Simulation Modelling of Technology and Capacity Design in Border Railway Station

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Abstract: **Simulation and modelling are the crucial methods which are recently used for infrastructural capacity dimensioning. This is not applied just for infrastructure, it's also applied on determination of the optimal number of workers on matched positions, as the number of shunting locomotives, squads, station regions etc. In this work you can see simulation model that enables dimensioning the work technology and the capacities of border railway station.**

Keywords **– modelling, simulation, capacity, technology, border railway station**

I. Introduction

The capacities of one railway station, in specified time period and terms, are enabling receipt, processing and dispatch trains. Defining capacity is needed to define the time tables, the traffic organization and technological processes, their optimization, planning of investments etc. The basic problem which arises is how to dimension capacities, so the train service can be carried out without problems. It's necessary to have in mind that, infrastructural facilities and resources are extraordinarily expensive, as at the building and procurement point also at the maintaining. And as a result of this, there are large expenses for working force. This means that their improper dimensioning can affect on the profitability of the work of the railway because railway capacity is not static. It is extremely dependent on how it is used [9].

In this paper it is shown how to dimension the technology and capacity in the border stations. Border stations are points in which there is a significant trains standing time on the way to the final destination. The trains in the border station are hold for passenger's exchange, the police and customs formalities, locomotives change, adding or removing wagons, technical and commercial review, receiving documentation from and off the trains, making documentation and so on. Often, the border station represents point of turnover for the passenger trains in internal traffic. All those standings directly affect on the capacities of the border station and its all on the grounds of the existing technology in processing of the trains.

In order to dimension capacities and technology of the border station are developed two models: analytical and simulation model. The models are tested on the example of the border station Kremenica.

Nowadays the most used ways to analyze and simulate the station traffic is to use some of the commercial expensive software's where the possibilities are limited. Considering that, my research showed that it is not needed to buy such software and to simulate traffics on the following kind of way.

In other systems it is necessary to use parallel processes to reduce the computing time and therefore simulators are related for solving with parallel computing based on a multiple-CPU server and they concentrate, in particular, on the speed-up performance [6] [13], but in this simulation, the processes are obtained by low performance computer.

The technology and railway station capacity modelling are presented in the following papers [12], [4][4], [5] and [10]. The paper [12] presents a simulation model for technology and capacities optimization for interim stations (transit stations) with usage of the Non-Markovian systems queueing theory. To simulate the railway traffic at the stations (into the railway transit stations), in [10] *Cellular Automata* is used, and in the [4] *hybrid Petri nets-based simulation model.* In the paper [5], marshaling yard station model is presented, where the station optimization is the main question, and is based on the simulation modelling of the technological operations such as train formation and unformation. The analytical modelling of the technological operations in the marshaling yards it is made in the paper [14].

In the work [7] for traffic congestion controls uses a queue thresholds. For the queueing theory is used the system GE/GE/1/N approximation. Developed to study the spread of traffic congestion in complex networks.

Modelling the spread of traffic congestion in complex rail networks in [8] is used a Weight-evolving traffic network model which is based on Barrat–Barthelemy–Vespignani (BBV) model. This paper simulates and analyzes the process of the emergence and spreading of congestion, which is triggered by adjusting of data generating speed and data sending ability of the network.

In the literature I have found no papers which are dealing with optimization of the work in border stations using simulation modelling, but there are presented simulation models which are concerning the movement of trains to advance adopted technology in the transit railway stations.

The border railway stations shall perform customs work which could affect on the retention of the trains, especially in freight traffic. Retention time of trains is not neglected in passenger traffic. Moreover, there are other railway technical operations, such as: change of locomotive and train personnel, inventory of train, etc. which also affect the maintenance of trains at border stations. Technology and time of execution of

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customs operations and technology directly affect to infrastructure facilities dimensioning in the border station facilities.

For example among EU members, the trains are kept in border station in order to performance the customs affairs there, between certain countries there is some retention of trains for carrying out the railway technology operations.

This paper presents a simulation model for technology and infrastructure facilities optimization in the border railway stations based on discrete stochastic systems simulation such as the technological processes in the border stations and in other train stations. Results are compared with results obtained by analytical way.

