ENGINEER

international scientific journal

ISSUE
4, 2024 Vol. 2
ISSN
3030-3893

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TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

ENGINEER

A bridge between science and innovation

ISSN 3030-3893

VOLUME 2, ISSUE 4

DECEMBER, 2024

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 2, ISSUE 4 DECEMBER, 2024

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Tashkent State Transport University had the opportunity to publish the international scientific journal “Engineer” based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **ISSN 3030-3893.** Articles in the journal are published in English language.

The impact of attracting an additional shunting locomotive to railway technical stations on the utilization indicators of rolling stock

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Abstract: Indicators of rolling stock utilization are continuously analyzed to ensure the required number of units is supplied in accordance with transportation volumes. This article presents two software packages designed as instrumental tools for evaluating the performance indicators of locomotives and wagons. As a result, an automated system has been developed to calculate rolling stock utilization metrics, taking into account the freight volume at each station and the technical-operational characteristics of the railway, enabling the deployment of additional shunting locomotives.

Keywords: Technical station, shunting locomotive, rolling stock, performance indicators, operational fleet, software for electronic computing machines

1. Introduction

Each railway network is responsible for recording and reporting wagon transportation indicators within its jurisdiction. One of the key transportation indicators is the distance traveled by loaded wagons, which varies across different railway networks. In most cases, these indicators are calculated using automated systems [1-9]. Regular analysis of traction unit utilization indicators enables the determination of the required number of rolling stock units in line with transportation volume demands.

Traction units are the primary mobile components of railway transport. Currently, the calculation of rolling stock utilization indicators in regional railway junctions, stations, and sections is performed manually. This leads to inefficient time management among railway personnel and does not allow for periodic assessments of the impact of engaging additional shunting locomotives on rolling stock utilization indicators.

The study [10] developed a methodology for evaluating the impact of organizing shunting operations with various numbers of locomotives on railway transport efficiency. This paper continues that research by providing specific insights into the impact of engaging additional shunting locomotives at railway technical stations on rolling stock utilization indicators.

2. Research methodology

Considering that the number of train locomotives is directly related to freight flow and the number of shunting locomotives depends on the volume of shunting operations at the station, it follows that the number of shunting locomotives directly affects the number of train locomotives required for the section.

The number of train locomotives required for transportation operations is determined using the following formula [5]:

$$M_N = K_N \cdot Q_i, \text{ loc.} \tag{1}$$

where

K_N – the coefficient of locomotives required per train pair;

Q_i – the full cycle time of locomotives (hours).

The value of K_N can be expressed in terms of Q_i as follows:

$$K_N = \frac{Q_i}{24} \tag{2}$$

The full cycle time of locomotives is expressed as:

$$Q_i = \frac{2 \cdot l_{uch}}{v_{uch}} + t_{asos} + t_{ayl} + \sum t_{sb}, \text{ hour} \tag{3}$$

where

l_{uch} – the length of the locomotive operation section (km);

v_{uch} – the section speed of train movements (km/h);

t_{asos} – the average dwell time of locomotives at the home depot station (hours);

t_{ayl} – the average dwell time of locomotives at the turnaround depot station (hours);

$\sum t_{sb}$ – the time required for crew rotation per day (minutes).

Engaging additional shunting locomotives at key stations reduces train locomotive dwell time at those stations. Therefore, the average dwell time at the home depot station is calculated as:

$$t_{asos} = \frac{\sum M \cdot t}{\sum M}, \text{ hour} \tag{4}$$

where

$\sum M \cdot t$ – the total locomotive-hours at the home depot station;

$\sum M$ – the number of train locomotives, loc.

