The Possibility of Utilising Maximum Capacity of the Double-Track Railway By Using Innovative Traffic Organisation

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Abstract

This paper will analyse the existing capacity of the double-track railway line M104 Novska – Vinkovci – Tovarnik – State Border – (Šid), located along the RH1 national corridor in Croatia. Upon the analysis, the paper proposes a new and innovative way or organising railway traffic on the line, which is a reflection of the maximum capacity utilisation regardless of the train transport route. Before using the proposed organisation, the track must be fitted with the modern signal and safety system which ensures traffic along the single track of the double-track railway line in both directions. Furthermore, the paper puts forward the methodology and impact of certain proposed criteria on the new organisation method. A simulation of the proposed organisation, using OpenTrack software, examines the results in terms of justification for using such a concept. The M104 railway serves as a case study for testing the innovation in railway traffic organisation.

Keywords: railway track capacity, innovative traffic management, dynamic traffic management, simulation method, OpenTrack

1. Introduction

Railway traffic, known for its large transport volume on mid and long distances, requires quality tracks to deliver quality service. Lack of investments in railway tracks is exactly why there is a lack of sufficient track capacity on certain lines. Namely, investments in railway tracks require enormous financial means with a long-term repayment

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period (over 20 years). At the same time, once a railway infrastructure is constructed, it cannot be constantly used in exploitation without periodic examination and maintenance, in order for it to remain efficient. This regular maintenance is more times a type of saving method for the railway undertaking, which in turn leads to performance hinderance which again leads to the reduction in transport speed, increase in journey time, as well as a change in the track geometry. The consequence of all this is a drop in track performance and reduction in the maximum available capacity of the railway track, that is, its permeability and transportability.

Many authors propose various solutions to track capacity degradation, Landex et al. (2006) speak of a new method of calculating UIC 406 methodology in Denmark and examples. Sogin et al. (2013) compare and analyse the capacity of single- and double-track lines. Quaglietta (2013) handles the problem the optimization of capacity on the railway networks. Research explore ways to increase the capacity of the network. That means maximization of the technological efficiency of the system by shortening the length of block sections, thus reducing the minimum line headway and the energy consumption but increasing investments cost. This paper presents a design approach addressed to identify the signalling layout which minimizes the investment and management cost, while respecting the required level of capacity. To solve this problem, authors Quaglietta (2013) present an innovative design framework where a stochastic multi-train simulation model integrates within a “black box” optimisation tools. Ljubaj et al. (2018) show how to increase railway capacity and simulation of this new proposed solution. Camaj et al. (2015) show how to use special software for simulation technological activities of complex transport centre. Masek et al. (2016) present how increase train capacity by using a new type of railway freight wagon.

This paper starts from the fact that every line, single- or double-track, possesses certain capacity regardless of the direction of transport.

The track capacity of the double-track railway line in the railway network of the Republic of Croatia will be analysed and criteria for later development of the methodology for utilising the maximum available capacity of the double-track line will be developed. In fact, an adequate definition of the criteria will be later used to construct a model for managing the unutilised capacity of double-track lines. The reason for analysing the double-track line is because on such a line there is track capacity in certain daily intervals that remains unutilised, and as such, could be used as additional available capacity.

Upon defining the criteria, they will be tested on a previously devised computer model of the double-track M104 railway Novska – Vinkovci – Tovarnik – State Border – (Šid). A specialized software package OpenTrack will be used for the initial simulation of the new traffic organisation and modelling and simulation of railway systems.

Conclusive remarks will include the obtained results of the analysis which will be expressed in terms of infrastructure fees that the railway undertaking may charge, as well as future research plans in that area.