The model is tested on example of Kremenica border railway station in Macedonia, which is planned in all strategies for reconstruction, and it is a boundary between a country that borders the EU (Macedonia) and EU Member State (Greece).

II. Type and purpose of the Kremenica station

Kremenica station is located on the main railway line Veles-Bitola-Kremenica-Greece border, which is a part of the Corridor's X arm "D", Kremenica also is a frontier station between the Macedonian Railways (MZ) and the Greek Railways (CH). Kremenica has competence for receipt, processing and dispatching passenger trains and goods trains in internal and international traffic. Station has two tracks for receipt and dispatch trains, where trains are stopping to exchange passengers, locomotive change and customs procedures, while the loading and unloading of goods wagons is envisaged to be made on the reversing triangle. Neighboring station are station Bitola (MZ) and station Mesonisie (CH).

III. Simulation model

For station Kremenica capacity and technology modelling is used GPSS/FON V.4.0 simulation program. According to model needs, input and output train speed are defined.

Train retention time in the model devices it is calculated by the following equation:

$$t_{zd} = \frac{3{,}6 \cdot (L + \ell_{voz})}{V} \tag{1}$$

where:

L - length of the elements in the real system expressed in meters;

ℓ_{voz} - length of train expressed in meters;

V - train speed when the train is passing the observed device, expressed in km/h.

For the purposes of the model, length of the elements (devices) of the real system are calculated, and the retention time on them. However, the real time, when device is busy and the train is passing, is far greater. The train retention at the first element in the formation of driving route[1] is calculated according to the equation:

[1] In the modelling (according to the train movement dependence table for this model), it is taken that one driving route includes more devices (example: one or more group's switches, tracks etc.)

$$T_{ze} = t_{fp} + t_{us} + \frac{3{,}6 \cdot (L + \ell_{voz})}{V_{ul}} \tag{2}$$

where:

t_{fp} – driving route formatting time; in this work is 0,3 *min* or 18 *s;*

t_{us} - signal perception time when the trains are moving with classical speed (9 *s*);

V_{ul} – average train speed when the train is entering the station (*km/h*).

Occupation time of the "n" element in the driving route (T_{ze_n}), is calculated by the following equation:

$$T_{ze_n} = t_{fp} + t_{us} + \sum_{i=1}^{n-1} t_{zd_i} + t_{zd_n} \tag{3}$$

where:

$\sum_{i=1}^{n-1} t_{zd_i}$ - train retention time sum on the previous devices on the driving route;

t_{zd_n} - train retention time on the "n" device.

Similar logic applies when it comes to the output driving. The occupation time of the "i" track device in the shunt-dispatching yard is calculated by the equation:

$$T_{ze_i} = t_{zd_i} + t_{fp} + t_{ot} + \frac{3{,}6 \cdot \ell_{voz}}{V_{izl}} \tag{4}$$

where:

V_{izl} – average speed when the train leave the station (*km/h*);

t_{ot} - train dispatch time, which is taken to be 1 min.;

Occupation time of the "*n*" output device in the shunt-dispatching yard is:

$$T_{ze_n} = t_{fp} + t_{ot} + \sum_{i=1}^{n-1} t_{zd_i} + t_{zd_n} \tag{5}$$

Model boundaries are: from station Bitola side is the dispatch main signal of that station and from Mesonision station side boundary is the country border line. Input device from Bitola side is OTSEK1 and from Mesonision side is OTSEK2 device. These two devices are first devices in which the trains are entering in the simulation system.

Although the input devices in the model are first devices which are taking transactions, also they are last devices in the simulation output drive from Kremenica station.

Trains entering in the system is done after they leave the station Kremenica or Mesonision (border station in Greece), and that is performed after the trains leave the last station switch or after the dispatch of the train. And the trains exit from the system is performed after they leave the last device of the system, i.e. after the main exit signal of the Kremenica station on both sides. All devices are shown in (Fig. 1.).

