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The “Journal of Transport” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

The journal is published 4 times a year and contains publications in the following main areas:

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- Car Service;
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- Traffic Organization;
- Operation of Railways and Roads;

Tashkent State Transport University had the opportunity to publish the scientific-technical and scientific innovation publication “Journal of Transport” based on the Certificate No. 1150 of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. Articles in the journal are published in Uzbek, Russian and English languages.

CONTEXT / MUNDARIJA

Effective organization of train movement taking into account the costs of electrical energy

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Abstract: The main goal of the work is to save the total cost of running trains. The standard of time and graphic times of the stay of trains at the stations were analyzed analytically and the total cost of their electric energy distribution was determined. As a result, a scheme for the zonal organization of train traffic in general expenditures and saving electricity consumption was created. It has been proposed to set graphical times when sending trains from stations, spending on electricity daily distribution, and zonal organization of train movement in TTG (train traffic graph).
Keywords: Electricity, railway section, train traffic graph, expenditure rate, zonal movement.

1. Introduction

The effective organization of the process of transportation of rail transport, including the movement of trains of various categories, determines the possibilities of saving the consumption of electric enenrgia by sending freight trains taking into account the distribution of electricity expenditures during the day in terms of graphic times installed from railway stations. [1, 2, 6, 8].

The experience of organizing train traffic based on optimal options, including the movement of passenger trains at railway stations on an optimal train traffic graph (TTG), provides the opportunity to reduce electricity consumption by 5-6%. [3-5]. Therefore, the organization of the movement of freight trains on railway sections by the distribution of electricity expenditures is an urgent issue.

2. Literature analysis and methodology

Scientific research was carried out by many scientists and specialists on the identification, analysis and assessment of factors that negatively affect the movement of freight trains in various categories in their effective organization, and on the development of methods for organizing train traffic on an invariable graph and determining the cost of electricity [7-9, 11-14].

In particular, author Yan Xu in his scientific research [12] proposed a novel approach to electric energy-efficient integrated micro-macro to increase movement speeds in the development of TTG. This method allows high-speed trains on TTG to save electricity through a programming model of optimizing the speed of movement.

Author Gerben M. Scheepmaker [13] has developed a method for determining electricity consumption, taking into account the factors affecting trains during their movement. The developed method provides an opportunity to save electricity consumption, taking into account the repair work in different parts of the TTG.

Nezewack W.L. [14] at railway stations, the indicators of TTG are optimized in accordance with the criterion for the consumption of electrical energy for braking and pulling the motion content in the conditions of slowing down and accelerating trains. Methods for determining the non-winding losses of electricity as a result of optimization are presented, and the indicators of their implementation in practice are analyzed.

In particular, it is currently analyzed that the cost of electricity consumption on the Railways of Uzbekistan is distributed to them for different situations (Figure 1). The results of the analysis showed that non-transport dependent consumers accounted for 6%, rail consumers for 14%, and train torts for 80%. It follows that the organization of train traffic requires the development of a new approach to saving the electricity consumption spent on them.

Train traffic in railway stations is carried out taking into account the technology of distribution of the cost efficiency associated with the standards of stopping time of freight trains at stations. It is necessary to assess the total spending, taking into account the graphical timing of the organization

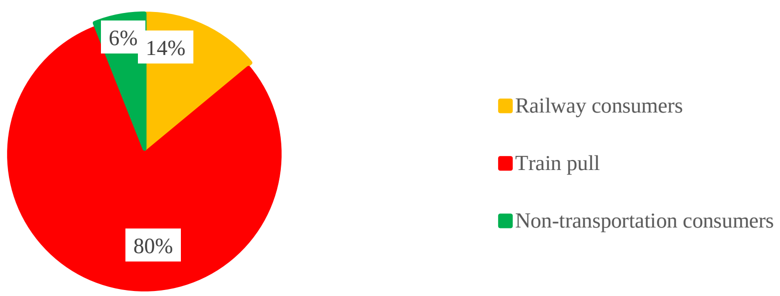

Fig. 1. Diagram of the distribution of electricity consumption on the Railways of Uzbekistan

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of train traffic on railway sections and the planning of their shipment from stations.

