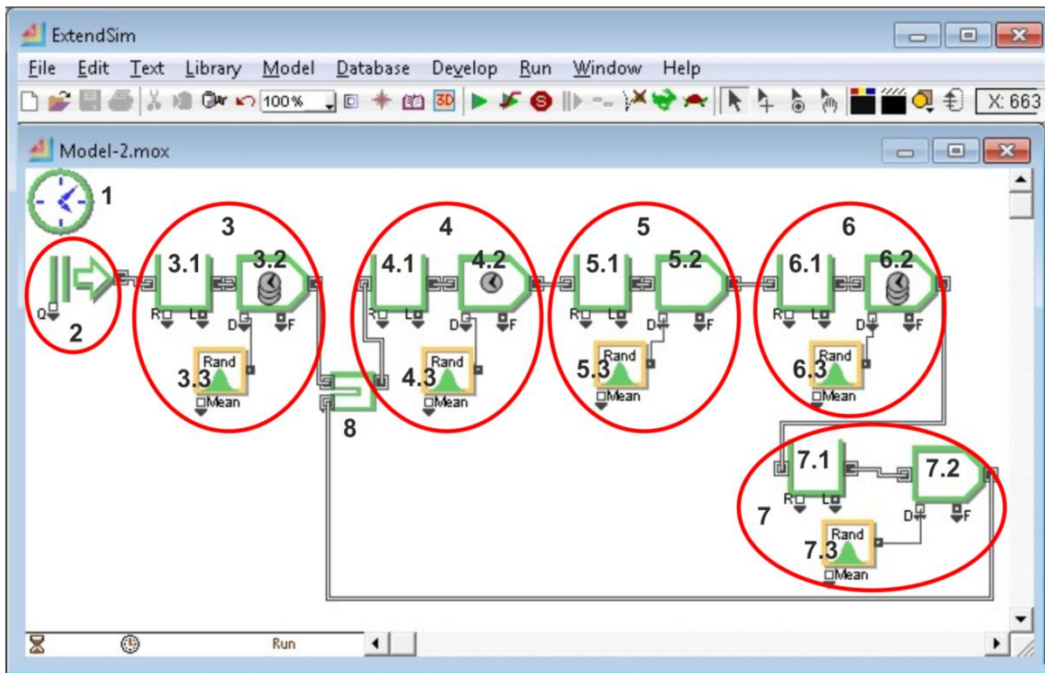


FIGURE 5 – SIMULATION MODEL OF THE EXAMINED TRANSPORT SYSTEM

On the modelling desktop of the simulation system there are stored blocks, which represent single parts of the system:

1. block EXECUTIVE, which represents measurement instrument of the time of the simulation and its control, in this case, it measures 8 hours, one shift,
2. block CREATE, which represents parking lot, from which cars will be entering the system with interval  $8 \pm 2$  seconds and realize the distribution of the goods,

3. group of blocks, which represent road to the railway station, we understand road as the multi-channel service equipment (Figure 6) before which line of the not served cars may occurs (block 3.1 QUEUE), which are leaving the line and which are entering the road as the multi-channel service equipment (block 3.2 ACTIVITY, with capacity 100) on which they have to stay certain time  $4,5 \pm 0,5$  minutes (block 3.3 RANDOM NUMBER), block 3.3, from defined interval, for each car it generates its concrete delay,