Fig. 1. Scheme of the devices used in the model simulation

The movement of trains in the model as in the real system, as same in the model, it's subject of certain patterns. In the movement of trains through the station are used many different types of routes: entry, exit and transit routes and overlap routes. Due the consideration of all necessary and possible driving routes for this model routes table is developed, in which we enable the realization of all simultaneous driving. In the model for routes regulating and security the following rules are used:

1. When we are forming a route (entry route means that a overlap route is included), another route can be formed if only these two do not overlap, intersect or touch,
2. All relevant signals whose implementation could jeopardize the route (front, ends, or jeopardizing with overcoming), should show a signal of prohibited driving,
3. The route in any of its parts must be unoccupied by other vehicles or bands.

In the model are processed 3 types of trains such as: passenger, goods transport (classical technology) and goods transport (combined transport technology). Based on the statistical examination it is established that 25% of the trains are passenger trains, and to 75% are freight trains, from them, the 50 % are classic cargo and 50% are intermodal.

Testing of models is made for the following terms of train's traffic with the alternatives included:

- ALTERNATIVE1 (for 1 pair of trains in 4 hours),
- ALTERNATIVE2 (for 1 pair of trains in 3 hours),
- ALTERNATIVE3 (for 1 pair of trains in 2 hours),
- ALTERNATIVE4 (for 1 pair of trains in 1 hour).

Generation of trains is performed by equal distribution in minutes, like this: ALT[240,30], ALT2[180,15], ALT3[120,10] and ALT4[120,10].

The testing results are shown in (Figures: 2, 3, 4,).

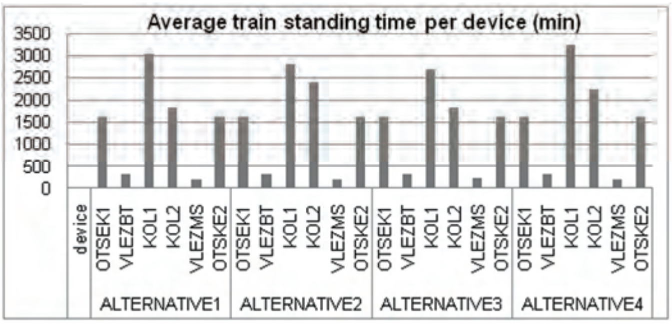

Fig. 2. Average train standing time per device (min)

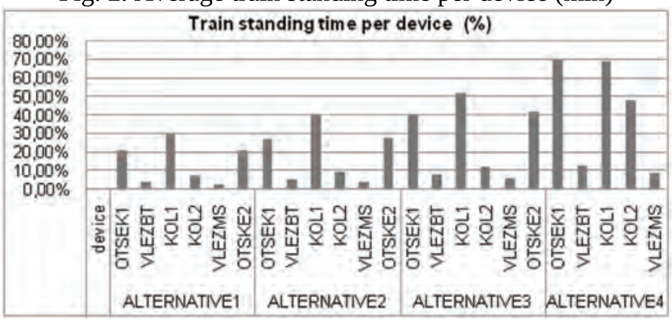

Fig. 3. Train standing time per device (%)

At the fourth alternative it can be recorded that the devices OTSEK1, OTSEK2 and KOL1 are used about 70% of the time, which means that the alternative 4 is bottleneck in these two devices for the specified quantity of traffic, while the occupation of the other devices is going from 5% to 40% with a tendency to increase in relation to decrease the interval of incoming trains.

On the basis of the obtained results for the warehouses on both entering sides, Bitola and Mesonision, it is provided that their capacity is not envisaged fully yet, but at the first alternative there is a standing of 82 minutes and arises, which is quite long time. That can tell us that the capacity of the station is not sufficient for processing the trains. This standing time grows at the alternative 4 up to 163 min and 93 min, or average in hours, 2.7 h and 1.6 h.

The testing results on alternatives are showing that there is standing of the trains in lines (on main signals) only just for alternative 3 and 4.

Next significant fact, from 22 trains, which are entering Kremencia station by the third alternative from Bitola side, 2 trains are standing on the main signal of Kremenica, while in the fourth alternative 18 of 22 trains from the station Bitola side and 18 of 18 trains from Mesonision side are standing on the main signal and waiting to enter the Kremenica station (Table 5). That means from 81% to 100% of the trains which have entered the Kremenica station are stopped on entry, with high value of standing time from 39 to 211 minutes for both sides, Bitola and Mesonision, which means all trains which have entered the Kremenica station from Mesonision side are kept at entry main signal.

