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Investigation of platforms at railway station switch area with regard to capacity using computer simulation

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Abstract

Railway stations represent important points in railway infrastructure. In the past, railway stations were in many cases built out of city centres due to various reasons. Nowadays when stations are being reconstructed it is relevant to think about building new railway stops near city centres to make railway transportation more attractive to passengers. This approach also motivates passengers to change their transport mode to railway which is eco-friendly with small side effects to life in city centres (e.g. need to have parking places, accidents etc.). The aim of this article is to assess in general the step of designing and building new stop with platforms outside original railway station with impact on train delays in stochastic conditions, impact on timetable construction and on railway capacity at all using microscopic stochastic simulation model created in the OpenTrack simulation software.

Keywords: Railway traffic simulation, capacity of railway lines, railway platforms

1. Introduction

Railway passenger transport should be competitive with individual car transportation as well as with bus transport. Some railway stations are located almost out of the municipalities (e.g., Praha-Podbaba or Krasikov), so walking distances are often too great. Presented research is focused on one of possible options how to make railway more attractive for passengers. This option is based on moving the platforms to location out of original railway station if this place is located closer to municipality (see Fig. 1). A question that the railway administration must address is potential reduction in railway capacity and impact on stability of railway operation.

Trains at platforms located out of station occupy station switch point area as well as the line section during boarding and alighting of passengers.

Precisely designed timetable can partially compensate these limitations but there remain issues with schedule in stochastic conditions with focus on punctuality.

Application of stochastic simulation model developed in the microscopic simulation software OpenTrack seems to be an adequate way to assess this stability.

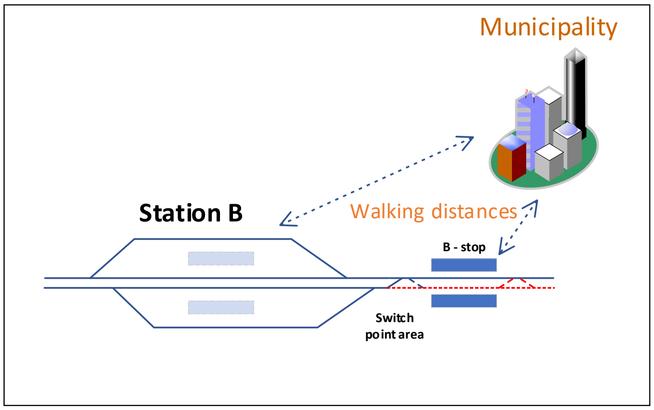

Figure 1. Simplified scheme of situation.

The aim of the research is to investigate whether there are factors related to possible platform movement to outer location that would systematically affect capacity and reliability on such railway lines. The research is based on the use of a computer stochastic microsimulation model.

Operational stability is related to infrastructure capacity. The need to wait on clearance (releasing) of a track should be described as an error in capacity calculation. The results can help decide whether moving platforms is the right step.

This research is conducted within a project leading to modified methodology of railway infrastructure capacity assessment. Position of platforms is one of the features influencing capacity of a railway line and its impact needs to be assessed using simulation model.

2. State of the art

Usage of computer simulation to assess railway traffic is quite common task nowadays.

The issue of platforms in railway stations is examined from two different perspectives. The first one is train platforming problem (designing plan for platform occupancy by trains at the station to have minimum conflicts in real traffic), the second one is simulation of passengers' movement at platforms and stations.

The paper (Bosina E. et al., 2015) is focused on walking and waiting at platforms. It is pointed out that the distribution of passengers along the platform is uneven by waiting.

Delay propagation and process management are researched by (Goverde R.M.P., 2001). The relations between arrivals, departures and dwell and transfer times at the station of Eindhoven (the Netherlands) are assessed.

The railway station is considered as an interconnected complex of routing, timetabling and platforming by (Dewilde at al., 2013). Coordinated approach to assess capacity regarding all these aspects is seen as a presumption for reliable and efficient operation. Mentioned paper is focused on busy railway stations (Brussels, Belgium), but we would like to apply similar complex approach also to relatively small stations.

