THE TRAFFIC SIMULATION IN THE PUBLIC TRANSPORT TERMINAL

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Summary: The town of Ostrava (the Czech Republic) proposed to build a new public transport terminal for bus traffic in order to improve traffic organization in the locality and to make public transport more attractive for passengers. The project of the new hub expects to build some new constructions (platforms, parking places etc). The aim is to find out if the proposed number of constructions is sufficient for expected number of transport lines and passengers in the transport hub. The computer simulation is used to solve the problem of the hub verification. Two simulation models are created in application called Witness to simulate the traffic in the transport terminal. The simulation methods have proved to be very suitable for verifying quantitative parameters of transport projects. The research found out the delay "a desirable phenomenon" for the number of parking places. The delays reduce their required number.

Keywords: simulation, mass passenger public transport, bus, transport terminal, passenger transportation, Witness

INTRODUCTION

The public passenger transport takes an important role in the Czech Republic for a long time. The share of public passenger transport of the total transported passengers was 56,4% and of the total transport performance was 37.2% in Czech republic in 2008. The public transport is even more important in the urban transport. The share of public passenger transport is about 60% and the share of car transport is only 15% in cities such as Ostrava (330 thousand inhabitants). Yet what has happened in the past 20 years is the significant increase of individual car transport performance. It brings substantial downside in the field of ecology (pollution), lifestyle and health, the state economy (imported oil), private economy and time management (traffic jams), safety (traffic accidents), etc. The aim of public institutions is to counter the trend of decreasing the importance of public transport.

1. THE TERMINAL "BOŽENA NĚMCOVÁ PARK"

The town of Ostrava proposed to build a new terminal (transport hub) for bus traffic in the locality called "Sad Božena Němcová". The reasons for building the hub are unsatisfactory conditions in the current organization of public bus transport. There is a system of 8 stops near the busy intersection. The distances among some stops are more than 500 meters. The locality has insufficient parking places capacity for buses etc.

The new terminal, in the form as proposed, tries to solve all the problems described above. The proposal envisages the construction of four boarding platforms, one leaving platform and 18 parking places for buses.

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12 existing lines are finished in the hub nowadays and potentially 15 lines are going to be finished there after finishing the hub. All of the lines are the part of the Ostrava transport system, which integrates train, tram, trolleybus and bus transport. The estimated volume of traffic for the morning peak hour of the working day is 1710 - 2110 passengers per hour in both directions. It represents the largest number of passengers for all terminals in Ostrava. Moreover, near the locality there are further terminals: The Ostrava main railway station with 1090 passengers per hour.

The aim is to find out if the proposed number of constructions (platforms, parking places) is sufficient. There are several methods to solve the problem. Nowadays, "pencil and paper" is usually used in the Czech Republic. It is expected, that significantly better solution can be achieved with computer simulation. This research deals with the computer simulation of the traffic in the terminal. The main goal is to determine whether the proposed number of 18 parking places is sufficient for the anticipated level of traffic in the terminal.
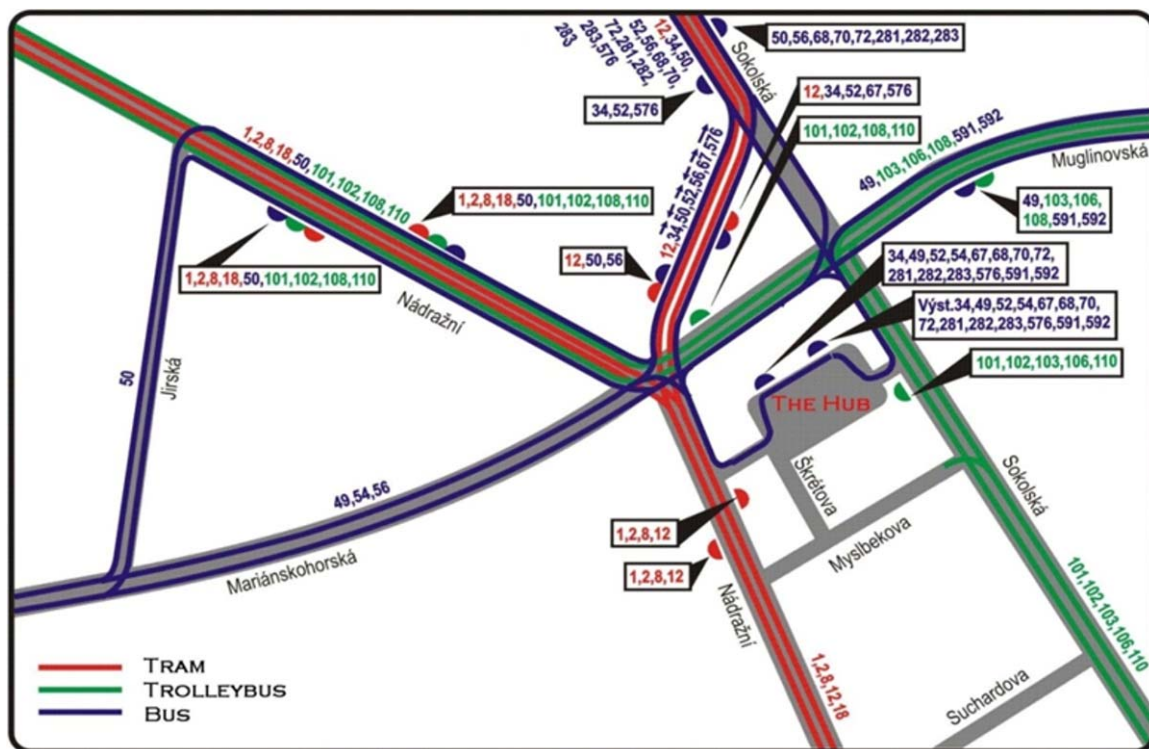

