Establishing the impact of empty freight trains on the capacity railway lines

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Abstract. Currently, according to the standard schedule of Uzbekistan Railways JSC, the timing of departure, acceleration, and braking of freight trains is determined uniformly for different weight compositions on each section of the railway track. This, in turn, does not allow for an accurate assessment of the level of utilization of the existing permeability capacity of the railway section. In this study, the impact of accounting for the period of the schedule based on the proportion of freight trains of different weights in the movement schedule is examined with respect to the permeability capacity of railway sections. Uzbekistan Railways JSC has demonstrated that the existing permeability capacity of single-track and double-track railway sections can be increased by 7% and 5%, respectively, under existing operating conditions.

1 Introduction

The existing throughput capacity of railway sections primarily depends on the development of infrastructure and locomotive power. Considering that these parameters constantly improve as a result of the variability of wagon traffic, it can be concluded that the throughput capacity of railway sections is one of the ‘eternal’ problems. In turn, railway administrations must monitor the status of their current throughput capacity and take measures to increase it in order to ensure a stable flow of trains from the sections. Therefore, the undeniable relevance of research on the basics of the impact of freight trains with different parameters on the throughput capacity of single- and double-track railway sections is justified.

2 Materials and Methods

The methodology for evaluating the capacity of railway sections in railway transportation, known as the "Guidelines for Railway Infrastructure Capacity Evaluation", was developed in 2010 with the objective of determining the capacity of railway infrastructure components by applying accounting procedures based on the aforementioned guidelines [1]. However, certain factors that influence capacity, such as different types of heavy trains, the construction of third tracks on double-track sections, etc., were not fully considered in these.
Consequently, there is ongoing scientific research aimed at improving the capacity of railway sections on a global scale [2-16]. For instance, in the doctoral dissertation of A.V. Yelovikov, a comprehensive methodology was developed to assess the feasibility of constructing third tracks on double-track railway sections. Through mathematical analysis of continuous movement of freight trains, a method for determining the minimum length of the third track was proposed. Furthermore, it was established that the speed of freight trains has minimal influence on the minimum length of the third track [15]. In the doctoral dissertation of A.I. Besedin, a new approach was proposed, based on dividing the railway section into independent elements using graph theory as the basis for segmenting the temporal interval. Thus, the author aimed to enhance the accuracy of calculations presented in the Guidelines for Railway Infrastructure Capacity Evaluation and even identified certain aspects of capacity. The author’s work has been applied in railway operations and has been incorporated into the Guidelines for Railway Infrastructure Capacity Evaluation [16].

In modern operating conditions, efficient utilization of a wagon is understood as a combination of operational indicators, the fulfillment of which is directly linked to the wagon’s profitability over a given time period. The most objective indicator of a freight wagon’s utilization during transportation can be demonstrated by the empty (unloaded) mileage ratio, which characterizes the proportion of the wagon that has traveled without a load during the inter-repair period compared to the total distance covered. In JSC “Russian Railways”, the empty mileage ratio was 39% in 2007 and 2008 and 41% in 2009 [17]. These indicators correspond to the period when small operator companies with their own wagon fleet appeared in JSC “Russian Railways”. Operator companies began to emerge in the United States in 1985, and during this period, the empty mileage ratio was 45% [18]. In European countries, the period of growth for this ratio corresponds to the 1990s, and government subsidies were allocated to sustain railway operations in such a situation [19].

There are several scientific studies aimed at reducing the empty mileage of wagons. In particular, in [20], it is noted that the percentage of empty wagons is significantly higher in small operating companies compared to large companies. This situation can be explained by the fact that large companies serve relatively longer routes, resulting in a lower proportion of through operations. On small companies, the degree of wagon specialization is significantly higher.

Considering the potential decrease in competition, measures have been taken to consolidate operator companies, resulting in an empty trip ratio of 39% in JSC “Russian Railways” in 2021. In Uzbekistan Railways JSC, this indicator was 48% in 2021.