Different methods for station capacity assessment are compared by (Malavasi, G. et al., 2014) and a new synthetic approach is proposed. This newly proposed approach is focused especially on railway nodes. It is based on deep analysis of some exisitng methodologies for capacity assessment. The way of computation can be classified as analytical. The most important fact for our research is that one of the case studies is focused on the Uhersko station with similar extent of traffic as considered in this paper. There are also untypically located platforms at first and last station tracks at Uhersko railway station.

Routing of trains through a railway station as a sub-problem of automatic timetable generation that is presented by (Zwaneveld, P.J. et al. 2001). This confirms the need of a complex approach to platforming and capacity.

Simulation of railway operation is scope of the paper (Novotný R. and Kavička A., 2019). It is focused on interconnection of micro and mesoscopic simulation approaches.

Computer model for precise train delay calculation is presented by the paper (Fikejz J. and Merta J., 2017). The emphasis is put on application of localisation systems.

The simulation can be applied to other transport networks. The paper (Flores, I. et al., 2015) focuses on the case of urban networks.

3. Methods for capacity assessment

Even though the platforms are formally a part of the station area, capacity impact of platforms moved out of station is usually related to subsequent line.

Important fact is that the switch points and connecting tracks between main (line) tracks are in front of the platforms or behind them (see red marked infrastructure in Fig. 1) and if it is possible to overtake a train at platform. We analysed five stations with moved platforms in the Czech Republic (Praha-Podbaba, Opatovice nad Labem, Brandýs nad Orlicí, Krasíkov, Hoštejn) and there are both types at disposal.

In general, three types of methods for capacity assessment can be used: analytical, simulation and combined.

3.1. Analytical approach

The aim of this research is also to verify selected analytical indicators using computer simulation.

When the station main signals are between platforms and the station, a decrease in capacity can be expressed by the formula (1). Let Δn be capacity difference (number of trains per time); r rate of trains stopping at platform; T duration of analysed time frame [min]; t_{stop} increase of travel time caused by stop [min], it means total of time for deceleration, acceleration as well as dwell time and t_{occup} occupation time (of line section) by trains passing with no stop needed for capacity assessment (occupation or headway time).

$$\Delta n = \frac{r \cdot T \cdot t_{stop}}{t_{occup}\left(t_{occup} + r \cdot t_{stop}\right)} \qquad (1)$$

The difference between this presumption and reality in the case of stochastic operation will be assessed using stochastic microsimulation model.