The daily average mileage of train locomotives is determined as follows:

$$S_{lok} = \frac{2 \cdot l_{uch} \cdot 24}{Q_i} = \frac{48 \cdot l_{uch}}{Q_i} = \frac{2 \cdot l_{uch}}{K_N}, \text{ km/day} \tag{5}$$

According to the “Methodology for Assessing Railway Operational Indicators,” the density of wagon movements in a section (G_i), multiplied by the section length (L_i) multiplied by the section length:

$$\sum nS_{\text{yuk}_i} = G_i^{\text{yuk}} \cdot L_i \text{ wag-km.} \tag{6}$$

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The operational rolling stock (n_{ish}) used during transportation is determined based on wagon-hour values and calculated as follows:

$$n_{ish} = \frac{\sum nt_p + \sum nt_{tex} + \sum nt_{yuk}}{24}, \text{ wag.} \quad (7)$$

where $\sum nt_p, \sum nt_{tex}, \sum nt_{yuk}$ – wagon-hours spent in motion, at technical stations, and at loading stations.

3. Results and Discussion

During the study, two software tools were developed for automated calculation of rolling stock utilization indicators according to the “Methodology for Assessing Railway Operational Indicators”:

1. Software for Locomotive Utilization Analysis. This software calculates locomotive utilization based on the freight volume and technical-operational characteristics of each station.

It determines locomotive-related metrics such as train gross weight (tons), operational locomotive fleet (locomotives), daily average locomotive mileage (km), locomotive cycle time (days), and daily locomotive productivity (ton-km gross).

2. Software for Wagon Utilization Analysis. This software evaluates wagon utilization indicators, considering the freight volume and operational characteristics of each station.

It calculates indicators such as the average dynamic load per freight wagon (tons/wagon), operational fleet average dynamic load (tons/wagon), average gross weight per wagon (tons/wagon), wagon cycle time (days), loaded trip distance (km), total trip distance (km), the number of technical stations encountered during the wagon cycle, and daily average mileage of operational wagons (km/day). The operation algorithm of the program for calculating the performance indicators of wagon usage is shown in Figure 2.

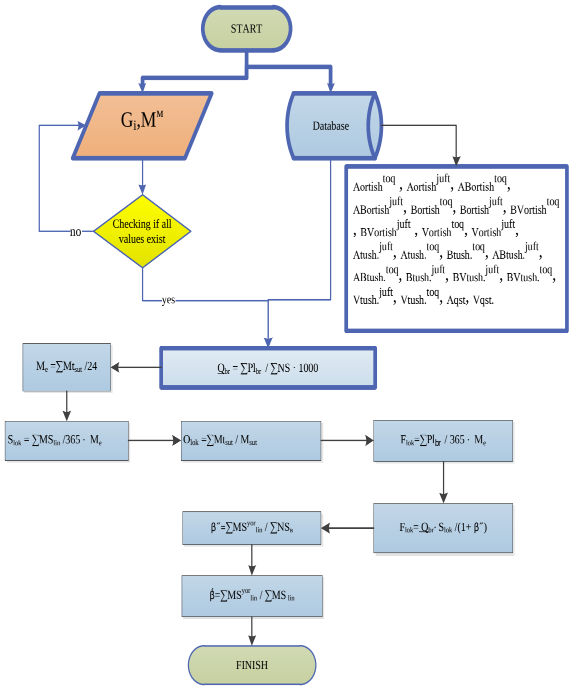

Fig. 1. The operation algorithm of the program for determining the performance indicators of locomotive usage

The impact of engaging an additional shunting locomotive was analyzed for a train flow consisting of 9 to 29 rolling stock units across 108 daily work schedule plans (Figure 3).