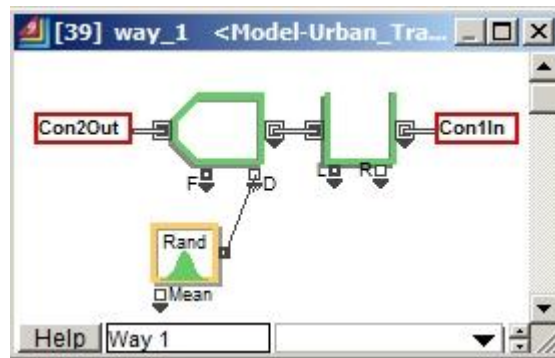


FIGURE 6 – SIMULATION OF THE ROAD AS MULTICHANNEL SERVICE EQUIPMENT

4. group of blocks, which represents loading boxes into the car on the railway station, this activity is understood as the simple service equipment (Figure 7), from which the line of waiting cars may occurs (block 4.1 QUEUE), which are leaving the line and going for the loading into the simple service equipment (block 4.2 ACTIVITY, with capacity 1), in which they have to stay for certain time  $5 \pm 1$  minutes, which is needed for loading of the car (block 4.3 RANDOM NUMBER), block 4.3, from the defined interval, for every car it generates its concrete delay,

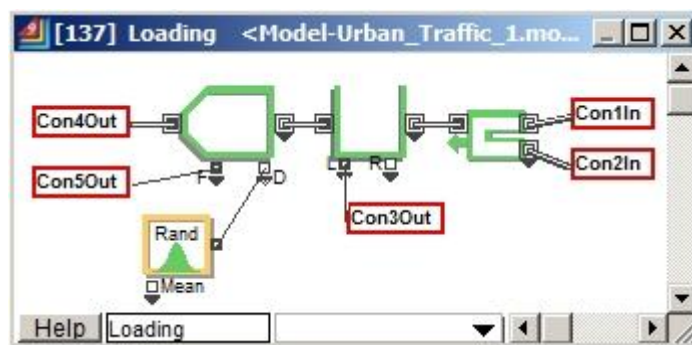


FIGURE 7 – SIMULATION OF CAR LOADING AS SIMPLE SERVICE EQUIPMENT

5. group of blocks, which represents road to the warehouse, we understood the road as multi-channel service equipment, from which the line of the not serviced cars may occurs (block 5.1 QUEUE), which are leaving the line and which are entering the road as the multi-channel service equipment (block 5.2 ACTIVITY, with capacity 100) on which they have to stay certain



time  $19 \pm 4$  minutes (block 5.3 RANDOM NUMBER), block 5.3, from defined interval, for every car it generates its concrete delay,

6. group of blocks, which represents unloading boxes from the cars into the warehouse, this activity is understood as multi-channel equipment (Figure 8), from which the line of waiting cars may occurs (block 6.1 QUEUE), which are leaving the line and going to the unloading as multi-channel service equipment (block 6.2 ACTIVITY, with capacity 3), in which they have to stay for certain time  $9 \pm 1$  minutes, which is necessary to unload the car (block 6.3 RANDOM NUMBER), block 6.3, from defined interval, for every car it generates its concrete delay,

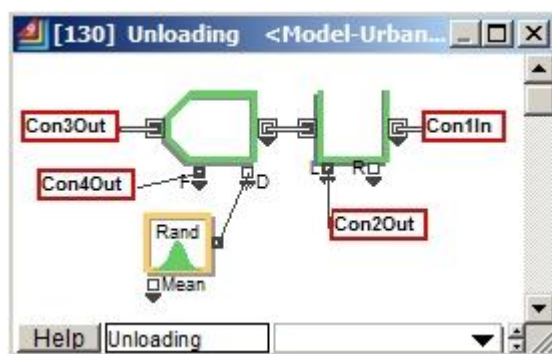


FIGURE 8 – SIMULATION OF CAR UNLOADING AS MULTICHANNEL SERVICE EQUIPMENT

7. group of blocks, which represents road back to railway station, we understood the road as the multi-channel service equipment, from which the line of not served cars may occurs (block 7.1 QUEUE), which are leaving the line and entering the road as the multi-channel service equipment (block 7.2 ACTIVITY, with capacity 100on which they have to stay certain time  $19 \pm 4$  minutes (block 7.3 RANDOM NUMBER), block 7.3, from defined interval, for every car it generates its concrete delay,
8. block SELECT ITEM IN, makes the connection of the flow of the cars leaving the parking lot with the possible flow of cars returning from the warehouse.

