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INVESTIGATING THE INFLUENCE OF FIXED ASSIGNMENT OF PLATFORM TRACKS TO TRAINS ON THE RESULTING STATION CAPACITY USING SIMULATION

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ABSTRACT

The paper focuses on the simulation assessment of the operation of a railway station with mixed passenger and freight traffic whereas various options how to assign tracks for considered trains are presented with assessed results. As a base variant of tracks assignments is considered variable tracks assignment that is applied nowadays in the Czech Republic. There are also presented variant with mixed approach – subset of trains is organized with variable tracks assignments, but another subset of trains is organized with fixed assignments and results of various scenarios are presented.

Keywords: capacity, simulation, railway station, platform track

1. INTRODUCTION

Railway transport infrastructure is usually very expensive. Spatial demands of this infrastructure are also high. Demand after as most effective utilization of this infrastructure is based on these reasons. The result is that the extent of infrastructure is sometimes minimized, but regarding operation of all demanded trains.

Transport operation must be effectively scheduled as well to meet these presumptions as well. The issue is if this operation (time schedule and track occupancy plan) will be stable in the case of stochastic conditions, because various train delays and irregularities can occur in practice. Possible lack of additional infrastructure can amplify delays or other operational problems, because this infrastructure is not possible to be applied in the case of irregularities in operation. For example, a train can increase delay by waiting in a station (platform) track, because other empty track can't be reached due to missing of some of switches (replaced due to reduction of infrastructure costs) etc.

Microscopic simulation belongs to usually applied tools for modelling of such issues, including assessment of railway infrastructure capacity. These models are classified as microscopic, because each train with a set of train features is modelled on this resolution level. Principle is that the model simulates train traffic operation on defined part of infrastructure (usually a few stations with line segments interconnecting them). Given time schedule is repeated within individual replication of simulation model with different (stochastic) inputs. For example, input delays on arrivals of individual trains into modelled area can be stochastically changed. Each replication is assessed by a set of output features like increment (change) of delay by individual trains or ratio of time when individual infrastructure elements (e.g. station or line tracks, switch areas etc.) are occupied etc. Collective assessment of a set of replications can be made to make the results more general.

Simulation models are usually applied for assessment of given infrastructure and of given timetables. Operational features can be assessed in this way, but in strictly given situation.

Hypothesis of this research can be stated in following way. It is possible to apply simulation (to get suitable results) for a general case where different configurations of infrastructure will be modelled by application of a different set of operational constraints. The aim is to assess given particular situation, but to assess minimization of infrastructure extent regarding extent of operation as a general feature.

The presumption is that each train will have strictly given position in planned time schedule of operation and adequate extent infrastructure will be reserved for this train. On the other hand, resting (remaining, ineffectively applied) infrastructure will be totally replaced. This situation can be modelled as a time schedule with strict allocation of tracks to trains (or vice versa). Time schedule assessed by simulation must be conflict-less in the case of fully regular operation (according to planned time schedule). The issue is, what can happen in the case of stochastic operation (with train delays) as it is objectively common in practice. Strict allocation of trains to tracks must be ensured any time, including the situation when a train will wait on given track although other tracks can be possibly at disposal as unoccupied. This represents the situation when infrastructure extend will be reduced to minimum according to time schedule (plan). Requirement on conflict-less operation by regular operation is applied. On the other hand, if serious

problem with stability of time schedule will occur, change of track allocation can represent a fact that the station will be equipped by additional infrastructure with no need to change modelled infrastructure. Assessing on the same level is ensured in this way.
Applied stochastic microscopic simulation represents an ideal tool for evaluating this problem because the characteristics of such operation are difficult to detect by the analytical methodologies used (e.g. UIC 406).
This research is part of the PosiTrans project that is focused on the research of aspects affecting the capacity of railway transport infrastructure using simulation and transport modelling tools.