Fig. 1 - The lines routing diagram in the hub zone

2. THE TRAFFIC SIMULATION IN THE TERMINAL

The computer simulation is used to solve the problem of the hub verification. The simulation model was created in application called Witness to simulate the traffic in the transport terminal. The Witness works by enabling you to represent your real world processes in a dynamic animated computer model and then experiment with alternative 'what-if ?' scenarios to identify the optimal or suboptimal solution. This application is primary designed for industrial manufacturing simulations, but it can be used for transport simulations as well. The aim is to design a simulation model that would be as faithful as possible to simulate the

expected traffic in the terminal on one hand, and simple enough on the other hand. These criteria are partly contradictory. That is why two models were created:

- the line model (most closely simulates the expected traffic in the terminal),
- the simple model (the simplest, but all requirements on faithful traffic simulation are fulfilled).

3. THE LINE MODEL

The easiest way to characterize the traffic system in the terminal is the following sequence:

1. the vehicle comes to the leaving platform,
2. passengers leave the vehicle,
3. the vehicle goes to the parking place
4. the vehicle waits for the next operation of the line,
5. the vehicle leaves the parking area,
6. goes to the boarding platform,
7. passengers board,
8. the vehicle leaves the hub.

The process is simulated using these elements and relations between them: the vehicle (modeled in Witness with element called: *parts*), the platforms (*machines*), parking area (*buffer*). The main reference index is the actual number of vehicles in the parking area. The index is watched and recorded with following elements: record (*fileread*), variables (*Vreal, Vinteger*), graph (*timeseries*) and function (*Nparts*).

The process mentioned earlier, was described as simply as possible. In practice, there are dozens of variations of the operational processes in the terminal. It is necessary to count all the variants to get accurate output data and to deal with all details in entry and exit of vehicles from the terminal, depending on its deployment on the line as well as other sub-options and implementation of operational process. Several functions (for example if-then-else) are used to achieve the required behavior of the model.