Before the single simulation it is necessary to adjust parameters of entry requirements in the individual blocks, i.e. cars entering the system and their delay in the individual parts of the traffic system (Figure 9), just like they result from analysis of transportation activity captured by formalized scheme.

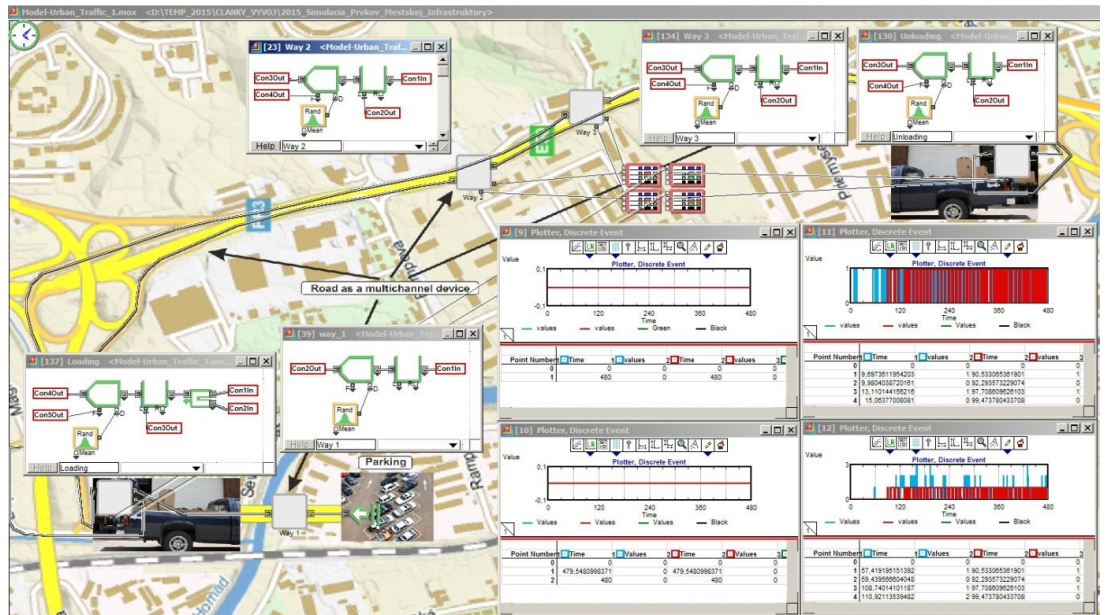


FIGURE 9 – COMPLEX SIMULATION MODEL FOR SOLUTION OF THE TRANSPORT SYSTEM

From the simulation results for three cars, which carry out transport of goods between the railway station and warehouse, it can be stated, that the usage, loading utilization at the railway station is at 29.4%, whereby the number of loaded cars was 29 and the loading utilization in the warehouse is 16,8 %, whereby the number of unloaded cars was 27 (Figure 10). During the 8 hours of system operation, there were two more cars left on the road between the station and warehouse. The results show, that on the loading parking lot, i.e. railway station and also on the unloading workplace, i.e. in the warehouse, there are reserves and downtime originate.