2. Capacity — term and issue, the methodology of determining track capacity

Railway track capacity is the most significant parameter that defines the track based on the criterium of maximum output. Track capacity can be static or dynamic. Dynamic capacity includes static capacity and the temporal and spatial dimension. Therefore, track capacity is the maximum number of trains operating in a certain time interval along every section and each track for each direction. It is easy to conclude that track capacity is the most important track parameter, which lets us gain insight into the use and exploitation condition of the track. Bogović et al. (2006)

There are different methods of determining railway track capacity, but the most accepted and unified method is the one approved by the International Union of Railways (UIC) — the UIC 406 method. The method consists of 5 steps which must be taken in order to provide an accurate result. HŽ Infrastruktura d.o.o. (2014).
2.1. UIC 406 Methodology

Back in 2014, the UIC recommended a new method of calculating the utilisation of the capacity of a track by compressing timetable. It is unique in the way that it is applicable to real-time timetables. Apart from the capacity calculation, it also makes it possible to determine the capacity of intersections based on the same principles. To determine the maximum track transport capacity, the track first needs to be divided into sections, which consist of several interstation spacings. For each section, a maximum railway transport capacity needs to be calculated for the limited interstation spacing. The limited spacing is the space between two neighbouring stations, in which the median several interstation spacings.

There are five steps to be taken when determining capacity by means of compressing:

- Defining the infrastructure and limiting the timetable,
- Defining the section for estimation,
- Calculating the utilisation of capacity,
- Estimating the utilisation of capacity,
- Estimating the existing capacities – this part uses the calculations from the previous steps on the representational sections of the railway which is then completed with additional train routes until a desired (defined) capacity utilisation is achieved.

Capacity utilisation may be calculated using the following formula:

\[
\text{capacity utilisation} = \frac{\text{occupancy time + additional times}}{\text{defined time interval}} \times 100 \% 
\]  

whereby additional times refer to any time added with the aim of ensuring transport quality HŽ Infrastruktura d.o.o., (2014).

Upon the calculation of capacity utilisation, an estimation needs to be made (step 4). If the capacity utilisation value is under 100 per cent, a part of the capacity has remained unutilised. In that case, additional routes are needed until the utilisation on the analysed section reaches 100 per cent or until it is no longer feasible to add a route Ljubaj et al. (2018).

2.2. Description of the proposed solution to the issue of track capacity

In accordance with the usual purpose of using a double-track railway is ensuring train traffic in two directions along the same section, where each track is used for train traffic in a specific direction (in Croatia, right-hand traffic). Based on the aforementioned methodology, a double-track capacity is determined based on the current timetable for each direction for which the track is intended.

However, this paper assumes that a track has a certain capacity regardless of the defined direction of traffic along a certain track, which offers the possibility of adjusting the track to the current transport demands, and thereby the maximum utilisation of capacity it can provide. This would be beneficial particularly at peak times, in the morning and the afternoon, when commuters head towards administrative and economic centres — the times that create a greater transport demand. Similarly, in the harvest season, when there is a lot of transport of goods towards certain destinations (ships in ports, etc.), the same issue takes place which results in an increase of transport demand for that direction. One of the techniques to tackle such disturbances and occurrences of additional demand is by offering and utilising the unused track capacity, i.e. utilisation of the track capacity that has not been defined in the design for that direction. Therefore, the additional track would not be used constantly for that direction, rather it would only be used when there is a great need at certain times during the day and in certain time slots — when feasible and required.
(shown on Fig.1). Along these track sections, i.e. railway line, additional signal and safety equipment needs to be installed which would enable the maximum utilisation of performances offered by the track. Naturally, since the track had not been designed for that direction, it would be used only as an exception for that purpose, and only when certain indicators and criteria are met to justify the use of the track. The following part of the paper will define individual criteria and indicators and demonstrate their significance in the entire process of using the irregular track for the traffic direction for which it had not been designed.

![Schematic representation of possible case scenarios of track utilisation](image)

**Fig.1.** Schematic representation of possible case scenarios of track utilisation (a) normal, b) same direction right c) same direction left)

### 3. Defining and describing the criteria of maximum utilisation of track capacities

In order to adequately manage the additional available track capacity, we need to define the criteria that affect the innovative traffic management analysed in this paper.