When sending trains from the station, the total expenditures were determined using the following parameters. [2, 3]:

a) expenditures associated with train stops at (P_{in}) intermediate stations within the precinct include the following [2]:

- ($P_{l.br}$) total spending for the locomotive brigade's operation in terms of train stopping times;
- acceleration and deceleration of trains costs for ($P_{a/d}$) (electricity);
- expenditures in the ($P_{l.w}$) use of locomotives and wagons;
- electricity (P_e) spending costs for stopping trains.

The total spending on intermediate stations is determined by the following expression

$$P_{in} = P_{br} + P_{a/d} + P_{lw} + P_e \quad (1)$$

$$P_{lb} = (t_{in.av} + t_{ac} + t_{dec}) \cdot \frac{e_{br}}{60}, \quad (2)$$

there

$t_{in.av}$ – General stop time norms in intermediate stations by graph time;

t_{ac} – acceleration time at possible stops at stations (3 minutes);

t_{dec} – slowdown time (2 minutes)in possible stops at stations;

e_{br} – expenditures rate 1 brigade-hour, som/hour.

$$P_{a/d} = 3{,}8 \cdot (Q_{loc} + Q_{br}) \cdot \vartheta_{run}^2 \cdot \alpha \cdot 10^{-6} \cdot N_{st}, \quad (3)$$

there

Q_{loc} – the locomotive weighs, tons;

Q_{br} – brutto weight of action content, tons;

ϑ_{run}^2 – train running speed is, km / h;

α – in locomotive mechanical work, the energy consumption of 1 ton-km is equal to 3.6 kV/H;

N_{st} – number of stops at intermediate stations by graph time.

$$P_{lw} = (t_{in.av} + t_{ac} + t_{dec}) \cdot \frac{(e_{loc} + e_{wag} \cdot m_w)}{60}, \quad (4)$$

there

e_{loc} – expenditures rate locomotive-hour, som/hour;

e_{wag} – expenditures rate wagon-hour, som / hour;

m_w – number of wagons in train traffic.

$$P_e = Ч_e + t_{in.av} \cdot \frac{H_{st}}{60}, \quad (5)$$

there

$Ч_e$ – cost of one $kW \cdot hour$ electric power, som;

H_{st} – The norm of electricity consumption to stay standing for 1 hour, $kW \cdot hour$.

b) the following costs arise from the (P_{tech}) expectation of direct graph times as a result of the increased standing of trains at technical stations [3]:

- cost of (P_{lw}) use of locomotives and carriages (by train waiting time;
- ($\sum P_{tech}$) costs to use other train wagons and locomotives in changing the graphical times of trains.
- (P_e) electricity expenditure during train parking

$$P_{tech} = \sum P_{lw} + P_e, \quad (6)$$

$$\sum P_{lw} = \sum_{i=1}^{k} t_i \cdot \frac{(e_{loc} + e_{wag} \cdot m_w)}{60}, \quad (7)$$

there

k – the number of trains exceeding the norm, or the number of first graph times used in order;

t_i – Stopping time of i train, minutes.

3. Results and conclusion

Sending a train from the station requires an analysis of compliance with the total cost based on the observance of graphic times. It is necessary to assess the compliance of the use of graph times with electrical energy costs using data describing the state of the train. Train traffic spending (8) is defined using the expression.

When sending trains from the station by chart times, the number of factors affecting them (P_{in}) increases. However, in this case, the (t_{in}) single variable intermediate stations, the sum of total time, take into account the times when the train remains standing, acceleration and deceleration. This variable again takes into account the weight of two-parameter trains (equal to the sum of Q_{loc} and $Q_{loc.br}$) and the number of ($N_{in.st}$) stays at intermediate stations with graph times. For the graphical time of trains, the train weight is chosen with a variation of 500 tons in the range from 2,500 tons to 6,500 tons. The number of stays at intermediate stations is accepted from 1 to 10 (train traffic is taken from TTG based on the train movement plan). The number of ($N_{in.st}$) trains staying at intermediate stations is determined by the times of the regulatory train traffic graph (RTTG).