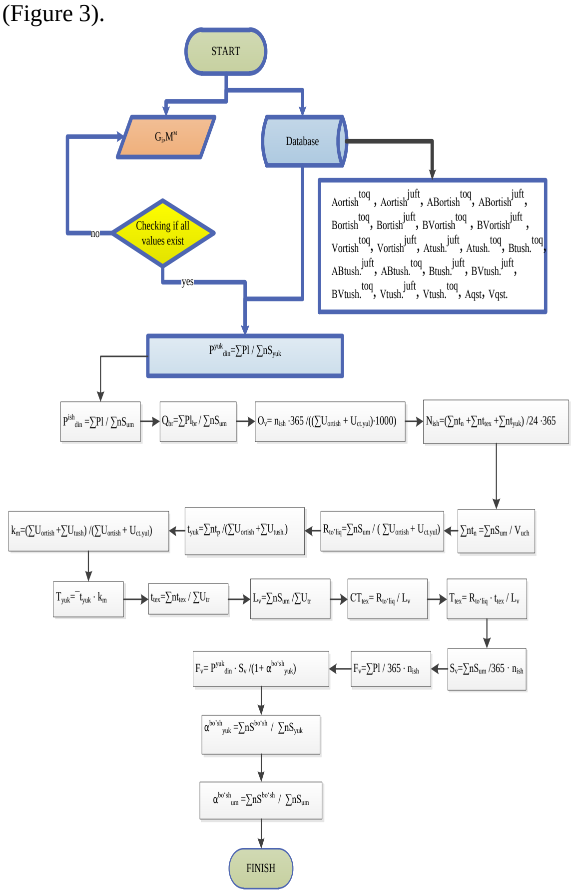

Fig. 2. The operation algorithm of the program for calculating the performance indicators of wagon usage

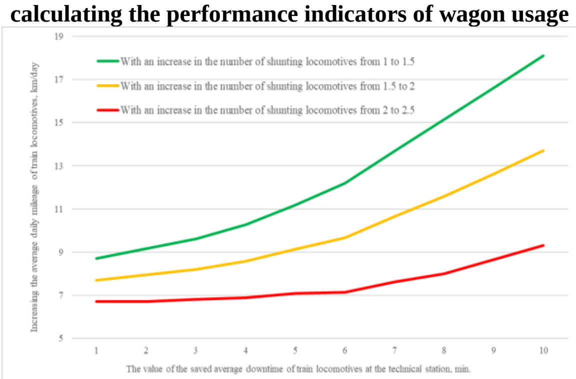

Fig. 3. The dependence of wagon processing time savings due to the involvement of an additional shunting locomotive on the average daily mileage of train locomotives

As seen from Figure 3, the involvement of additional shunting locomotives at railway section stations allows increasing the average daily mileage of train locomotives by 10 km per day.

Using the developed program, a graph of the dependence of the working fleet of the regional railway junction on the wagon dwell time at the technical station was constructed (Figure 4).

As seen from Figure 4, under the studied workload conditions, involving additional shunting locomotives can reduce the dwell time of transit wagons at technical stations by 0.1 hours (6 minutes), resulting in an average saving of 21 wagons in the working fleet.

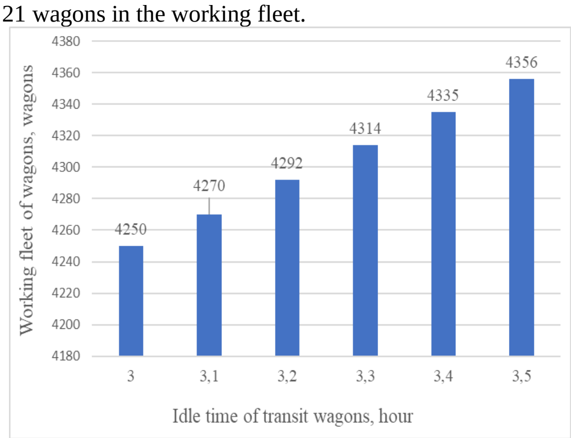

Fig. 4. Graph of the dependence of the regional railway junction working fleet on the wagon dwell time at the technical station

4. Conclusion

1. To enable periodic assessment of the impact of engaging additional shunting locomotives on rolling stock utilization indicators at railway technical stations, two software tools were developed for evaluating locomotive and wagon utilization. These tools automate the calculation of utilization indicators based on freight volume and railway operational characteristics.

2. The effect of engaging additional shunting locomotives on train locomotive utilization was analyzed. It was found that engaging additional shunting locomotives at railway section stations increases the daily average mileage of train locomotives by 10 km.

3. The developed software was used to analyze the relationship between operational fleet size and transit wagon dwell time at technical stations. Results indicate that engaging additional shunting locomotives reduces the dwell time of transit wagons by 0.1 hours (6 minutes), allowing for a reduction of 21 operational wagons.

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