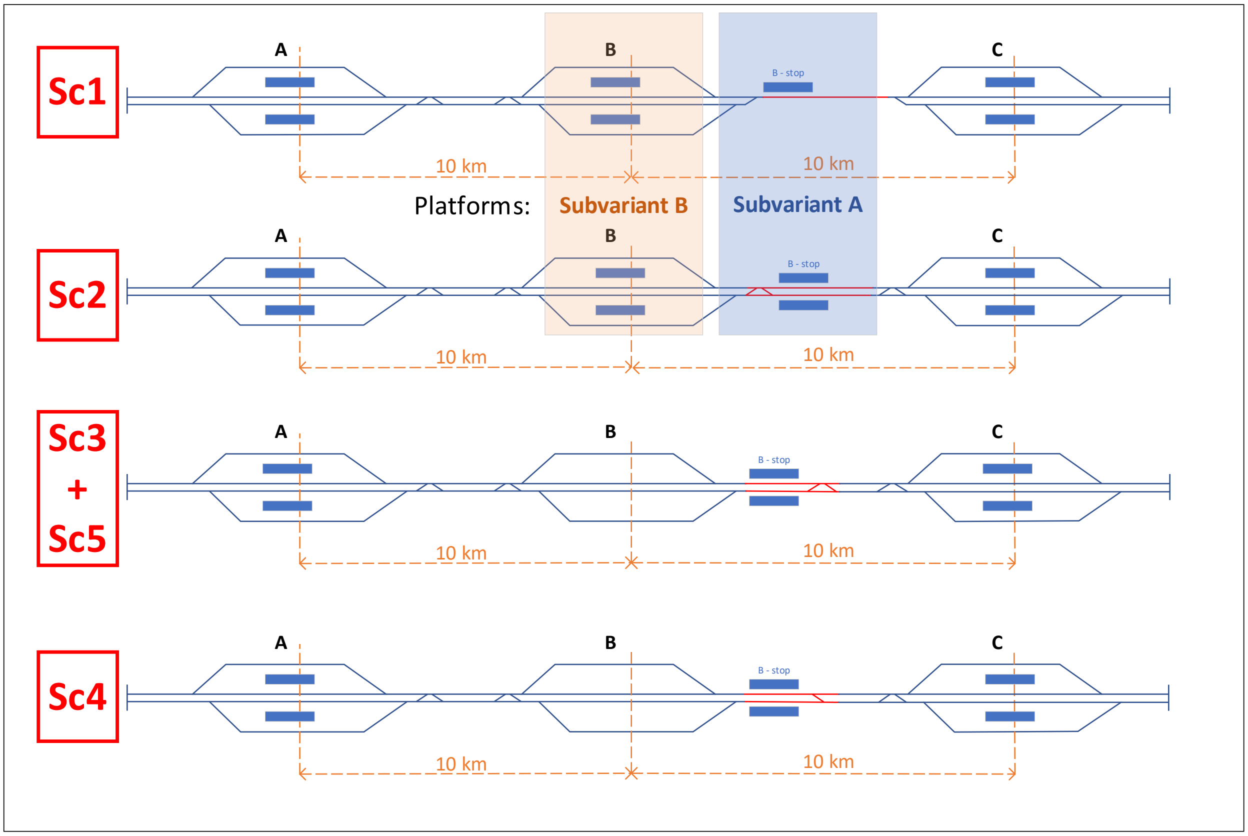

Figure 2. Investigated scenarios (infrastructure) with highlighted changes.

3.2. Simulation model

Microscopic stochastic simulation model in OpenTrack simulation software is applied for evaluation of examined situation related to the platforms out of the station.

Simulation model includes all relevant data about infrastructure as well as about moving clients (trains) – train dynamics, timetable etc. so that in deterministic conditions train run without any disturbances and it is common to verify couple of variants with assessment of results and their comparison.

But main purpose of the simulation approach is to verify the scenarios in stochastic conditions so in this paper, we will focus especially on increment of delays in stochastic conditions individually for each train and it might be also interesting to focus on train categories because interaction between long-distance (passing through) and regional trains (stopping at platforms) creates the core of this research.

4. Case study

A case study was conducted for evaluation of all relevant indicators. The operation used in the case study, including its parameters and data about it, was created as a fictitious model, but it is generally based on routines common in the Czech Republic.

Modelled infrastructure corresponds to the Fig. 1 and details for individual scenarios is in Fig. 2. It is a model railway line consisted of 3 railway stations named as A, B and C. Distance between stations is 10 km. Potential moving of platforms is tested in the case of station B and the platforms are moved approximately 750 m to the line segment between B and C. Railway line is double-tracked in the segment A-B. The segment B-C is modelled in both variants as single-tracked or double-tracked within the study.

Line is equipped with automatic block system which is common nowadays for this kind of lines. It is based on signals dividing line into sections. So, there can be more trains in the intermediate section at the same time.

4.1. Simulation scenarios

The study is based on 5 simulation scenarios marked as Sc1–Sc5, as can be seen in Figure 1. Timetables differ in structure and number of trains.

Infrastructure variants are focused on location of platforms in Sc1 and Sc2. Sub-variants A assess the platform in outer position, closer to municipality. Sub-variants B are focused on platforms at station as it is originally. Moving the platforms is considered only in case of the station B. The scenarios Sc1 and Sc2 differ in number of line tracks between stations B and C.

The mutual comparisons of scenarios Sc2, Sc3 and Sc4 are focused on different variants of line tracks interconnection at station B. Crossover (switch points), connecting both main line tracks, is located between the station B and platforms in outer position (sub-variant A). The scenario Sc3 is focused on the case when the crossover is behind moved platform. Train that arrives as the second in order can possibly overtake the train stopped at the platform for passengers. The scenario Sc4 is modification of a scenario Sc3 with reduced extent of the infrastructure (removal of part of the crossover). The scenario Sc5 is based on the same infrastructure as the scenario Sc3.

