XXI INTERNATIONAL SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '24
October 10-11, 2024; Niš, Serbia

Original scientific paper DOI: 10.5937/Railcon24039A

ANALYSIS OF STATION'S CAPACITY REGARDING THE APPLIED INTERLOCKING SYSTEM, ON THE EXAMPLE OF THE TENT KALENIC STATION

Miodrag ALEKSIĆ[1] [0009-0003-7296-2268]
Predrag JOVANOVIĆ[2] [0000-0002-7502-9727]
Dragana MACURA[3] [0000-0002-6439-7938]

Abstract – *Capacity of railway station is highly dependable on used interlocking system and traffic management pattern. Interlocking system's improvement requires significant financial resources, while traffic pattern could be changed by applying different management rules, depending on transport demand. This means that it is desirable to determine a certain trade-off between these parameters, up to the maximum capacity utilization index with the existing interlocking system. Several methods have been developed that consider given parameters for station capacity determination. In this paper we compare some of the methods for capacity determination, using the example of the Kalenic station, which was recently taken over by TENT from another industrial system.*

Keywords – railway, station capacity, capacity utilization index, traffic pattern.

1. INTRODUCTION

Thermal Power Plant "Nikola Tesla" (TPP NT) is a power plant complex in the Republic of Serbia operated by Elektroprivreda Srbije (EPS). TPP NT is the largest electricity producer in the Southeast Europe. Annually, TENT generates more than 50% of electricity in Serbia. TPP NT has the industrial railway – a railway managed by a business entity and used for the transport of goods and/or persons for its own business. Their industrial railway has highly intensive rail traffic with 50 pairs of trains per day, transporting mostly coal, but also materials and equipment for TPP Kolubara and TPP NT and other users. One train usually consists of 27 wagons, and an average cargo of 1,520 t. The daily volume of transport is 76,000 t of coal, and 2,300,000 t monthly. The industrial railway with this volume of work is one of the busiest railways in Europe. TPP NT invests permanently in its railway system so it works more efficiently, reliably, and safely.

An interlocking system plays a crucial role in ensuring safe and efficient railway operations by preventing accidents caused by conflicting movements on tracks. It ensures that only one train is allowed to enter a specific section of track at a time, thus preventing collisions and ensuring safe operations. The system uses electronic technology to monitor the position of switches and signals, as well as the presence of trains on the tracks. There are many benefits of using the modern interlocking system such as the capacity of railway stations, enhancing compliance with safety regulations and standards, and improving productivity and efficiency of the railway system.

By opening a railway market and with more actors in the railway market, the capacity of the railway infrastructure has become a bottleneck for the entire railway system [1]. As a result, the quality of transport services has diminished, primarily due to increasing train delays and the reliability of transport services. Efficient capacity utilization is a railway challenge around the world. The paper [2] emphasized that railway capacity is a very complex concept due to many relevant factors such as infrastructure, rolling stock, signaling and operation planning. In their paper, over 60 papers related to railway capacity have been examined and the contributions are summarized.

2. CAPACITY CALCULATION METHODS FOR THE SWITHCING AREAS

Infrastructure capacity represents the number of train movements that can be realized in the considered time. Capacity utilization index can be calculated either as a ratio of the number of operating routes and all possible routes within given time interval, or as a ratio

[1] EPS, TENT Belgrade – Obrenovac branch, Obrenovac, Serbia, Miodrag.Aleksic@eps.rs
[2] University of Belgrade – Faculty of Transport and Traffic Engineering, Belgrade, Serbia, p.jovanovic@sf.bg.ac.rs
[3] University of Belgrade – Faculty of Transport and Traffic Engineering, Belgrade, Serbia, d.macura@sf.bg.ac.rs

of switching area occupation time and total observation time.

Today, there are several widely accepted methods for capacity utilization assessment of the switching area. All of these methods assume already defined traffic pattern, in terms that sequence of the running routes is known, or, at least, that the probability of the next route could be determined, for each successive route.

Within this paper, Potthoff method [3] and method proposed by UIC 406 Leaflet [4], will be discussed.

2.1. Potthoff method

The Potthoff method is based on global analysis of the traffic pattern within time period T. At the very beginning, method requires topological analysis of the switching area in order to mutually compare all assumed (possible) routes. The most convenient data structure for this task is compatibility matrix, in which rows and columns represent all considering routes. Each element in such a matrix represents compatibility or incompatibility of the two routes (at intersection of the given row and column). Two routes are mutually incompatible if they are mutually intersecting, diverging, converging, consecutive at same infrastructure element, frontally in a collision, or if the row and column represent the same route.

After competition of the compatibility matrix, the number of all movements should be determined, considering each predicted route, in order to determine the average number of compatible routes. To obtain the average number of compatible routes, the respective weight coefficient for each pair of routes should be calculated as:

$$n_i \cdot n_j \tag{1}$$

and the average number of compatible routes will be calculated as:

$$n_{med} = \frac{N^2}{\sum(n_i \cdot n_j)} \tag{2}$$

where:

- N represents total number of movements,
- n_i number of movements considering route i,
- n_j number of movements considering route j.

