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

Original scientific paper DOI: 10.5937/Railcon24095V

OVERVIEW OF METHODS FOR DETERMINING THE CAPACITY OF THE RAILWAY NETWORK

Julia VARADINOVA[1]
Petar KOSTADINOV[2]

Abstract – *The throughput and transport capacities of the railway sections, lines and network are characteristic technical and operational indicators showing the technical and organizational capabilities of the specified elements of railway transport for the realization of the volume of transported work. The report provides an overview of the methods used to determine the throughput on the railway network. The throughput capacity of a specific railway section was analyzed in connection with the ongoing and upcoming works on the implementation of a number of investment projects in the railway infrastructure and implementation of the ERTMS/ETCS system.*

Keywords – railway infrastructure, railway network, throughput and transport capacities.

1. INTRODUCTION

Rail capacity is a critical aspect for the efficiency and reliability of the transport network. It includes the ability of rail infrastructure to support a certain volume of traffic for a given period of time. Capacity analysis is important for planning, managing and optimizing rail operations. It has an impact on the Train Timetable (VGS). According to various characteristics, an optimal GDV is prepared. Using different models and simulation software can help model different scenarios and estimate capacity under different conditions.

2. OVERVIEW OF RESEARCH IN THE FIELD. THROUGHPUT AND TRANSPORT CAPACITY

There are several main aspects of the throughput and carrying capacity of railway elements [1][2][3]:

- maximum throughput and transport capacity;
- necessary throughput and transport capacities for the proposed volume of railway transport work.
- The available throughput is that available to the operational element at a given time;
- Capacity reserve is the difference between the maximum and required throughput.

The maximum capacity of a railway section in question, of a track or of another operational element of the railway network is the maximum number of trains of a certain weight (composition) that can pass this element per day or other period of time considered, depending on the existing technical equipment, type and type of locomotive and the system for passing trains under this element.

The maximum carrying capacity of a track, railway section or other operational element of the railway network shall be the maximum number of net or gross tonnes that may be omitted in a year or other period considered, also depending on the evolution of the capabilities of the mobile vehicles, the qualification of personnel and the use of technical means.

In all cases, a specified maximum capacity and certain parameters of mobile vehicles corresponds to a specified maximum transport capacity.

The main elements by which the maximum capacity is determined for a certain period of time considered are railway interstations, sections, stations and lines [2][4].

The required throughput is the number of trains (wagons) obtained at the parameters of maximum throughput, depending on the proposed volume of transportation for a considered, realized or planned period of time, for which it is determined.

The determination of the specified types of throughput and transport capacities should be done depending on the different types of progressive technologies and ways of traffic organization, using variant schemes, as well as relevant modern methodologies [18].

The maximum throughput shall be determined by the following formula:

$$N_M = \frac{A - A_{ПОСТ}}{a} \quad (1)$$

[1] Todor Kableshkov" Higher Transport School, 1574, Bulgaria, Sofia, jvaradinova@vtu.bg
[2] Todor Kableshkov" Higher Transport School, 1574, Bulgaria, Sofia, pkostadinov@vtu.bg

trains (or pairs of trains) where:

A-total resource (opportunity);

Apost – part of the resource that is needed for the needs of this device or for other devices not directly related to the passage of trains, in the same units of measurement;

a – expenditure of the same resource for the realization of the passage of one train or pairs of trains, respectively, or of a group of trains with a certain uniform frequency of passage.

The available throughput is that available to the operational element at a given time;

Capacity reserve is the difference between the maximum and required throughput.

The types of throughput and transport capacity are presented in works [1][2][6][7][8] [9].

2.1. Impact of capacity and transport capacity on train traffic organisation

The organization of train traffic is realized on the railway lines on the basis of a pre-developed and approved schedule. It reflects the number of trains, the times of their arrival, departure or transit through the stations, the times of their movements in the interstations, the tying of their locomotives in the stations, the interruption of movements in the interstations, the work of all operating units of the railway transport.

In order to carry out the correct organization of train movement, a train schedule is drawn up, based on preliminary optimization for each section and each railway line. On the basis of it, the timetables of the individual trains shall be determined, indicating at each of them and for each station and stop the times of arrival, transit and departure, inter-station distances, permissible speeds on the elements of the railway line, the inter-station travel times of trains and the meetings or exceedances of each train at the stations with the other trains, respectively. The methods are described and discussed in detail in works [1][6][10][11][12][13]. In the works of [2][3][14][15][16][17]18][19] [20] and [21] are described types of train schedules, according to different characteristics.

