Measures of effective use of the capacity of two-track sections of JSC “Uzbekistan Railways”

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Abstract. The article first presents the analysis of the complete structure of all two-track sections of JSC “Uzbekistan Railways” with mixed traffic, and then the proposals of local and foreign scientists regarding the determination of the coefficient of displacement of freight trains from the graph on two-track sections in conditions of mixed traffic are described in detail. In addition, the factors affecting the displacement coefficient of freight trains from the graph were analyzed, as well as the reduction of the time interval of the arrival of freight and high-speed passenger trains that arrive at the separation points in a row in the track direction, and as a result of the organization of train movement based on the technology of connecting, increasing the maximum number of freight trains in the sections suggestions were made regarding the issues.

1 Introduction

Currently, a series of measures are being implemented to accelerate the transport transit potential of our Republic, including the creation of new transport corridors (Trans-Afghan, China-Kyrgyzstan-Uzbekistan, etc.), acquisition of new power plants, etc. Undoubtedly, these measures will create a basis for increasing cargo flows and the number of transit freight trains in the future. In this case, due to the increase in the number of freight and high-speed passenger trains on sections with a mixed traffic system, there will be more delays of freight trains, a decrease in the throughput capacity of the section, an increase in delivery times of goods, and an increase in various cases of damage due to the delay of goods. Therefore, it is necessary to avoid the occurrence of disputed situations between the railway and customers. Increasing the throughput capacity of freight trains on double-track sections with a mixed traffic system is one of the pressing issues to prevent such situations.

The Joint-Stock Company “Uzbekistan Railways” has launched the high-speed passenger train “Afrosiyob” on routes between Tashkent-Samarkand, Samarkand-Karshi, and Samarkand-Bukhara. The plan is to begin running this train on sections of the Bukhara-Mishken route. In addition to ensuring the safe operation of high-speed passenger trains on...
2 Materials and Methods

\[ \Delta N_{\text{reserve}} = f(\Delta t \cap N_{\text{high-speed}}) \]

and

\[ \varepsilon = f(\Delta t \cap N_{\text{high-speed}} \setminus \{ \text{passengers arrival} \}) \]
trains from the schedule due to consecutive high-speed passenger trains sent on their way to separation points.

Overall, according to the guidelines [1], the train capacity of railway sections is differentiated into calculated and actual. The calculated train capacity is determined as the maximum number of freight trains (pairs of trains) of a given weight and length that pass through a given section in a unit of time (day), in accordance with the technical equipment of the railway station and the train traffic organization method. The required capacity is usually less than the calculated capacity, taking into account that different classes of trains displace freight trains. The demand capacity is the number of trains per day required to fulfill the transportation plan.

Currently, analytical, graph-analytical, and simulation modeling methods are widely used to determine the capacity of a computational train. Of course, the displacement factor of freight trains from the schedule has a significant impact on train capacity. To do this, it is necessary to analyze the factors influencing the displacement coefficient of freight trains from the schedule (Figure 2).

Based on the analysis, in accordance with the conditions for organizing the movement of trains in "UZBEKISTAN RAILWAYS" JSC, the possibility of passing freight trains on existing sections and the shift coefficient from the schedule were explained by the following functions [1-3, 12-13].

$$\Delta = f(A, S, Q, L, T_{\text{high-speed}}, N_{\text{high-speed}}, q_f)$$
$$\epsilon = f(I, A, N_{\text{high-speed}}, T_{\text{high-speed}}, g_f, q_{\text{high-speed}})$$

Fig. 2. Analysis of factors affecting the displacement coefficient of freight trains according to the schedule.
In general, we write the estimated capabilities of freight trains and their maximum number of days the given speed of freight and high-speed trains follows:

\[ q_{f} - q_{high-speed} \]

\[ q_{f} \leq q \leq q_{high-speed} \]

\[ \Delta_{f} - \Delta \leq \Delta \leq \Delta_{hig} \]

Table 1. Based on methodological recommendations [1] and scientific research [2, 3, 14], the following are the boundary conditions:

- \( I_{0} \leq I_{f} \leq I_{0+} \)
- \( I_{0} \leq I_{f} \leq I_{0+} \)
- \( \frac{\Delta_{f}}{\Delta} \leq \Delta \leq \Delta_{hig} \)
- \( q_{f} \leq q \leq q_{hig} \)

Here are the objective functions, the following boundary conditions must be satisfied:

\[ \Delta_{f} \leq \Delta \leq \Delta_{hig} \]

\[ q_{f} \leq q \leq q_{hig} \]

Technical equipment of railway sections;

- \( I_{0} \leq I_{f} \leq I_{0+} \)
- \( I_{0} \leq I_{f} \leq I_{0+} \)
- \( \frac{\Delta_{f}}{\Delta} \leq \Delta \leq \Delta_{hig} \)
- \( q_{f} \leq q \leq q_{hig} \)