There are 3 basic variants of timetable as well. The scenario Sc1 has an individual timetable reflecting one-tracked operation between stations B and C. This timetable has 2 minor modifications differing in the position of platforms at station B.

Scenarios Sc2, Sc3 and Sc4 are based on second variant of timetable designed for double-tracked operation in whole line A–C. Minor modification for both sub-variants of platforms A and B in the scenario Sc2 exists as well (trains stop at B-stop or at the station B whereas departure time stamps for stations A and C are considered as the same).

There is specific timetable designed for Scenario Sc5 (using infrastructure of Sc3). This third variant represents case of extended sojourn time of trains at outer platforms. This situation can occur in some situations, e.g., in the case of an interchange node of more public transport modes (train, bus).

4.2. Scenario Sc1

Scenario Sc1 is dedicated to assessment of single-tracked operation between stations B and C. The operation is consisted of 30 trains (12 stopping at B, 18 passing). Theoretical capacity computed for this operation is n = 51 trains/6 hrs. This capacity should be reduced by Δn = 6 trains/6 hrs (see formula 1) due to moving of platforms out of the station B.

The expected effect that the moving of platforms would worsen operational stability was confirmed for passing trains only. Average increment of delay by running on this line is 20.53 seconds. This value is increased by 7.34 seconds when the platforms are located out of the station B. Other situation is by stopping trains. These trains can reduce delay by 145.38 seconds in the case of standard position of platforms. When the platforms are out of station, delay can be increased by 26.07 seconds in average.

Different results for the two types of trains are since the line track is reserved together with platforms and that this occupation starts earlier by stopping trains. In the case of equal priority of both trains this can be seen as an advantage.

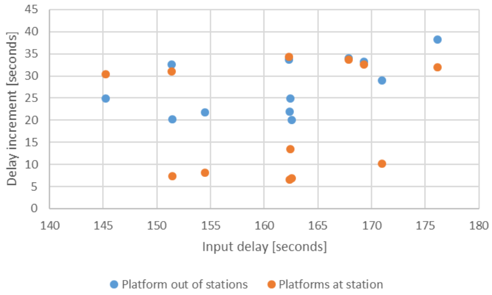

Figure 3. Scenario Sc1 – Delay increment.

It can be seen in the Fig. 3 that the value of delay increment by running on the line A-C is almost not influenced by value of input delay. Trains passing the station B is displayed only.

4.3. Scenario Sc2

The railway line is double tracked in total length including the segment between stations B and C. The station B is equipped with a crossover – switches interconnecting line tracks. This crossover is located between station tracks and moved platforms. Both options of platform location are compared.

The effect of platform position is relatively small, but the outer position is less favourable for the ability to reduce delays on the line. Railway operation is asymptotically stable in both cases. Possible delay can be reduced by 36.12 s in average when the platforms are at the station B. When the platforms are located out of the station the delay can be reduced by 32.07 s only.

A better comparison is provided by analysing of individual trains. There are 46 train routes in simulated timetable. Stability deterioration was recorded for 28 of these trains (57.14%) related to moving of the platforms out of station. When a train is affected, average increment of delay is equal to 18.44 s. Position of platforms has no effect on 9 trains with no change of average delay.

In the timetable there are 3 groups of 4 trains created to consider effect of time gap from the previous train. The first ones follow the non-stopping train with a time gap of 15 min. There is no impact of platform location in the first case (15 min). These trains can reduce delay by 36.2 s with standard deviation 1.1 s by both platform locations. The trains of second group follow the stopping train with a gap of 11.5 min. Impact of platform is small. Average value of delay reduction is 9.6 s when the platforms are at the station and 9.2 s when they are outside. Standard deviation is 5.8 s and 5.7 s respectively. Finally, trains of the third group follow the stopping train with a minimum gap of 6.5 min. These trains can increase the input delay while running on the line. When the platforms are at the station B, delay can be increased about 20.6 s in average (with standard deviation 3.3 s). Moving of platforms out of the station means average increase about 63.5 s. Standard deviation is 7.1 s, because delay increment vary from 58.2 s to 75.6 s by individual trains. The sub-conclusion is that, although statistically inconclusive, technologically there is a need to monitor the time gap between stopping and passing trains, as stopping trains may cause an increase in delays for other trains.