2.2. Impact of maximum capacity on train schedules

Methods and approaches for determining the maximum throughput depending on the main influencing factors are presented in works [2][6][7][8][9][10][11] [12][13][22][23].

The maximum throughput and carrying capacity of railway interstations and sections, depending on the main influencing factors, mainly the different types of train schedules and the schemes for their passage, the ways of ensuring the movement of trains in the interstations and stations leads to the determination of:

A) The maximum capacity of single-track (single) interstations under a simple parallel traffic schedule [2].

(B) Maximum throughput on a non-paired parallel traffic schedule [2].

C) Maximum throughput for parallel paired package and partial-batch traffic schedules [2].

E) Capacity of sections with one-way and double-track interstations and elements in parallel paired traffic schedule.

F) Maximum capacity of double-track interstations in parallel train schedule.

(G) Maximum capacity of railway sections with a non-parallel paired train schedule.

Studies of the throughput capacity of the railway network in Bulgaria under different conditions have been made in the following works: [1][6][7][8] [17][24]. At work [18] the unevenness of the movement of freight trains in one section has been studied.

2.3. Main factors affecting throughput

Infrastructure elements:

- Research shows that multi-track and double-track lines significantly increase capacity compared to single-track lines [27].
- Advanced signalling systems such as ETCS Level 2 allow for shorter intervals between trains, increasing capacity [28].

Operational practices:

- An effective timetable can minimize downtime and increase capacity utilization. Various studies look at timetable optimization algorithms that balance between passenger and freight trains [29].
- Motion Control:
- Real-time traffic management and dynamic timetable adjustment are key to capacity optimization [30].

Technical characteristics of the rolling stock:

- Faster trains with better acceleration characteristics can increase capacity by reducing travel times and increasing the number of trains that can use the infrastructure for a given period [27].

2.4. Case studies

The European Rail Traffic Management System (ERTMS) has been introduced in many countries to increase capacity and safety. Research shows that ERTMS Level 2 allows for shorter intervals between trains and increases capacity by up to 40 [31].

Japan's Shinkansen high-speed train system demonstrates high throughput thanks to specialized lines and strict schedule control. Research shows that Shinkansen lines can support up to 14 trains per hour in one direction [32].

In the United States, where freight transport dominates, research has focused on route optimization and train planning to increase capacity. Big Data Simulation and Analytics Models Are Used to Improve Efficiency [33].

3. IMPACT OF CAPACITY ON TRAFFIC BETWEEN BULGARIA AND TURKEY

Throughput plays an important role in the current state of railway transport in our country. The rehabilitation and modernization of major railway lines in Bulgaria leads to strong traffic restrictions. Due to its geographical location, a large cargo flow from Asia to Europe passes through our country. Currently, the border between Bulgaria and Turkey is served by only one border checkpoint - Kapikule-Svilengrad. Prepared traffic forecasts show an upcoming increase in freight traffic across our border. In addition to the connection between Asia and Western Europe, between Bulgaria and Turkey, after the outbreak of the war in Ukraine, a new route of connection from Asia to Ukraine and the eastern parts of Europe is being sought, which again leads its way through our country. For the movement of trains between Turkey and Romania, at the moment the transport must pass between Dimitrovgrad and Gorna Oryahovitsa, where, however, the throughput capacity is 30 trains, and in some places it is even more limited. The only option for the passage of trains at the moment is through Mihaylovo - Karnobat - Sindel - Ruse. With this detoured route, the distance is 168 km. This leads to a search for solutions for easier and faster traffic. Such an option is the construction of the line Yambol - Elhovo - Lesovo - Edirne. It shortens the distance to 80 km, and in addition to The shorter route, when building a completely new line, will be able to comply with all European requirements and to implement all new technologies and requirements of the European Union. An analysis shows that in the presence of such a line, the traffic of goods between Southeastern Bulgaria and Turkey will also increase. The construction of this line will also be in accordance with the requirements for necessary and maximum throughput, with a sufficient reserve to be used in the expected increase in the cargo flow along this route. It will also facilitate customs activities at border stations.

4. CONCLUSION

A literature analysis of rail capacity reveals that efficient management and modernization of infrastructure are key to increasing capacity. The research and methods presented in the literature provide a rich set of tools and strategies that can be applied to optimize rail operations and improve both passenger and freight transport services.

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