The total cost rate for the organization of freight train traffic on railway sections within Uzbekistan Railways is shown in Table 1. The electricity consumption for the movement of trains on railway sections is distributed differently during the day (Table 1).

Table 1

Expenditures rate for freight trains on the Railways of Uzbekistan

No	Name of expenditures	Value, sum.
1	Wagon-hour	917
2	Locomotive-hour	114270
3	Brigade of the locomotive brigade-hour	157585
4	Elekrtovoz-hour	34760
Electricity consumption ($1 kWT \cdot hour$)		
5	Daytime rush hour from 06-00 to 09-00 and from 17-00 to 22-00	1350
6	The daytime time interval is from 09-00 to 17-00	900
7	Night time interval from 22-00 to 06-00	600

In order to plan the movement of trains on railway plots, the power consumption in the shipment from the technical station according to the different distributed state of the shipment was increased to operation on the basis of RTTG.

The operating costs for each variant of train movement distribution ($\sum P_e$) are determined by the following expression.

$$\sum P_e = \sum_{j=1}^{p} P_{st.j}, \qquad (8)$$

there

$P_{st.j}$ – expenditures arising due to the fact that the train stops at the intermediate stations of the plot for the graphic time with the selected train;

j – serial number of graphic time from the planning of sending trains.

The total spending determined by taking into account the number of station stays and time of stay to ship trains at the railway stations according to the specified graphic time was expressed in Figure 2.

The results of the analysis of staying at intermediate stations for sending trains on railway plots according to the specified graphic time (Figure 2) electricity consumption is the most expensive during the day, respectively (Schedule 1) (daylight hours from 06-00 to 09-00 and from 17-00 to 22-00: 152437÷400806), average (daylight hours from 09-00 to 17-00: 14654÷384356 22-00 to 06-00: 143687÷376056) showed a change in total spending. According to the results of the analysis, as a result of the change in the time standards for staying at intermediate stations when sending a train by graphic time, electricity consumption was caused by different distribution during the day from 06-00 to 09-00, during the day from 09-00 to 17-00, and between 22-00 and 06-00 at night.

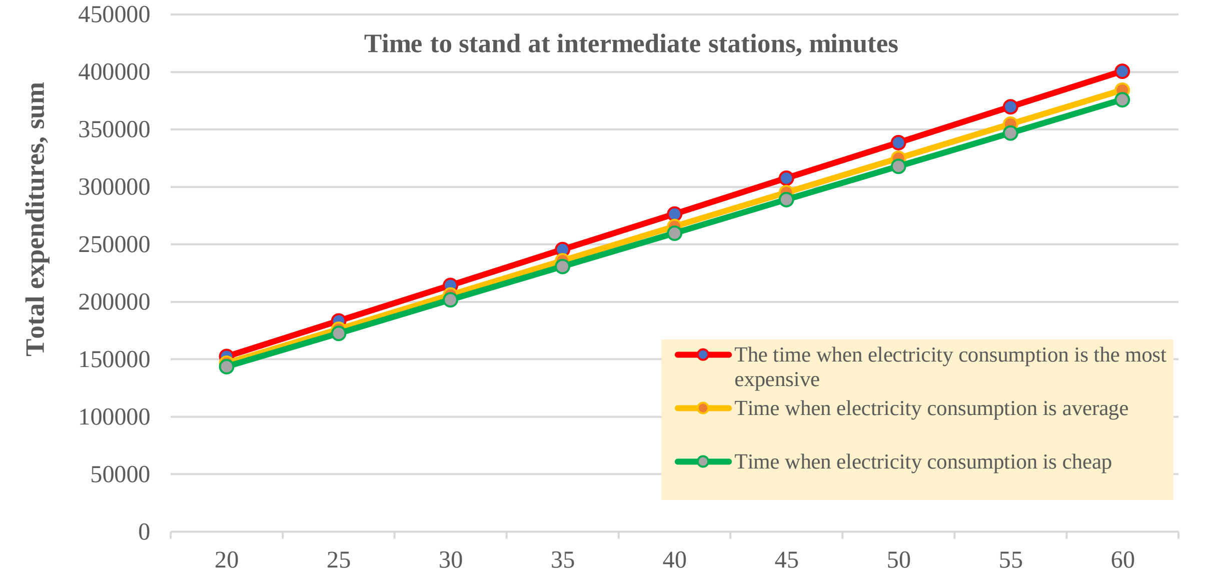

Fig. 2. Staying at intermediate stations when dispatching a train by graph time is the expenditures in the change in time standards (number of stops 1÷9).