A sub-conclusion is that, although statistically inconclusive, there is a need to monitor the time gap between stopping and passing trains, as trains stopping on outer platforms may cause an increase in delays for other trains. This conclusion can be supported by the technological principles of rail transport.

The minute value of the delay may seem small, but it should be considered that it refers to the effect of a single point on the transport network. The combined effects of several such points could cause a bigger problem.

4.4. Influence of input delay value

Simulation scenario with increased delay value has been elaborated for estimation of influence of input delay. Mean value of input delay was doubled (to 510 s) using negative exponential distribution with maximum value increased to 2000 s, but the rate of delayed trains remained the same (63%).

The delay was reduced by 32.1 s in the standard case and by 71.1 s in the case of a higher mean value of the generated input delays while the train was running on the line. These absolute values sound good, but relative values are worse. Input delay is reduced by 19.0% (in average) in standard case. In the case of increased mean value of input delay, this delay is increased by 1.1%.

Better illustration about relation between average value of input delay and rate of reduction (negative values) as well as extension (positive values) of this delay while running on the line is shown in the Fig. 4. It can be concluded that although the input delay can be better reduced at larger values, proportionally this possibility is weakened.

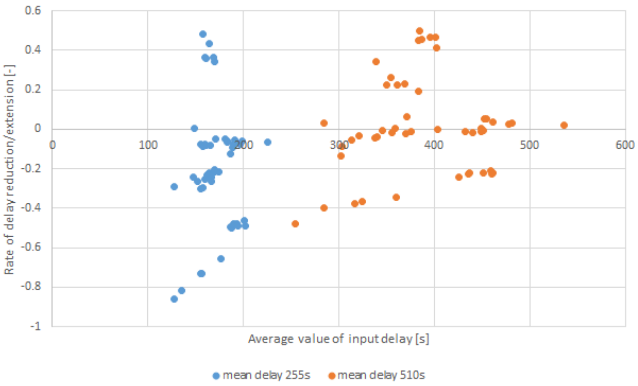

Figure 4. Input delay reduction

4.5. Scenario Sc3

Location of crossover is the only difference between scenarios Sc2 and Sc3. The crossover can be located between station tracks and platforms in outer position (marked with black colour in the Fig. 1) or behind these platforms (red colour). Moving the crossover behind platforms makes overtaking a train at the platform by another train possible. Only scenarios with the platform in the outer position are compared in this scenario. Position of the crossover itself has small effect without outer platforms.

In general, only a small effect was observed. On average, a train will reduce the delay by 35.07 s during its journey along the entire line. Moving the crossover behind the platforms placed in outer area increased this value about 0.51 s only.

Impact on individual train routes is greater as it is shown in the Fig. 5.

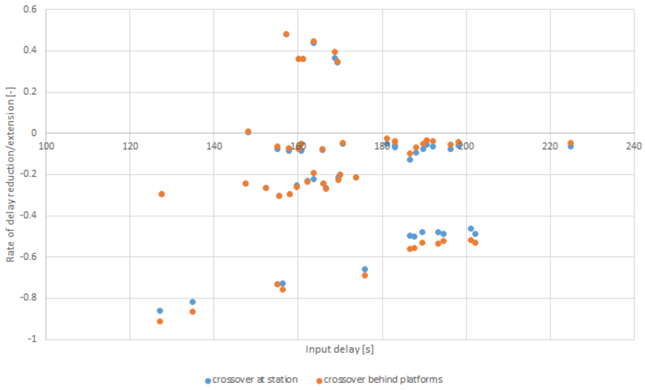

Figure 5. Input delay reduction - crossover

The values for individual trains coming from both scenarios are comparable. The values for the case with crossover behind platforms present better or the same ability to reduce the delay for 51.0% of trains. It beneficial especially for trains in direction C – A. This issue cannot be solved in a simply and general way. It is related also to structure of timetable and to extent of station and number of trains. Individual simulation assessment can be recommended for each individual case.