The criteria that directly or indirectly affect the potential decision to utilise the additional track capacity are the following.

#### 3.1. Number of trains holding

This criterion shows how many trains are not operating while holding and waiting to continue towards their destination. It also reveals the state of locomotives — whether they are moving or stationary. For haul vehicles to be used economically, they need to be moving, because only by moving do they generate profit and not a loss for their managers.

#### 3.2. Train ranking

The train ranking criterion indicates the significance of a certain that is supposed to operate on the network but is unable to do so. Also, train ranking indicates the potential loss of a certain train due to the inability to operate due to insufficient capacity. Therefore, a train of a higher rank in passenger or cargo transport has a higher cost of holding time than a lower ranking train, which means that in usual circumstances, it should have priority of traffic over all other trains.

#### 3.3. Train holding – Insufficient capacity

This criterion is essential because it directly indicates how much time a certain train has lost while holding due to insufficient capacity, i.e. inability to operate.

#### 3.4. Train holding cost

Holding cost is a parameter which is directly related to the previous two parameters, placing them in a direct cost ratio, i.e. indicating the cost of train holding.
3.5. Cost of train holding from the opposite direction

This parameter is a direct consequence of train operation from the direction with insufficient track capacity. It is the cost parameter, that is, the loss for the train that should operate on a certain track but is unable to do so because the capacity was already assigned to another train. Specifically, this might refer to an inbound train from the opposite direction to the train in question.

3.6. Transported cargo priority

Importance or value and type of goods being transported by train also plays an important role in making decisions on train holding and available capacity. Generally, more valuable goods should be given higher priority than the economically less valuable (e.g., groceries that easily go bad).

3.7. Train driving distance

A distance which train covers is a criterion that affects the overall significance of the train and right to use available capacity. For instance, train holding time is less important for long distance trains than for the short distance ones. Namely, a train covering long distances can make up for its delays throughout the remained of its operation, whereas a short distance train is less likely to achieve that.

3.8. Infrastructural costs

Infrastructural costs incur (for the infrastructure manager) when a train is holding on the railway line or station or several stations, creating an additional expense, since these trains congest the infrastructure, particularly in stations, where it is essential for normal operation of trains. At the same time, infrastructural costs are also incurred for railway operators, which is why it should be minimised as much as possible.

3.9. Hauling costs

Hauling costs affect the overall train costs. It would, therefore, be wise for the electric and diesel-powered vehicles not to hold and waste energy but to operate on the track and invest that energy into moving trains.

In order to elaborate the innovative traffic organisation, the following chapter will analyse in detail the simulation process, that is, the calculation of potential additional capacity which might become available for utilisation.

4. The case study of a possible application of innovative solutions to traffic organisation

This part of the paper will attempt to simulate the proposed solution of the double-track M104 railway line, which already has the predisposition to be a test track for this kind of concept. However, before the construction and testing of the model, the M104 needs to be further described.
4.1. Description of the M104 railway line Novska – Vinkovci – Tovarnik – State Border – (Šid)

![Fig. 2 Illustration of the M104 line in the railway network map of the Republic of Croatia](image)

The M104 (shown on Fig. 2) is the main international railway line located on the former X Pan-European transport corridor and part of today’s RH1 national Croatian corridor. The M104 track connects to the European Mediterranean corridor and the Rhein-Danube corridor. It is a 185 km long double-track line, electrified with 25 kV, 50 Hz system and fitted with the APB (Absolute Permissive Block). The track is in a relatively good condition, allowing speeds of up to 160 km/h at some sections, with the average speed of 80–100 km/h. The braking distance along the entire line is 1500 meters, and since the track is mostly of lowland character, the maximum measurable resistance is 6 daN/t HŽ Infrastrukutura d.o.o. (2018).