The main output of the model is the *timeseries*, which is a graph of the number of occupied parking places at time. The graph is updated every minute to achieve the required accuracy. See the structure of the line model in the picture below.
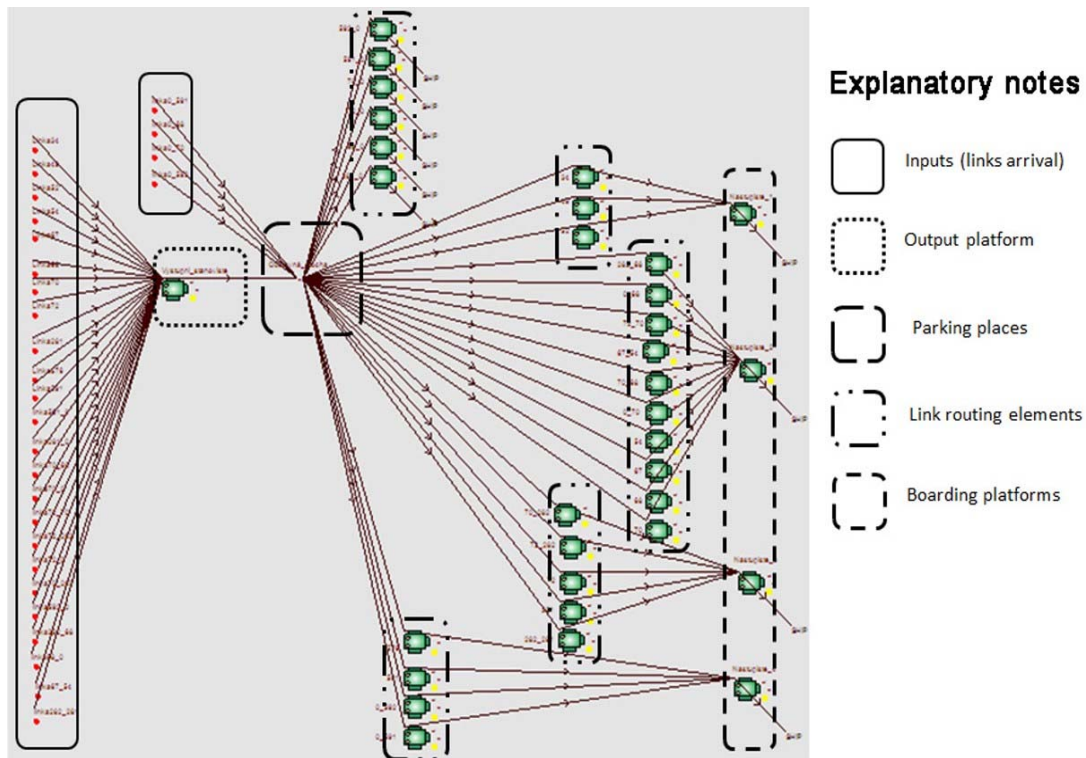
Fig. 2 - The line model structure

4. THE SIMPLE MODEL

The above described model has the disadvantage because it is quite large. It contains more than 100 elements. Its relative complexity is determined by the number of lines and the number of combinations of arrivals / departures of buses assigned to lines. However, the assignment of vehicle to the line is irrelevant in task of availability of parking places. The simulation model can be significantly simplified given this reasoning. The characteristic vehicle movement sequence follows: the vehicle enters the hub with single input channel (*part*), the vehicle proceeds to the output platform (*machine*), continues to the parking area (*buffer*), passengers board the vehicle at the platform (*machine*) and the vehicle leaves the hub through the output channel. The number of platforms can be reduced and is equal to the maximum number of buses that depart from the terminal at one time. The number of occupied parking places shows the graph and it is counted and recorded with *variable*, the *Vreal* element shows the next departure time. This gives a total number of 15 elements, which represents a substantial reduction compared to more than 100 elements in the model, which takes into account the vehicle assignment to the lines. However, it is not possible to do some experiments with the simple model, for example delaying selected lines.
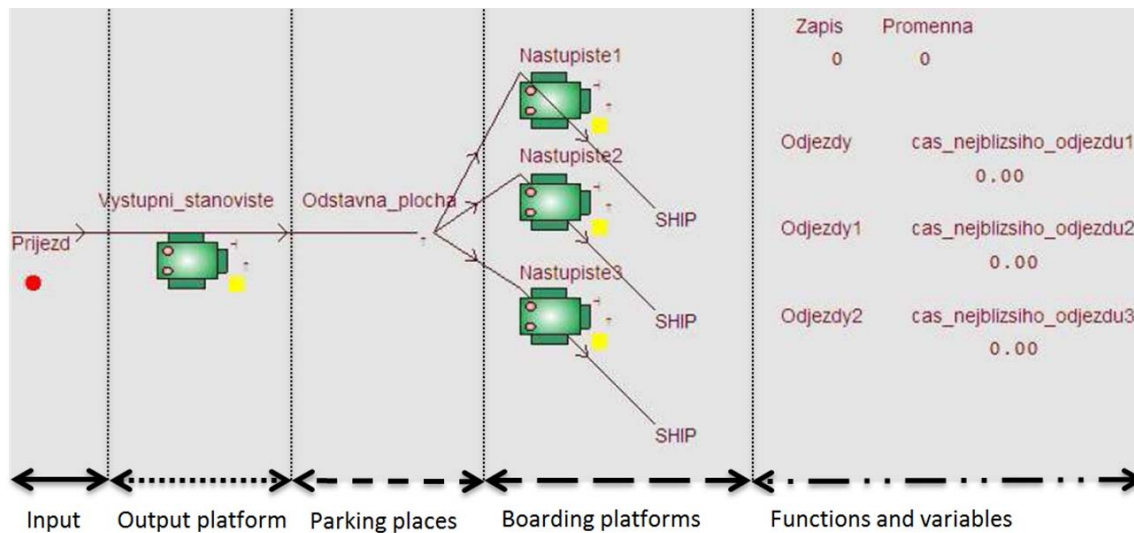
Fig. 3 - The simple model structure

5. EXPERIMENTS WITH THE MODELS

The input data for the models described above – line and simple ones, are based on the deterministic terms - the valid timetable. In fact, the real operation in any mode of transport is based on the stochastic terms. It is necessary to perform experiments with the simulation models, leading to greater closeness of the simulation results to the reality.