Trains scheduled to be shipped from the technical station will cause graphics times to wait. Therefore, the determination of the total cost of using locomotives and wagons at the technical station is calculated according to the following expression.

$$t_{tech} = \sum_{i=1}^{d} t_i. \qquad (9)$$

At the technical station, the cost of (P_{lw}) use of locomotives and carriages to ship trains in graphic times (by train waiting time), the total cost (9) taking into account the cost of (P_e) electricity at the time of stopping trains-was determined by expression, and the result was given in Figure 3.

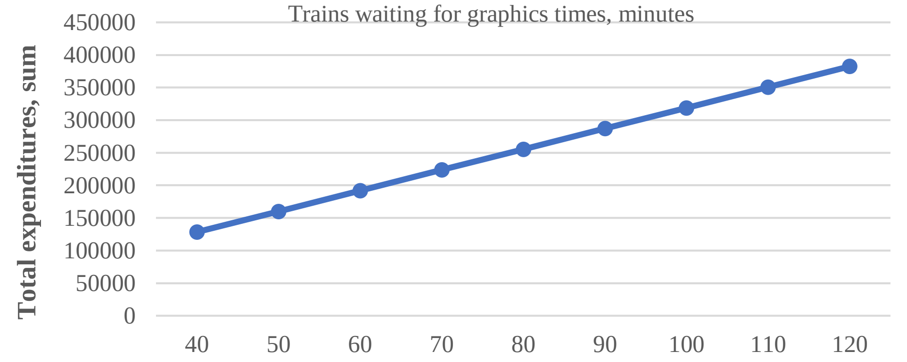

Fig. 3. The expenditures of trains scheduled to be shipped from the technical station in anticipation of graphics times

Based on the results of the analysis, the cost of using locomotives and wagons (in terms of train waiting time), taking into account the expenditure of electricity at the time of stopping the trains at the technical station in terms of the change in the expectation of the specified graphic times, the total spending averaged 128376÷414184 rubles, respectively. So, when planning the departure of trains from the technical station, it was found that it is advisable to send trains by comparing the costs of using locomotives and cars (in terms of train waiting time), the costs of using trains at the technical station according to the number of stops at the intermediate stations and the time standards of staying.

At the Uzbekistan-Khovos-Jizzakh railway station, which is owned by Uzbekistan railways, passenger train traffic runs from 06^{00} to 09^{30} in the morning and from 17^{00} to 22^{00} in the evening at times when electricity consumption is expensive. Freight train traffic was analyzed in the "Uzbekistan-Khovos-Jizzakh" railway section on the double and odd lines from 09^{30} to 17^{00} am with an average electricity value in December 2023 and at intervals of 22^{00} to 06^{00} pm with low electricity value (Table 1) (4 and 5th pictures).

From Figure 4, it can be concluded that freight trains are changing to 4÷9 trains from 10^{00} to 17^{00} in the morning and 5÷10 trains from 22^{30} to 06^{00} in the evening, respectively. So, in this section, the movement of passenger trains in the time intervals from 10^{00} to 17^{00} in the morning and from 22^{30} to 06^{00} in the evening in both directions is considered to be a less organized period.