For all mutually compatible routes, the respective weight will have value equal to zero.

In the following step, the matrix of occupation times has to be formed. Within that matrix, the elements with $i = j$ will have the value of infrastructure occupation time with route i, while for elements with different routes ($i \neq j$), the value represents the period during which the route j may not be run, because the is an incompatible movement on route i.

After the determination of each element t_{ij} of occupation matrix, the average occupation time is calculated as:

$$t_{med} = \frac{\sum(n_i \cdot n_j \cdot t_{ij})}{\sum(n_i \cdot n_j)} \tag{3}$$

At the end, the total occupation time, *B*, and capacity utilization index, U, should be calculated, for the station, or switching area, as a whole:

$$B = \frac{N}{n_{med}} \cdot t_{med} \tag{4}$$

$$U = \frac{B}{T} = \frac{N}{n_{med}} \cdot \frac{t_{med}}{T} \tag{5}$$

where *T* represents total observation time.

Further, method allows us to rate traffic pattern quality, through calculation of the total delay generated within the switching area, as the sum of all delays related to each pair of incompatible routes, since each movement forbids movements of all incompatible routes. For calculation of those generated delays, probability of the next movement should be introduced, as well as some other assumptions, such as FIFO type of service, regardless of train ranks. Also, to conduct a complete quality assessment, apart from route pairs, one should consider probability of simultaneously route execution with each set of two compatible routes, three compatible routes, and so on.

2.2. UIC method

A procedure for capacity calculation recommended by UIC is based on compression method. In practice, it means that all route paths should be as close as possible to each other, i.e. at minimum headway time.

Hence, at first step, minimum headways for each route pairs have to be obtained. For the duration of minimum headway time, considered movement is excluded by another movement. As, by definition, headway time represents a time period between passing by a point of two consecutive trains, the minimum headway time is calculated as the moment when the consecutive movement could start after the start of the previous movement. If the two movements are compatible, and therefore they could be run simultaneously, minimum headway time would have value of zero.

All minimum follow-up times between each pair of the assumed routes should form a matrix, very similar to compatibility matrix from the previous method.

Further, a timetable or route sequence has to be available; the UIC method for capacity calculation of the switch area requires a movement sequence as a necessary input.

This method assumes that each route’s occupation time starts as soon as possible, after the preceding movement, regarding calculated headway time. Since the minimum headway time has a value of zero for compatible movements, parallel movements are taken into consideration.

The goal of the method is to obtain the total of all occupation times, which should result as the sum of all excluding times of concatenated movements.

To obtain total occupation time, table should be prepared in a way that the number of columns should be equal to the number of all possible routes increased by 2, while number of rows should be equal to the number of the movements provided by the timetable in a given time period, increased up to 3 rows, to provide repetition of the first two or three movements in order to disable "open end" of the timetable – this is requirement from timetable cyclicity.

The first movement should be placed at 0.0 minute, i.e. it is assumed that it starts immediately with observation period. After that, the first row should be populated with minimum headway values, regarding all other assumed movements. Further, at the beginning of each row, as starting time for the next movement the next the corresponding value from the previous row should be taken and then. For each row, the end of occupation times should be obtained by summarizing values from previous row and corresponding values from minimum headway matrix. In the case of compatible movements, the minimum headway time is equal to zero and it is possible that calculated value is lesser than the one in previous row, in which case it should be replaced with higher value.

Previous procedure should be repeated for all assumed movements according to given timetable, and for the repetition of first movement, from the first row.

Finally, the total occupation time is defined by the starting time of the additional movement (repeated the first one) and occupation time rate is calculated as:

$$OTR = \frac{t_{n+1}}{T} \cdot 100 \tag{6}$$

where t_{n+1} represents starting time of the additional movement and T represents observation time.

At the end, going backward the number of concatenations can be obtained. This number represents the chain of the execution of mutually incompatible movements, since some of the compatible are executed simultaneously. Ratio of the number of concatenations and total number of movements assumed by the timetable, give us the concatenation rate, φ, which explains incompatibility of given traffic pattern.

Considering selected methods for the capacity determination of the switching area, it could be concluded that capacity, apart of the switching area topology, greatly depends of implemented interlocking system. Modern interlocking systems enable shorter minimum headway times, which are the most important capacity parameters.

Introduction of the new, modern interlocking system demands significant financial investment, and usually it is delayed as much as possible. With the increase of the capacity utilization, switching area may become bottle-neck for the entire line, or even part of the network. Although there is no exact guidance when to upgrade interlocking system, usually capacity utilization rate of over 65% is considered critical, since the service quality significantly decreases with its incrementation. For the capacity utilization rates beyond 70% service quality is often very bad, while no operational measures could not be taken in order to decrease capacity utilization rate. That's why the capacity utilization rate of 60% is considered as trade-off point at which interlocking system modification or upgrade should be considered.