The basic experiment is the simulation of the lines delays. Delay is the same or late entry of vehicles into the hub. The delays were measured for the purpose of doing experiments. Pierson's test was used to find out with which probability distribution the delays can be approximated. With the significance level (p-value) $\alpha = 0.01$ and $\alpha = 0.05$ the hypothesis that the measured values come from the exponential probability distribution with the parameter ($EX = 1$ minute) cannot be rejected.

Two experiments were done with simulation models based on the measured data:
1)   delay of all lines (exponential probability distribution, $EX = 1$ minute)
2)   delay of the selected lines (exponential probability distribution, $EX = 2$ minutes).
Simulation models were adjusted for doing experiments.

The lines with arrival to the terminal at a negative simulation time were removed from the mode of delaying, because delays of these vehicles are not fully reflected in the positive simulation time. The probability that the delay reflects in the positive simulation time was calculated for 12 lines with arrival in the negative simulation time. The average probability that the potential delay will be reflected in the positive simulation time is 0.065. The experiment with delaying of all lines is preferable to do in the simple model. The experiments with delaying selected lines are done in the line model. See the results of the experiments in the graph below.
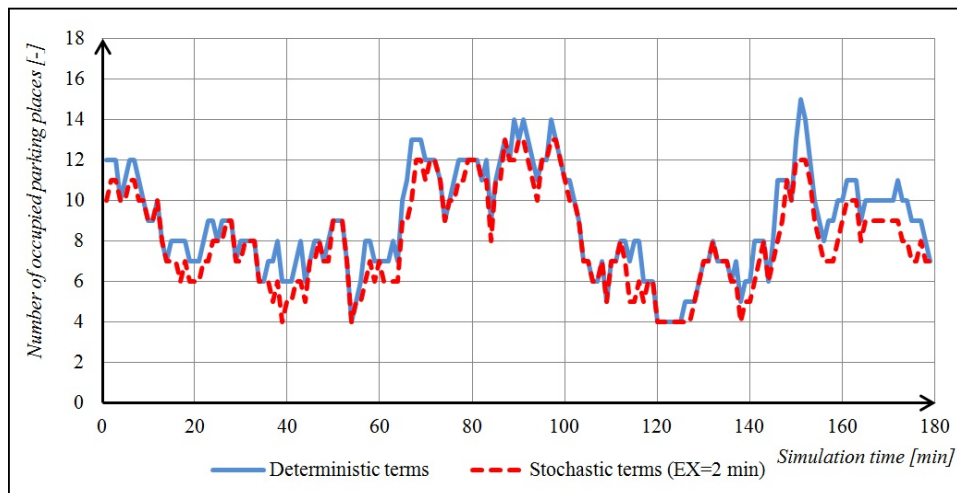
Fig. 4 - Results of the experiment: the simple model, all lines delayed, EX = 1 min

As can be seen in the graph, so far the lines are delayed, the number of vehicles in the parking area is lower or equal to the number of vehicles parking in the deterministic terms at any time. We can say that the delay is "a desirable phenomenon" for the number of parking places. The delays reduce the required number of parking places. The results of all experiments are listed below.

Tab. 5 - The results of all experiments in deterministic and stochastic terms

Model type	Mode	Median	Average	Maximum	Modus
simple	deterministic	9	8,87	15	8
line	deterministic	9	8,87	15	8
simple	stochastic (EX=1 min)	8	8,10	14	7
line	stochastic (EX=1 min)	8	8,50	14	7
simple	stochastic (EX=2 min)	7	7,46	12	6
line	stochastic (EX=2 min)	8	8,12	13	7

CONCLUSIONS

The results clearly show that the suggested number of parking places is sufficient for the anticipated level of traffic in the terminal at the time between 5:00 and 8:00 and for real (valid) timetable. Although the simulations revealed that the parking area has sufficient capacity, it is not appropriate to reduce the number of parking places. It should be stressed that the simulation was carried out for the time from 5:00 to 8:00 at working day. It is not excluded that the requirements on the parking places are higher in other parts of the day.

Nowadays, similar verification projects are usually done with "pencil and paper" in the Czech Republic. Using modern methods such as computer simulation is the way how to realize these projects more precisely, faithfully and fast.

ACKNOWLEDGEMENT

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