The line is divided into sections Novska – Strizivojna Vrpolje, Strizivojna Vrpolje – Vinkovci, and Vinkovci – Tovarnik, due to organisational and technical reasons. Based on the calculations in the timetable from 2017/18 HŽ Infrastrukutura d.o.o. (2017), the most unfavourable is the section between stations Vinkovci and Ivankovo, section Vinkovci – Tovarnik where the maximum track permeability for Vinkovci – Jankovci is 167 trains, and Jankovci – Vinkovci, 183 trains Fakultet prometnih znanosti & DB Engineering & Consulting GmbH (2016).

4.2. Simulation of the innovation traffic organisation

The concept of the innovative new traffic organisation has been tested using the specialised software package for modelling and simulation in railway transport — OpenTrack. This simulation has aimed to determine what the actual permeability is on the track which, in its essence (default), was not intended for a train to operate in that direction. The track model itself has not undergone any modifications, but the train stations have been equipped with home signals at inbound sides of the tracks if they did not previously have any. These changes and upgrades were necessary prerequisites in order for the entire concept to be simulated. A schematic representation of the situation is shown in Figure 3.
When performing the simulation of train traffic on an irregular track, trains operate in interstation distances. Due to governing laws and safety reasons, the maximum allowed train speed is 100 km/h HŽ Infrastruktura d.o.o. (2018). These changes ensure the following capacity calculations:

For Jankovci – Vinkovci, where the right track of the railway has been analysed, the track capacity amounts to 64 trains a day.

For Vinkovci – Jankovci, where the left railway track has been analysed, the track capacity amounts to 64 trains a day.

5. Discussion and concluding remarks

Recognising the problem of insufficient track capacity is becoming more and more important due to the constant increase in the railway passenger and cargo transport, and due to the common transport policy which favours transporting passengers and cargo in an economically and environmentally more efficient mode of transport — in this case the railway. The insufficient capacity is particularly evident since railway undertakings from the neighbouring countries have not invested into the modernisation and development of the railway infrastructure because they opted for investments in road transport, which in turn led to a lack of funding for the railway system. With Croatian accession to the European Union and access to European funding and stronger political and social activity, things have begun to change, but in the meantime, there is a need for a solution.

One of the potential solutions presented in this paper is the possibility of utilising the maximum available capacity of the double-track railway line by implementing an innovative traffic organisation with minimum investments. This redistribution model would take into consideration the objectively available capacity a certain track has and attempt to put it into operation of maximum capacity utilisation, i.e. positive response to increasing demands for transport (additional capacity).
In order to develop this model, the track first needs to be fitted with modern signalling and safety systems for the trains to operate on tracks that were not meant for operation in the opposite direction.

The next step is to identify the times of day when the second (irregular) track should be used to satisfy the current transport demand.

Finally, the last step is to identify the criteria that affect the mechanism that decides on the use of the proposed solution of regulating train traffic. These criteria have been identified and described in this paper and will be used as a framework for further development of the model.

After the criteria have been validated and tested, they will become a basis for the development of the model that will help dispatchers and other executive personnel to easier and rationally make decisions about when and under what conditions they will let trains operate on the irregular track, and the time in which this process is economically and technologically justifiable.

The paper has also given an estimation of the obtained analysis result as well as a calculation of a certain amount of the railway infrastructure fee that the infrastructure manager can charge by using the additional capacity. According to a form for obtaining additional track capacity, an additional fee of 611 EUR+VAT can be charged for railway infrastructure for passenger trains, and 1255,68 EUR + VAT for cargo trains.

Such a solution offers a possibility for the railway operators to gain certain benefits from using additional capacity, which also offers a possibility of more passengers or cargo in a time interval, as well as the better utilisation of the modes of transport. Of course, the maximum amount refers to the peak time, at which the capacity utilisation exceeds 100 per cent. A more accurate indicator would be if the value referred to 1 hour since it is likely that the additional capacity will only be utilised for a few hours in a day, and only occasionally or hardly ever — a full day.

This paper represents an introduction and background for future research, development and testing of a model that will be operational and applicable in real-time operational conditions of the transport process.

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