Here are the boundary conditions for calculating the time interval between successive freight trains, min:

\[ t_{f} - t_{left} - t_{left} + t_{av} + t_{av} \]

\[ t_{f} - t_{left} - t_{left} + t_{av} - t_{av} - I + \frac{I}{I_{f}} \]

\[ t_{f} - t_{left} - t_{left} + t_{av} - t_{av} - I + \frac{I}{I_{f}} \]

\[ t_{f} \cdot \left( -\Delta \right) \]

\[ \frac{t_{f} \cdot \left( -\Delta \right)}{I} \]

\[ \frac{t_{f} \cdot \left( -\Delta \right)}{I} \]

\[ \frac{T_{f} + I_{hig} \cdot \left( -\Delta \right)}{I_{hig}} - \frac{T_{f} \cdot \left( -\Delta \right)}{I_{hig}} \]
The following formulas represent the calculations for determining the number of freight trains and passenger trains, considering factors for high-speed and mass transportation:

\[ N_{available} = \frac{\left( \sum_{i=1}^{n} t_{tech} \right) \cdot \alpha_n}{I} \]

\[ N_{required} = N_{available} - N_{required} \]

\[ \Delta N_{reserve} = N_{available} - N_{required} \]

\[ N_{hig-s}^f - N_{pass}^f = N_{hig-s}^f \cdot t_{tech} \cdot e_{pass} + N_{pass}^f \cdot t_{ technically required} \cdot e_{pass} + N_{s} \cdot t_{technical} \cdot e_{prefab} + N_{f} \cdot t_{technical} \cdot e_{prefab} - \beta \]

\[ e_{hig-s}^f - e_{pass} = e_{hig-s}^f \cdot e_{pass} \]

\[ e_{pass}^f - e_{f} = e_{pass}^f \cdot e_{prefab} - e_{prefab} \]

\[ N_{hig-s}^f \cdot N_{pass}^f = N_{hig-s}^f \cdot N_{pass}^f \cdot N_{f} \cdot N_{prefab} \]

The expressions above include parameters such as the number of freight trains, the number of passenger trains, the high-speed coefficient, the speed coefficient, and the reserve factor. These calculations are essential for optimizing the railway network's capacity and efficiency, particularly in high-speed rail transportation.
If the time interval between high-speed passenger trains is equal to or greater than a given value, then it is possible to send freight trains between packets. If the time interval between high-speed passenger trains is less than a given value, freight trains cannot be placed between packages, and in this column, high-speed trains are sent in a partially packet way [4, 7, 10, 11, 20-22].

We analyze the arrival time of successive freight and high-speed passenger trains at the separation points and the downtime when trains cross. The following plot was used to determine the minimum residence time value (Figure 4).

Fig. 3.
Let us fix the time of successive arrival of freight and high-speed passenger trains at the separation points. In this case, when high-speed passenger trains move at speeds up to 250 km/h, the route must be prepared 10 minutes before arrival at the separation point, and the distance of the train approach to the station must be at least three block sections (Fig. 5, 6) [1, 8, 9, 15, 21].

**Fig. 4.** Waiting time for a freight train when overtaking another freight train.

\[ T_{simple} = T_{arrival} + T_{cross} + I_{high-s} \cdot N_{pass}^{high-s} - \text{simple} \]

Here,
- \( I_{reserve} \) - the sum of the route preparation time and the additional reserve of the arriving high-speed passenger train, min;
- \( L_{nec} + L_{ba} \) - length of the neck of the separation point, m;
- \( L_{nec} + n \cdot L_{ba} + L_f + L_{high-s} \) - length of the section of the first block in the area of the place of separation, m;
- \( f_V \) - speed of freight and high-speed passenger trains, respectively, km/h;
- \( n \) - number of block sections;
- \( E_3S \) - distance between the interval of insulated rails and the traffic.
Result and discussion

As a result of calculations using the MatLab programming language, we create the following graphs:

Fig. 6. Graph of the time interval of the arrival of successive high-speed passenger trains on the route
of freight trains at the points of separation and the speed of trains
Similarly, as a result of freight train No. 2002 passing high-speed passenger trains
at the separation point, the total waiting time depends on the time interval of successive
arrivals on the track (Fig. 6).

Fig. 7. Graph of the total idle time of freight trains as a result of the passage of high-speed passenger trains at the separation point, depending on the time interval of successive arrivals on the track.
In general, based on the technology of connecting high-speed trains, the mathematical model of the total waiting time at the points of separation of freight trains when sending them in a partial package in the column depends on the number of destination stations to which high-speed passenger trains run (Fig. 8) [1, 17, 18]:

\[
T_{\text{simple}} = \sum_{i \in \{I, \dots, k\}} n_i \Rightarrow I_{\text{yo lSakay jo in}} + I_{\text{yo lSakay yet kel}} + I_{\text{YT lYo}}
\]

Fig. 8. Technology for connecting high-speed passenger trains by directions

Figure 9 shows the result for an even and odd number of trains.

Fig. 9. Waiting time for freight trains at a separation point based on high-speed passenger train connection technology
By utilizing the technological methods outlined above and employing mathematical models, we analyzed changes in the coefficient of displacement for freight trains from their scheduled routes, as well as the maximum number of trains that can be transported through individual sections.

**Fig. 10.** Comparative analysis of the coefficient of displacement of freight trains from the graph.

**Fig. 11.** Graph of the relationship between the maximum number of freight trains that can be passed through this section during the day, and the number of high-speed passenger trains.
Conclusion

The analysis of the results shows that the arrival time of consecutive freight and high-speed passenger trains in the points of separation is reduced from 30 minutes to 17-23 minutes depending on the speed of the trains, achieving an average reduction of 33%. Using train coupling technology, the total waiting time for freight trains at separation points is reduced from 153 minutes to 86 minutes when sending partial packages (an average of 5 trains per package), resulting in an average reduction of 43.8%. The deviation coefficient of freight trains from the schedule, in turn, decreases by an average of 9.3% depending on the speed of the trains (70/160). The proposed methods allow for an increase in the maximum number of freight trains that can be transferred from the section during a day by up to 24.1% with 10 pairs of high-speed passenger trains per day.

References