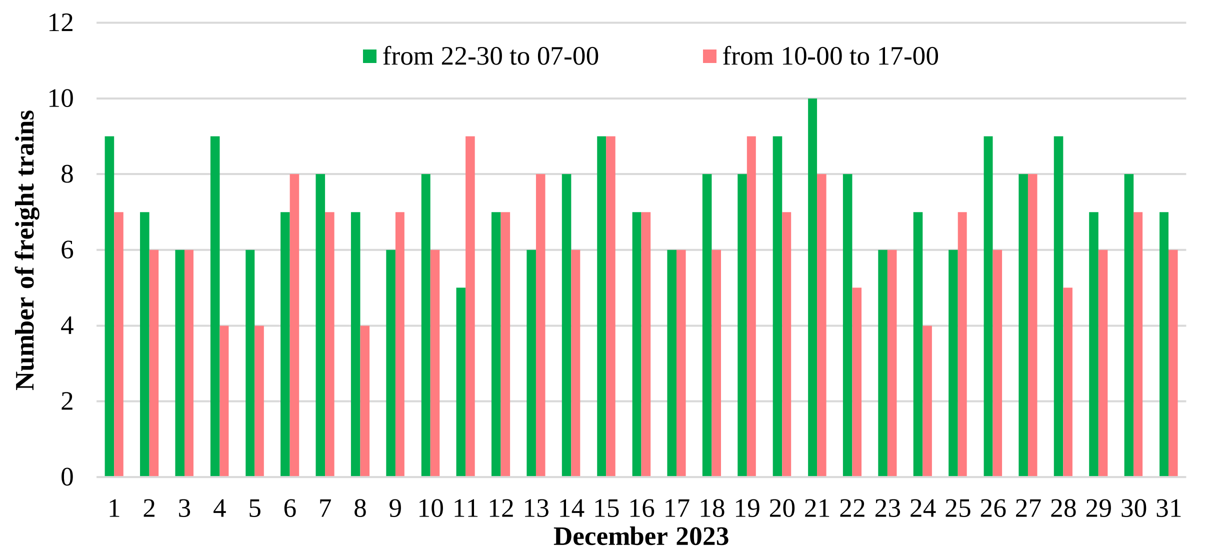

Fig. 4. Analysis of the movement of freight trains in the double direction of the "Uzbekistan-Khovos-Jizzakh" railway section (from 10^{00} to 17^{00} in the morning and from 22^{30} to 06^{00} in the evening)

According to the results of the analysis in Figure 5, freight trains are changing to 4÷7 trains from 08^{00} to 18^{00} in the morning and 5÷8 trains from 23^{30} to 04^{00} in the evening. So, it was found that the movement of passenger trains is not planned for the time intervals from 10^{00} to 17^{00} in the morning and from 22^{30} to 06^{00} in the evening even on the odd direction.

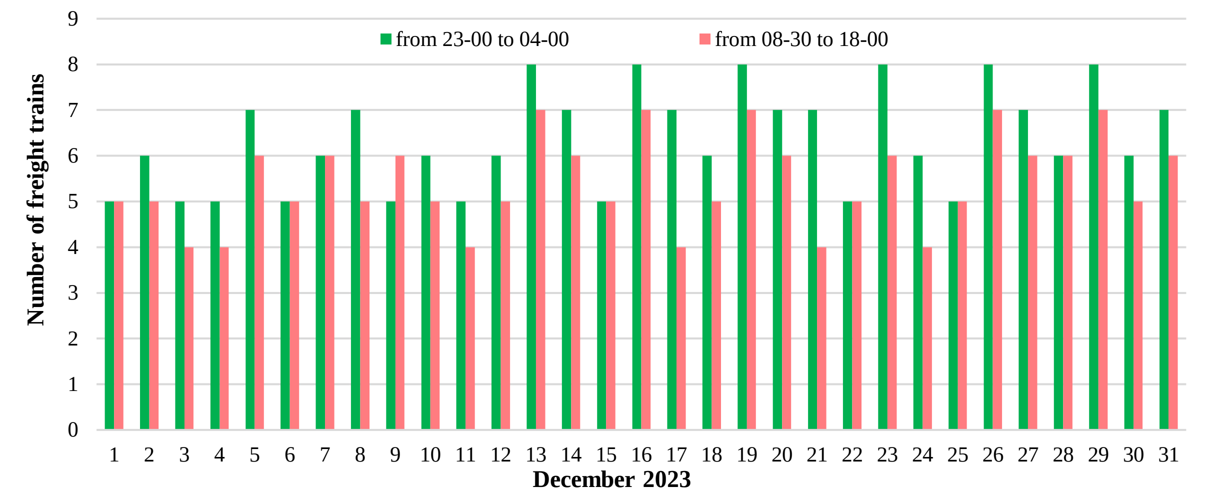

Fig. 5. Analysis of the movement of freight trains on the odd direction of the "Uzbekistan-Khovos-Jizzakh" railway section (from 08^{30} to 18^{00} in the morning and from 23^{00} to 04^{00} in the evening)