2. LITERATURE OVERVIEW

A considerable number of professional publications are devoted to the planning of train transport and the creation of models for such planning. Most of them, however, devote themselves to the issue of train transport planning very generally and only a few specialize in selected aspects of the issue. For example (Buchmueller1, Weidmann1 and Nash2 2018; Longo and Medeossi 2012), they focus in detail on the determination of sojourn times at the railway station. Although the determination of suitable sojourn times is closely related to the comfort of passengers during transfers and the choice of platform tracks, the issue of assigning platform tracks is not discussed in detail. Typical criteria applied by assigning of tracks to trains are maximizing the utilization rate or increasing efficiency of railway infrastructure.
As stated in (Yuan and Hansen 2007), there must be a compromise when planning a regular (especially passenger) train service between efficient use of infrastructure and improving the reliability and accuracy of the traffic. These objectives can be in a conflict due to fact that railway operation is usually a stochastic process. Systems with high ratio of capacity utilization have limited space (capacity reserves) for solution of irregular situation. Using a new analytical stochastic model, the authors attempt to address the emergence of so-called delays that arise in real rail traffic mainly due to irregularities and differences between planned (presupposed by time schedule) and real "every-day" operation (influenced by stochastic influences). One of the factors influencing the occurrence of subsequent delays and their size is also waiting for the release of the required platform track. It follows from the logic of the case that any tightening of operational conditions in the field of allocation of platform tracks to trains (e.g. strict plan of designated platform tracks without the possibility of any alternative) will contribute to increasing subsequent delays even at the slightest irregularities. It will also mean reducing the robustness of the timetable, i.e. reducing the ability to quickly and effectively absorb the resulting delays. This effect is based on the fact that possible alternative solution cannot be applied (e.g. using of an alternative station track) and the delay can be increased by waiting on tightly assigned infrastructure (track).
Some publications deal with the planning of railway traffic or the creation of models for simulating train traffic and its subsequent evaluation. They always consider certain simplifications which very often concern the issue of the allocation of platform tracks. There is often considered a situation where passenger trains can use all available platform tracks (Jensen, Landex, Nielsen, Kroon and Schmidt, 2017).
A number of publications (e.g. (Yuan and Hansen 2007; Andersson, Peterson and Krasemann 2013)) state that the requirements for the design of platform tracks have a negative impact on the robustness of the planned train schedules and the waiting for the release of the required platform tracks is one of the critical points for increasing delay. It is also the so-called "bottleneck" in the subsequent effort to reduce this delay.
The topic of the allocation of platform tracks is published in (Janosikova, Kavicka, Bažant 2012) on a detail level. The publication deals not only with the subsequent delays due to waiting for the release of the planned platform track but also discusses the impact of any change of platform track on passengers' comfort. The objective of this study is is the design of a mathematical model for a support of dispatcher decision-making in operational planning. With the support of this tool a dispatcher is able to better decide how to keep the train waiting for the occupied platform track - whether to change the plan of the desired platform track and thus reduce (minimize or not create) the subsequent delay. Or whether the train will continue to wait, for example, to keep comfort from passengers on transfers.

The research published by this paper is based on standard principles of microscopic simulation of railway operation. Such intersections with state-of-art level of research can be found in this field. The novelty is in the fact that the research tries to apply microscopic simulation for examination of given effect (the way of track allocation) despite simulation of given infrastructure as specific part of transport infrastructure. Results of this assessment will be applied in generalized methodology for assessment of capacity. Impacts will be evaluated parallel in two points of view. Time schedule stability is the first one, impacts on operation of connected line segments the second one. Research uncertainty is related to the fact how the results can be influenced by given local conditions. This can be discussed in the paper. On the other hand, transferability of results is invited, because there is an effort to apply simulation in general case and to incorporate results into general methodology for capacity assessment of railway infrastructure. All these aspects will be researched.

3. ADVANTEAGES OF FIXED PLATFORM TRACKS

The main presumptions leading to this research have been stated in the introducing chapter 1. On the other hand, these reasons can be more specified in more detail and some additional reason can be added.

Fixed assignment of platform tracks to trains is a theoretical variant in practice. However, there may be some of the following reasons that may result in at least partial application of such traffic.

3.1. Potential reduction of tracks

One of the most illustrative case is reduction of number of tracks. Each track represents investments for its construction as well as relative serious operation cost (e.g. for maintenance). These effects are characterized in introduction part of the paper.

3.2. Potential reduction of infrastructure elements

Effort to decrease infrastructure cost can be related to some of individual infrastructure elements as well. For example, some of switches (applied by trains minimally) can be replaced. This can be supported by remote way of dispatching. It can be presupposed that a train dispatcher having full information about traffic situation (in "line-wide" point of view) can organize the traffic in such way so this infrastructure elements will not be needed. Replacement of these elements can be compensated in this way.
Limited space can be the second reason for application of this measure in practice. Sometimes not all line tracks are accessible from or to all station tracks due to spatial reasons. For example, construction of some interconnecting track can be impossible in some directions due to spatial reasons.

3.3. Potential reduction of platforms

The third effect related to reduction of infrastructure is reduction of platforms although the track can still exist. State-of-art requirements on platforms and approaching routes to them are high due to reasons of safety and passengers' comfort. So, establishment and operation of platforms under current conditions represents cost as well. There is also the issue of maintenance, ensuring the equipment is serviceable for people with reduced mobility (lifts, etc.). This can lead to an effort to minimize the number of platforms.