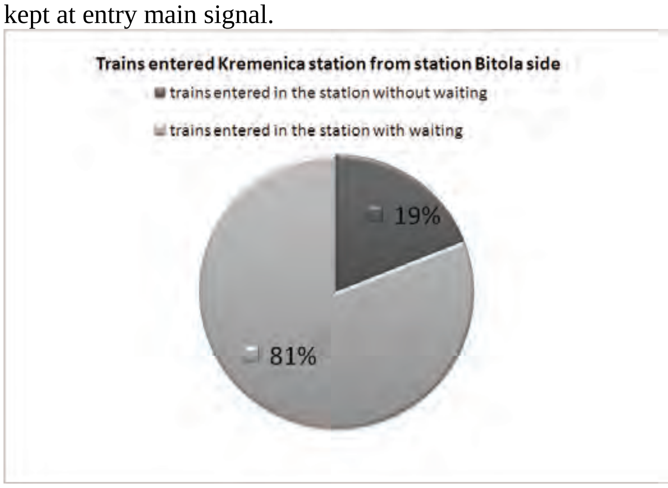

Fig. 4. Percentage of trains which entered the station Kremenica with and without standings at the entry from station Bitola side in Alternative 4

If the trains came as in alternative 1 and 2, the facilities already are sufficient, because they are not appearing waiting, according to the simulation. The analytical method has also showed that existing facilities can be satisfied, while the alternatives 3 and 4 are appearing need for increasing capacity or improving the technology of train processing, especially regarding the goods trains where are showed a big standings at entry into the system or waiting for trains processing.

When those two types of dimensioning are compared they give similar results, the analytical method showed that the expanding capacities can be considered if the trains come like in alternative 3 and 4. This means if the trains come in intervals of 120 min, and less, then a need for new equipment is shows up. In support of this obtained test results, which are showing great standing time in order to start the trains processing, it is indicating the purpose of expanding the capacity and intervention on the treatment technologies.

IV. TECHNICAL AND ORGANIZATIONAL MEASURES TO REDUCE THE RETENTION OF TRAINS AT THE BORDER STATION KREMENICA

All operations and activities carried out in border stations are necessary, because quality analysis can be divided into those which pursue public authorities and those which the railways run.

Kremenica railway station in the near future must be converted into common rail station for two administrations (MZ and CH). The prerequisite is a basic assumption under which the total retention time of passenger and goods trains could reduce on the both sides and thus could reduce the total travel time. Thus would enhance the competitiveness of the railway transport.

If Kremenica station would be a joint border station, it will accommodate all competent railway authorities for treatment and control of trains (MZ and CH staff) and state departments of customs authorities and police from Macedonia and Greece, and the presence of the competent inspection services (sanitary, environmental, veterinary, etc.).

Besides, modern trends in railway traffic are trying to use the international rail network for data transmission - HERMES and the electronic waybill form - DOCIMEL, which could significantly reduce the standings of trains at border stations.

CONCLUSION

Running the train traffic is just one of the many complex processes that take place in the complex system of railways. Railway processes are suitable for modelling and simulation, there for analytical models didn't give always the optimal solution, and the experiments in the real system could be lengthy, costly and risky. So, the model developed in this paper allows dimensioning of technology and capacity based on application of analytical models and simulation of train traffic through the border station Kremenica.

On the basis of the results obtained from the testing of the models can be concluded that the station would satisfy the needs for processing trains in interval bigger than 2 hours.

The measures offered are based on the experience of railways which belong to the EU, and members of the UIC (International Railway Union) and thus measures have to be applied by MZ and CH. So by turning the station into a common border station (common to both countries) as well as implementing new information technologies in the process of treatment and dispatching trains, would increase the processing speed of the trains. It is also essential in the joint station Kremenica all operations of the railways and the authorities to be maximally simplified and organized as a parallel work of individual operations as possible.

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