It is advisable to organize the movement of freight trains on the pair and odd lines of the Uzbekistan-Khovos-Jizzakh railway section under the ownership of the Railways of Uzbekistan during periods when electricity consumption is moderate and cheap. In addition, increasing the flow of freight trains during periods when electricity consumption is moderate and affordable determines the possibility of assessing the operational and economic indicators of the railway site.

In order to effectively organize the movement of trains on railway plots from the experiences of developed foreign countries, it is necessary to develop flexible options for the formation of trains, since the distribution of the electricity consumption rate in the TTG during the day varies. Therefore, a schematic outline of the zonal organization of the movement of trains taking into account the consumption of electricity in the organization of train traffic on the Railways of Uzbekistan was developed (Figure 6).

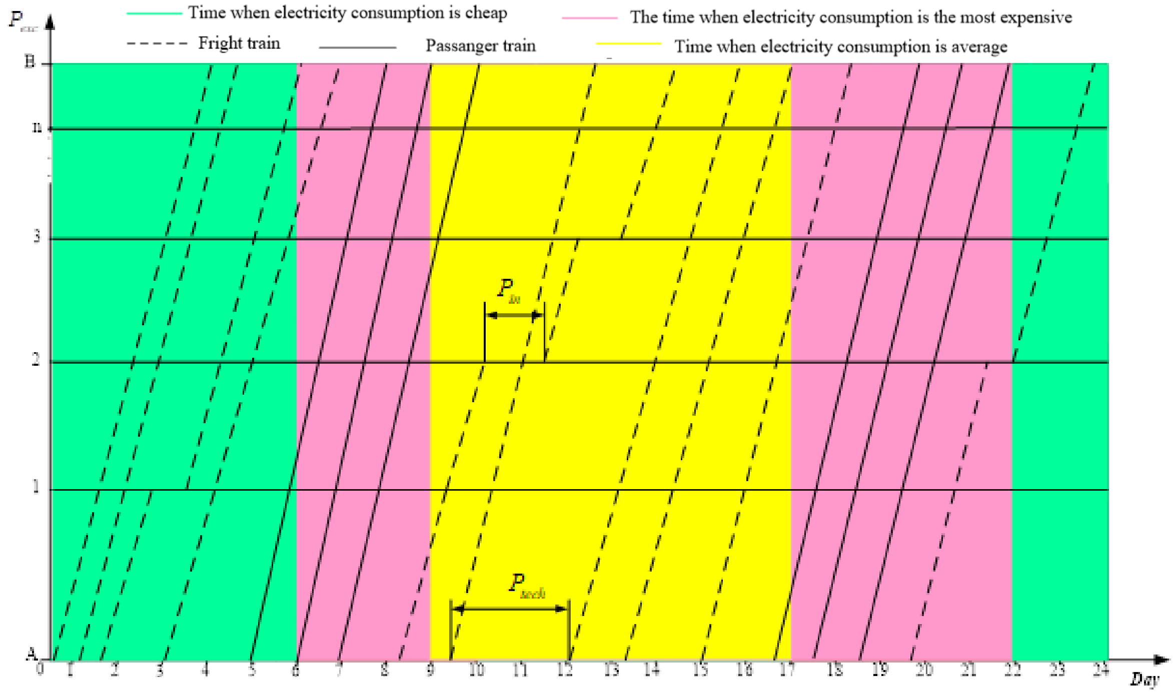

Fig. 6. Scheme of zonal organization of the movement of trains on the distribution of electricity consumption in the organization of train traffic in TTG

zonal organization of train traffic and the plan for the

The proposed approach (Figure 6) provides opportunities for zonal Organization of train traffic taking into account the distribution of the electricity consumption rate during the day, development of flexible options for a train layout plan, sending trains from the station by graphic time, and most importantly, saving overhead costs.

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