3.4. Facilitating the orientation of passengers

Fixed assignment of platform tracks to passenger trains in railway stations helps passengers to orientate whereas information about departure or arrival tracks (platforms) can be passed on to passengers even in advance. The information may appear in a static information documents, such as tickets or message boards in a station. Passengers can find their pathway at a station in advance, especially passengers can have this information before they arrive at the interchange station and the time for transfer can be reduced by facilitating the orientation of passengers.
Fixed assignments are also common in public bus terminals and passengers are used to it.

3.5. Shortening of transfer times

By placing trains on selected transport tracks, the need to overcome distances and height differences in the station can be significantly reduced, thereby time savings and reducing travel times in a network viewpoint can be reached.

3.6. Shortening of train sojourn times

It is possible to better direct passengers to specific boarding sectors of platform (to a coach with reserved seat) in advance. Possible delays occurred by boarding a train can be avoided and total sojourn time shortened in this way.

4. DISADVANTAGES OF FIXED PLATFORM TRACKS

There has been characterized advantages and motivations of timetable with fixed platform tracks in the chapter 3. It is necessary to mention disadvantages and operational problems occurred by such way of operation for complex solution of this issue.

4.1. Occupancy of planned traffic tracks

The basic drawback is a possible occurrence of a delay by the fact that the planned track will not be available at the given time, another track will not be available, and the train will have to wait at a home signal.

4.2. Transferred delays

For example, due to the need of wait by a train at a home signal for release of a platform track at a station, other trains may be delayed, including freight trains. For freight trains, due to the operating situation (occupation of passenger trains), it may be necessary to use a different transport track and thus slow down these trains (use a slow path at the station, unplanned stops). Delays can also be transmitted to surrounding track sections, especially single-track lines.

4.3. Influencing the connecting trains

Due to the possibility of passenger trains waiting for releasing the planned platform track, the problem can be escalated in case of waiting connecting trains on which the delay is transmitted. Alternatively, the connection link may even be cancelled.

5. MICROSCOPIC STOCHASTIC SIMULATION

To verify this approach, the microscopic simulation model of a railway station is used using the Villon simulation tool, where the generation of train delays on input to the simulation model is used to verify the possibility of using static determination of platform tracks, and the consequences of this approach are examined using multiple replications.
In the simulation model, all the essential details concerning the trains are applied, e.g. train dynamics, possibility to increase power of engine in case of train delay, transfer links between passenger trains, realistic behaviour of interlocking systems, etc.

5.1. Model parametrization

Following parameters were used in simulation experiments:

- *Number of replications* – for every scenario that is considered in simulation is performed 100 replications.
- *Simulation runs calculate with randomly delayed arriving trains*. The utilized train delays match to demands, which are involved in the forthcoming directive of SŽDC: Determining the capacity of railway systems.
- *Value of delay* is generated for each arriving train so that to each train category is applied probability of a delay occurrence (uniform distribution) and the delay value which is obtained from the generator corresponding to the exponential probability distribution.
- *Warming up period* of each replication (applied before collecting data items for relevant statistical analysis) takes *2 hours* of simulation time.

5.2. Evaluation of simulation experiment

The traffic optimization criterion for evaluation is increments of train delays in the modelled area (station). This is the difference between the train exit delay value from the model and the simulated (generated) delay value at the input to the modelled area.

In principle, this value is determined for every single train in each replication. In order to evaluate the simulation, the values of the delay increments thus obtained are processed as follows:

- Average value for each train for all replications.
- Maximum value that is reached for each train in all replicates.
- Average value for all trains in a given replication.
- Maximum value in a given replication.
- Average and maximum values for selected subsets of trains (typically passenger and freight trains, or trains on selected trains, etc.).

6. CASE STUDY

As a case study, a railway station located on a double-tracked line was chosen. One single tracked line is branching at this station as well. The station is an interchange node between passenger trains operated on double-tracked main line and on single-tracked line.

The network taken into a simulation model is extended by neighbouring line segments and by simplified models of 3 neighbouring railway stations. Traffic can be considered in complex point of view also with regard to interface between station and line transport technology.

The core station consists of 8 station tracks, 6 of them are equipped with island platforms with an elevated passenger passageway. It is a common example of railway station in the Czech Republic.

The morning peak hours' time was chosen for testing, when there is the greatest difficulty in organizing the operation of the railway station, especially in cases of passenger train delays.

6.1. Extent of Traffic in Simulation

There is a sample of 30 trains considered. The sample includes 8 passenger trains and 22 freight trains. All passenger trains are obligated to use station track with platform edge, because all of them are stopping for boarding and alighting of passengers. All tracks can be occupied by freight trains. Freight trains are also crossing from main double-tracked line to single-tracked line and vice versa.

6.2. Simulation Scenarios

There are 5 simulation scenarios considered within this simulation study. All of them are based on the same timetable, but they are differing by the way of assignment of a station track to a train. The overview is provided by the Table 1.