3. CAPACITY DETREMINATION FOR THE TENT KALENIC STATION

Railway station Kalenic in the past years was incorporated into TENT railways system from another industrial governance. The station represents the connection between railway network managed by Infrastruktura Zeleznica Srbije and transport system within TENT. At the moment, all switches in the station have to be set manually on the spot, and after setting to the required position, switches must be locked and keys have to be taken to the train dispatcher, for visual confirmation of the correct position.

Schematic view of the station is shown in Figure 1.

For the case study, we considered an average operational day, with total of 45 movements, of which 15 were shunting movements.

Both methods gave capacity utilization rate between 20 and 25%, which is relatively small utilization and, under the observed condition, the modernization of interlocking system should not be considered. Exact results are shown in Table 1.

Tab. 1. Capacity utilization for different calculation methods

Calculation method	Utilization rate [%]
Potthoff	21.94
UIC	24.24

The difference in the obtained results arises from the fact that Potthoff method does not consider exact route sequence, but the relative probability of upcoming movement, determined through the route frequencies within given traffic pattern.

As an operational rule, for shunting movements, safety zone is not the necessary requirement. That leads to the shorter minimum headways between two or more consecutive shunting routes. If a mandatory safety zone were to be introduced, immediately after the intended end point of the shunting movement, the capacity utilization rates would increase, but not significantly, since the total number of planned shunting movement is one third of the total number of routes (Table 2).

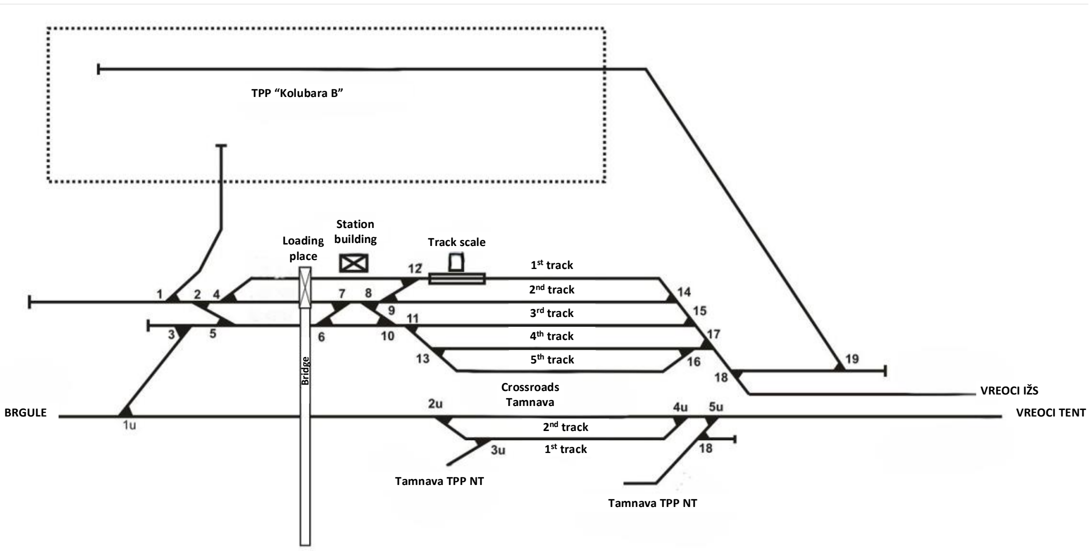

Fig. 1. The Layout of the Kalenic station

Tab. 2. Capacity utilization for different calculation methods and for required safety zone for all routes

Calculation method	Utilization rate [%]
Potthoff	24.38
UIC	28.17

For the next period, even with the increased traffic volume, operational measures should be sufficient to maintain the capacity utilization rate at the desired level.

4. CONCLUSION

In the previous period, the railway station Kalenic has been taken over for operations by TENT. The station is not equipped with modern interlocking system and all switches are setting up manually, on the spot.

However, according to the average transport volume examined for the one operational day, station capacity is sufficient for the satisfactory quality of transport service. Capacity utilization index is around 25%, which was obtained using two different calculation methods.

In the following period, especially in the case of an increase in the transport volume, attention should be directed to the side of the Kalenic station towards Vreoci, since the topology of the station is such that most routes from that side are mutually incompatible.

If one considers the potential modernization of the applied interlocking system, due to the relatively low level of capacity utilization, the eventual multi-stage application of modern systems should be considered, so that the level of investments could follow the potential gradual increase in transport volume.

REFERENCES

[1] P. Jovanović, N. Pavlović, I. Belošević, S. Milinković, *A Graph Application for Design and Capacity Analysis of Railway Junctions*, 8th International Conference on Railway Operations Modelling and Analysis (ICROMA), Norrköping, Sweden, 2019

[2] M. K. Sameni, A. Moradi, *Railway capacity: A review of analysis methods*, Journal of Rail Transport Planning & Management, Vol. 24, 2022.

[3] Potthoff, G., Verkerhrsstnomungslehre 1. *Transpress VEB Verlag für Verkehrswesen*, Berlin, 1963.

[4] Union International des Chemins de Fer – UIC, *UIC Code 406 – Capacity, 2nd Edition*, UIC, Paris, 2013.