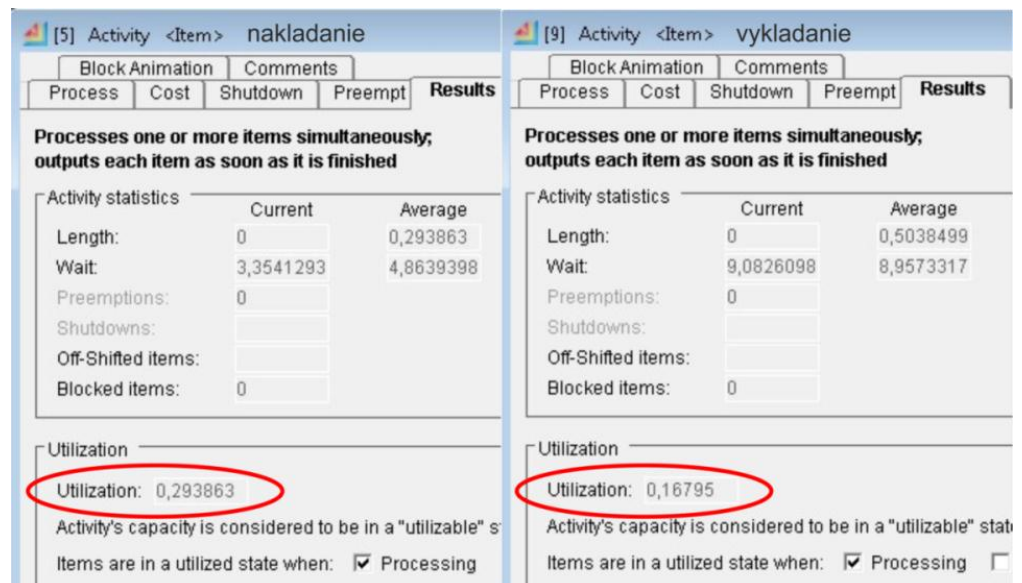


FIGURE 10 – WORK UTILIZATION LOADING AND UNLOADING BY USING THREE CARS

In the first phase it is necessary to adjust the system so that the loading into the pick-ups at the railway station would be fluent. Since it is single-shift high power it is possible to adjust system up to 100 % of utilization. For long-term of high utilization there would be a risk, that system will „fall“. The general principle is that the system, which does not have a reserve is not possible to effectively manage. Therefore, it is effectively to utilize the system from 75 to 90 %.

Using of 9 cars, usage of workplace at railway station grows up to cca 82,5%, which represents 78 loaded cars per 8 hours. Using of 10 cars, usage of workplace is cca 89%, using of 11 cars, usage of workplace is cca 95% and using of 12 cars, usage of workplace is cca 99%, loading will repeat 90 times. Putting more cars into the system has no meaning.

In terms of short-term high work utilization loading it is possible to send 12 cars into the system (Figure 11), which ensure fluent loading without downtime even although with some waiting in the line. If it would be long-term utilize system it would be preferable to send 9 resp. 10 cars into the system.