4.6. Scenario Sc4

The scenario Sc4 is a modification of the scenario Sc3 with incomplete crossover behind outer platforms. This is inspired by real application in the railway station Krasíkov. Average value of output delay (on arrival to final stop) decreased by about 0.38% in comparison with alternative of complete crossover behind platforms and increased by 1.03% in comparison with alternative based on crossover between outer platforms and station tracks. These differences are very small, and they are closely related to specific conditions. For this reason, application of microsimulation is strictly recommended for this purpose.

4.7. Scenario Sc5

This scenario represents a part of research focused on specific situation when there are extended sojourn times of stopping trains (5 or 7 min) at the outer platforms of the station B (due to e.g., mutual interchange between railway a bus transport at the station B).

Railway operation in this scenario is stable. The input delay is reduced by 69.8% in average. It means that extended sojourn times of trains may not be an issue. On the other hand, it also depends on number of trains and other properties of timetable.

Part of evaluation is dedicated also to interaction and time gap between trains. Each train with stop at station B is followed by passing train. Relation between time gap and volume of reduced delay is displayed in the Fig. 6. Average input delay of passing train is 157.03 s.

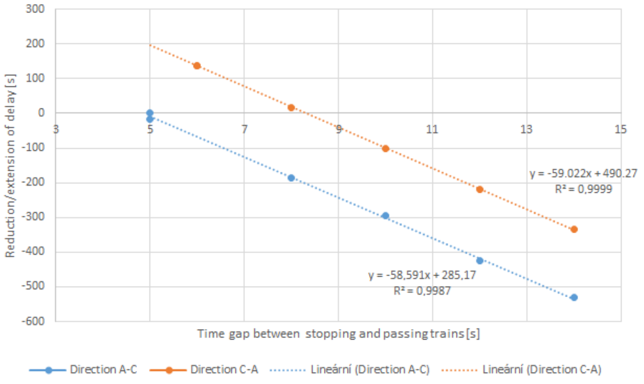

Figure 6. Impact of time gaps between trains

From the Figure 5 it is obvious that there is almost linear relationship that can befound between the ability to reduce delay and the time gap between trains in the simulation case study.

For complexity, reduction of capacity Δn is 13.5 trains/6 hrs in direction A-C and 17.1 trains/6 hrs in direction C-A due to extended sojourn time (7 min versus 5 min in opposite direction).

5. Conclusions

The main conclusion of the research as well as of this paper is that moving the platforms into outer area of stations is possible. It can improve attractiveness of railway transport for passengers due to reduction of distance to be walked. The impact on capacity is not too great, but some effects can be significant.

This solution can become a disadvantage in the case of passing trains running at short time gaps behind stopping trains. Passing trains are also more sensitive to possible delay increments.

A recommendation on where to place the crossover of the main line tracks has not been found as there are multiple factors affecting the situation.

Extension of sojourn times of trains at outer platforms is also possible and it is obvious from the scenario Sc5.

Final recommendations for railway infrastructure managers (authorities responsible for railway infrastructure) are that when they decide to move the platforms out of the station with potential to make railway more attractive for passengers, it should be assessed at first. Capacity impact is relatively small, but final operating conditions depend on many factors. Finally, it is recommended to use mainly stochastic microsimulation models in such cases because they allow the situations to be assessed in the context of many sub-factors affecting the resulting traffic characteristics.

Proposed analytic indicator for quick assessment of capacity change (see formula 1) corresponds to quantitative capacity aspects, but the relation with operational reliability was not confirmed.

The objective of the research has been met, the possibility of designing and using outer platforms in stations has been verified. The simulation scenarios were created the way that they allow the assessment in different contexts. The factor that emerged as dominant and systematically acting is the time gap between stopping and passing trains. Its increasing length had a positive effect on stability in the case study. For other factors examined, such as the position of the crossover, this was found to depend on a complex of many different factors.

The final recommendation for e.g., railway administration should be that using of outer platforms can be a suitable solution, with acceptable impact on capacity in general. On the other hand, as it was mentioned above, there are usually many specific local factors influencing this issue. These local factors can cause significant capacity or stability impacts as well so that application of microscopic simulation assessment for specific case should be recommended as well, especially when we talk about complex railway station with heavy traffic (impact of sequence of individual trains has been stated).

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