Table 1: Simulation Scenarios

Scenario	Description
VA	All trains can use any station track (priority lists of tracks are used for every train).
F6	6 passenger trains have fixed tracks due to passengers' comfort by interchange and time savings.
F8	All 8 passenger trains have fixed tracks. Possible reduction of number of platforms is illustrated (3 tracks are used for passenger traffic in spite of 6).
F8 + 3FT	Scenario based on F8, but extended by fixed assignment of 3 freight trains (for illustration of possible infrastructure limits, e.g. length of trains).
FA	All trains have fixed tracks. It is for illustration of 'rigid' timetables applied e.g. in the case of high capacity utilization.

These scenarios are used for examination of influence of changed operational conditions. The advantage is that the same sample of input delays is applied for all the scenarios. It means that the trains are coming with the same input delay into the modelled area (to the neighbouring stations). The results are comparable in this point of view.

6.3. Delay Increments

The punctuality of timetable is one of the core aspects for the quality level of railway operation. Possible lack of railway infrastructure capacity can be identified by extension of travel times – by increments of delays. On the other hand, for assessment of modelled system –

station and line segments in surroundings the value of input delay (delay occurred by drive on different infrastructure in front of assessed station) is not crucial. Increments of delay in assessed (modelled) area are the core factor.
The values of delay increments are measured in following way. The time when the train leaves the model is reduced by scheduled time and the delay on output is calculated. This value is compared to the value of delay on input and the increment of delay is defined.
There can be three results of this calculation:

- delay increment is equal to 0 – system stability is OK,
- delay increment is less than 0 – system stability is asymptotic (infrastructure is capable to reduce delays due to reserves),
- delay increment is more than 0 – system is increasing values of delays; it can possibly be caused by insufficient capacity of the system.

The third case is the most serious for the railway operation and for that reason this situation is highlighted by simulation assessment if occurs.

6.4. Average Delay Increment

The principle result is average delay increment assessed for all trains in all simulation replications. The results for individual simulation scenarios are in the Table 2. All (positive, zero and negative) values of delay increments are considered in this case (Table 2).

Table 2: Average delay increment per one train [s]

Scenario				
VA	F6	F8	F8 + 3FT	FA
20.9	39.9	39.9	40.1	45.0

The values in the Table 2 show that the average value of delay is increasing by increasing number of trains with fixed assignment of tracks to trains. On the other hand, the same value for scenarios of F6 and F8 refers about the fact that there is a relation to local conditions as well.

The lack of possibilities to solve the traffic situation in an operative way can cause extension of delay. For example, this can be an impact of possible reduction of infrastructure (reduction of number of tracks in station etc.).

Median of delay increments is equal to zero in all cases, because 19.5 – 26.0% of trains (according to scenario) are operated on time in the simulation.

6.5. Average Delay Increment of Delayed Trains Only

Average delay increment of delayed trains represents better feature for assessment of impact e.g. on passengers' comfort. In fact, passengers don't register possible reductions of delay, but they are considering the delay of their train. For that reason, average delay increment for delayed trains in assessed as well.

The term of 'delayed train' must be defined in advance. It is a train with the value of delay increment higher than 30 s. Since 30 s is the 'minimal time step' applied by design of railway timetable (in the Czech Republic), results of simulation are evaluated with precision of 1 s. This measure can compensate possible errors and highlight more serious increment of delay (more than 30 s).

The results are mentioned in the Table 3.

Table 3: Average delay increment per delayed train [s]

Scenario				
VA	F6	F8	F8 + 3FT	FA
289.5	339.9	342.4	338.7	345.0

6.6. Maximal Registered Increment of Delay

Sometimes it if effective to recognize what is the situation in the worst case. Maximal registered increments of delays are assessed due to this in the Table 4. On the other hand, there is no significant relation between the scenario and maximal value in spite of the fact that scenarios with fixed track assignments have slightly worse values.

Table 4: Maximal delay increments [s]

Scenario				
VA	F6	F8	F8 + 3FT	FA
2909	3503	3503	3503	3200

7. CONCLUSIONS

The paper introduces some of other effects that influence quality and reliability of railway traffic and railway infrastructure and these finding were assessed with computer simulation approach.

It is important to note that these findings are find out for just one railway station with one timetable and 5 different scenarios how to organize trains on available tracks within railway station.

The testing of fixed tracks for various variants brings quite surprising results mainly in comparison of variant FA to variants with partial fixed tracks and it could be interesting to test these approaches also for other scenarios or railway stations.

On the other hand, result of variant VA provides better results which is not surprise and this finding support current approach in timetable construction in the Czech Republic where VA variant is almost always used.

Therefore, further research in this area will pay attention to above mentioned aspects of reached results.

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