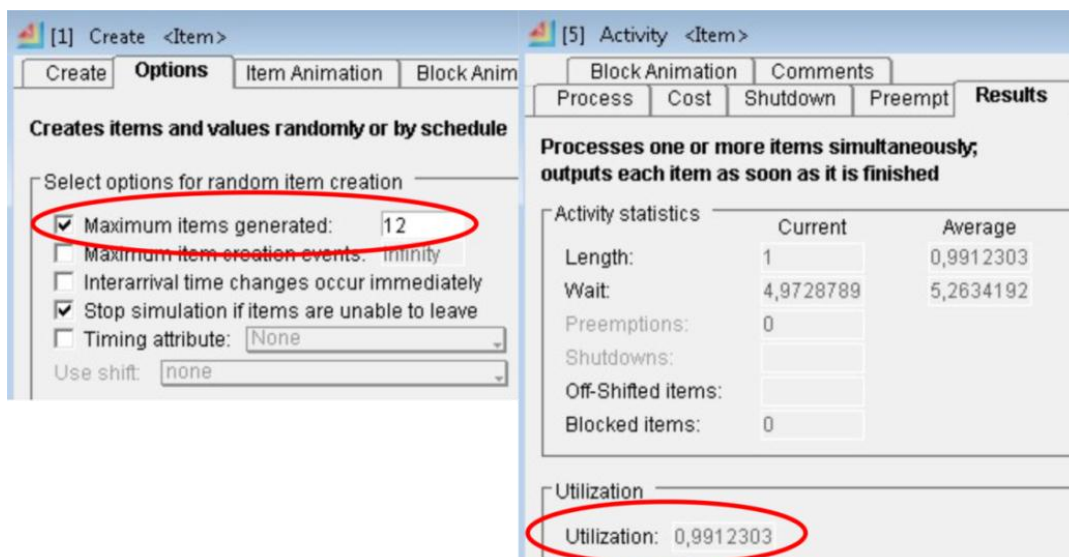


FIGURE 11 – LIMITATION OF ENTERING OF THE CARS INTO THE SYSTEM UP TO 12 AND USAGE OF WORKPLACE LOADING

In the second phase it is necessary to adjust traffic system so, that the unloading in the warehouse will be fluent and without downtime. Using of 12 cars, which realized the traffic, the usage of workplace unloading in the warehouse is 52%, which represents 84 unloaded cars. Since loading at the railway station is becoming narrower place at the higher amount of cars it is necessary to strengthen the workplace at the railway station with the next operating equipment, so it is possible to load two cars at the same time. We adjust simulation model to 15 cars, which will realize the transport of goods into the warehouse.

From the simulation using 15 cars for transport and the strengthening of the loading results, that usage of unloading will grow to cca 80%. Using of 20 cars, which realized transport of goods, usage of the unloading will grow to cca 94% (Figure 12).

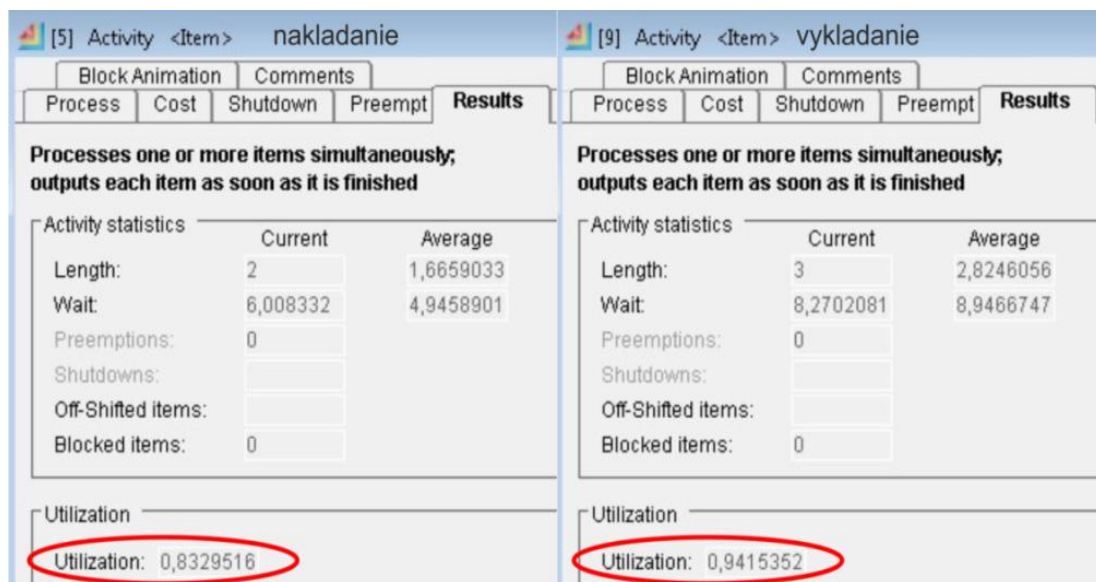


FIGURE 12 – WORKPLACE UTILIZATION LOADING AND UNLOADING USING OF 20 CARS AND THEIR TWO LOADERS

## 6. CONCLUSIONS

Within the simulation variants with 25 cars, 30 cars and 50 cars using for transport were examined. Workplace utilization “unloading” at the warehouse stayed at 94% even after massive enlarging of amount of vehicles. It follows that the cars disappear, stretch on the roads and it has no meaning to send more than 20 cars into the traffic system and thus uselessly increase the intensity of traffic in concrete city district.