Instead of trains of different weights, compositions consisting of empty wagons are used to present calculations based on the influence of trains with empty wagons on the capacity of single- and double-track railway sections in a concise manner. In this case, the available capacity of a single-track railway section is calculated as follows:

\[ N_{mav} = \frac{(1440 - t_{tex}) \alpha_i T_{davr}'}{T_{davr}'} \]

where:
- \( t_{tex} \) - technological time allotted for the repair and inspection of infrastructure, min;
- \( \alpha_i \) - coefficient of reliability of technical means and devices;
- \( T_{davr} \) - schedule taking into account the average speed of loaded and empty trains (calculated for a section that limits the capacity of the section), min.

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The value of $T_{davr}'$ is determined as follows when an empty train moves in one direction (for example, a pair):

$$T_{davr}' = t_m + \alpha \cdot (t^j - \Delta t) + \beta \cdot t^j + 2 \cdot \tau_{bk}, \text{min.}$$

Here, $t_m, t^j, \Delta t, \alpha, \beta, \tau_{bk}$ accordingly, the time of movement of freight trains in odd and even directions, min.;

The value of $T_{davr}''$ is determined as follows when the empty train moves in two directions (even and odd):

$$T_{davr}'' = \alpha \cdot (t^m - \Delta t) + \beta \cdot t^m + \alpha \cdot (t^j - \Delta t) + \beta \cdot t^j + 2 \cdot \tau_{bk}, \text{min.}$$

The throughput capacity on a double-track railway section equipped with three-point automatic block signaling, where freight trains of varying weights operate, is calculated as follows:

$$N_{mav} = \frac{(1440 - \tau_{tex}) \cdot (\alpha v^\alpha_{yur} + \beta v^\beta_{yur}) \cdot \alpha_i}{0.06 \cdot (3l_{bt} + l_p)}, \text{train}$$

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<th>Movement of empty trains</th>
<th>The share of empty trains, %</th>
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<th>$\tau_{bk}$</th>
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3 Results and Discussion

Table 1

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Table 1. Impact of different combinations of freight trains on the available throughput capacity of a single-track railway section.
The influence of freight trains of varying weights on the available carrying capacity of a double-track railway section was evaluated based on Equation (4) (Fig. 1). In this evaluation, the values of $\alpha=0.4; \beta=0.6; l_b=1500\ m$ were considered. As evident from Fig. 1, accurate consideration of the accumulation of empty trains when determining the schedule period indicates the existence of reserve capacity for the available throughput of double-track railway sections. Additionally, it is observed that the longer the block section length, the lower the available throughput capacity of the railway section. This conclusion is supported by the findings presented in the research paper [21], which indicate that the actual length of block sections, determined by the inter-train interval, is significantly greater than the length calculated based on safety requirements. By sequentially arranging block sections, it is possible to increase the existing capacity of railway sections. Therefore, it is concluded that this provides a basis for significant capacity enhancement.

Fig. 1. Influence of freight trains of different weights on the available carrying capacity of a double-track railway section.

The current throughput capacity of single-track railway sections was calculated for the conditions of Uzbekistan Railways JSC. The calculation of the schedule period took into account the proportion of freight trains with empty content, assuming it constitutes up to 5% of the existing throughput capacity of double-track railway sections.

4 Conclusion

In Uzbekistan Railways JSC, the standard schedule sets the same travel, acceleration, and braking times for freight trains of different weights within the designated zone. Consequently, it hinders the accurate assessment of the existing carrying capacity of the railway section. The impact of considering the schedule period based on the proportion of freight trains of different weights on the available throughput capacity of single- and double-track railway sections.
railway sections was evaluated. As a result, it was justified that in the conditions of Uzbekistan Railways JSC, the existing carrying capacity of single-track and double-track railway sections can be increased by up to 7% and 5%, respectively.

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