Simulation results clearly shows, that intensity of the traffic and utilization of roads within the concrete city district remained unchanged (Figure 13, Plotter 9, Plotter10) and it comes to increasing of power and overall workplace utilization and unloading (Figure 13, Plotter 11, Plotter 12). The advantage of the solution is that it has a capacity reserves for needs of future development of load, resp. possible change and decrease within the urban transport system of transport of materials and goods.

By the means of simulation, transport system was balanced according to the requirements and needs of the real load of the transport system and options of transport of city district. Simulation is fast and effective access to the solution of narrow places within the balancing of the system, including transport and distribution systems. The solution is to determine the exact number of cars for individual variants and needs of effective utilization of the transport system which clearly leads to effective utilization of

transport elements and to decreasing of intensity and reduce traffic volumes of overcrowded agglomeration.

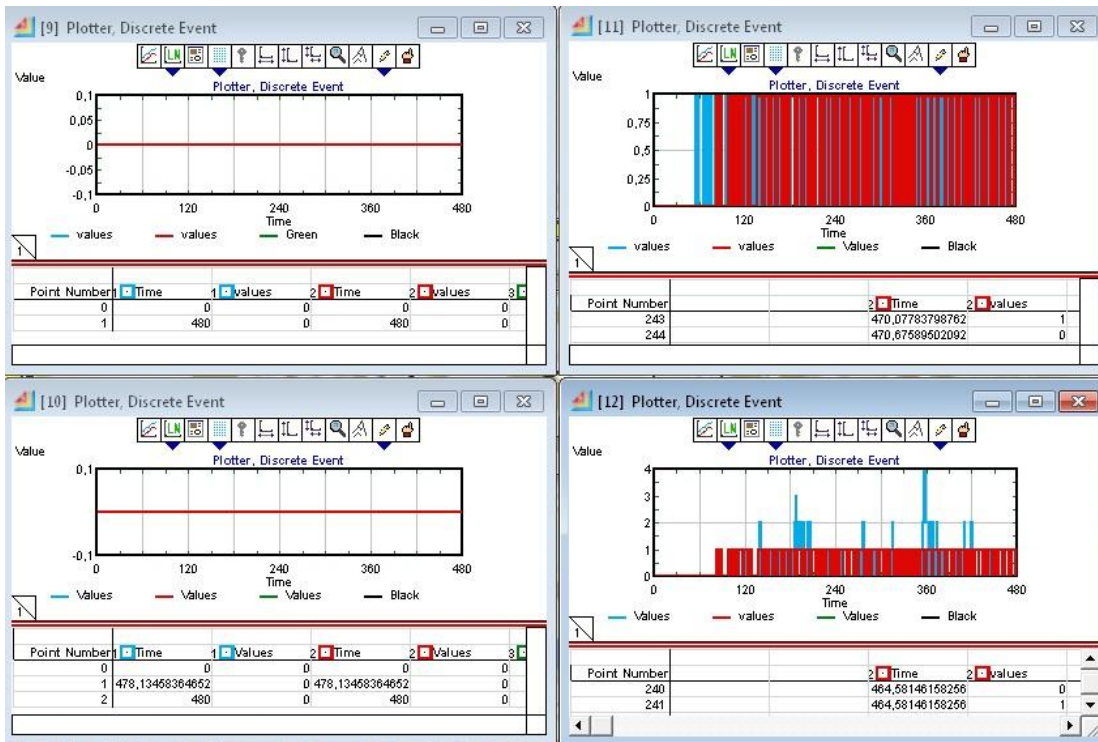


FIGURE 13 – BEHAVIOUR OF THE SIMULATION CAPTURED BY GRAPHS OF UTILIZATION OF THE ROADS AND SERVICE EQUIPMENT OF THE TRANSPORT SYSTEM IN CONCRETE CITY DISTRICT

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